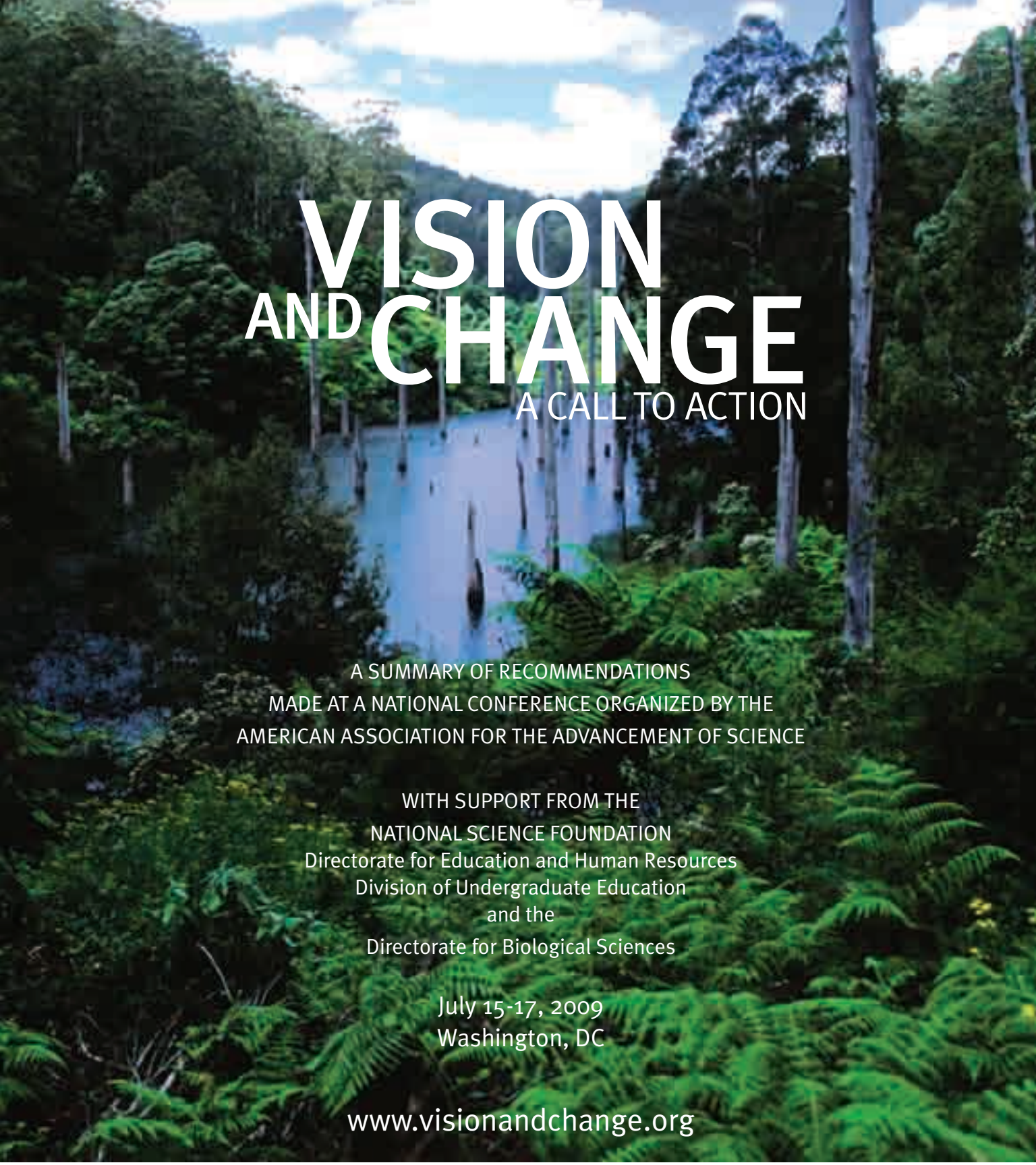

VISION AND CHANGE
A CALL TO ACTION

A SUMMARY OF RECOMMENDATIONS
MADE AT A NATIONAL CONFERENCE ORGANIZED BY THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

WITH SUPPORT FROM THE
NATIONAL SCIENCE FOUNDATION
Directorate for Education and Human Resources
Division of Undergraduate Education
and the
Directorate for Biological Sciences

July 15-17, 2009
Washington, DC

www.visionandchange.org

AAAS
ADVANCING SCIENCE, SERVING SOCIETY

About AAAS

The American Association for the Advancement of Science (AAAS) is the world's largest general scientific society, and publisher of the journal, *Science* (www.sciencemag.org) as well as *Science Translational Medicine* (www.sciencetranslationalmedicine.org) and *Science Signaling* (www.sciencesignaling.org). AAAS was founded in 1848, and includes some 262 affiliated societies and academies of science, serving 10 million individuals. *Science* has the largest paid circulation of any peer-reviewed general science journal in the world, with an estimated total readership of 1 million. The non-profit AAAS (www.aaas.org) is open to all and fulfills its mission to "advance science and serve society" through initiatives in science policy; international programs; science education; and more. For the latest research news, log onto EurekAlert!, www.eurekalert.org, the premier science-news Web site, a service of AAAS.

For more information on the AAAS Vision and Change in Undergraduate Biology Education Initiative, see http://www.visionandchange.org/.

VISION AND CHANGE

IN UNDERGRADUATE BIOLOGY EDUCATION
A CALL TO ACTION

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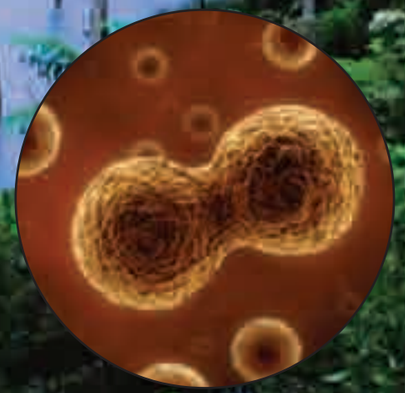
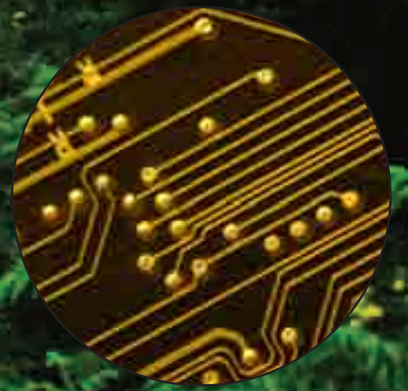
Most faculty agree that to be scientifically literate, students need to understand a few overarching core concepts:

- Evolution
- Pathways and transformations of energy and matter
- Information flow, exchange, and storage
- Structure and function
- Systems

As important, undergraduates need to understand the process of science, the interdisciplinary nature of the new biology, and how science is closely integrated within society. Students also should be competent in communication and collaboration, as well as have a certain level of quantitative competency, and a basic ability to understand and interpret data.

To be current in biology, students should also have experience with modeling, simulation, and computational and systems-level approaches to biological discovery and analysis, as well as with using large databases.





"To learn something in the classroom and then be able to put it to use in a real-world application is great."

BIOLOGY EDUCATION: AT A CRITICAL WATERSHED IN HISTORY

We all have work ahead of us to ensure that the transformations we make in undergraduate biology classrooms around the country reflect the biology we do in the 21st century. I am confident our community is up to the challenge. Because after all, if not now, then when? And if not us, then who?

—Carol Brewer, University of Montana, Vision and Change Conference Co-Chair

A revolution is underway in biology. The major focus of the biological sciences – understanding life – remains the same, but the science has experienced a major transformation. Breakthrough discoveries during the second half of the 20th century cross disciplinary boundaries, changing the nature of the questions asked, while emerging technologies have allowed new approaches to the ways biologists investigate these questions. At the same time, thanks to advances in neurobiology, educational psychology, and evolving theories of learning, researchers have a better understanding of how students of all ages learn, allowing faculty to more effectively introduce this new biology to all undergraduates and assess their learning.

This convergence of advances in biology and the science of learning comes at a time when the nation, indeed the world, is faced with large and urgent challenges, from global climate change and energy, to food production and health care, all of which connect to research, study and policies that touch on the biological sciences. Faculty have a unique opportunity to inspire a new generation of undergraduates to address these pressing societal challenges, but they also face a unique challenge to ensure that all undergraduates develop a level of biological literacy needed to make informed decisions about the complex problems facing the world today.

Fortunately, most college students, regardless of their majors, take at least one introductory biology course during their undergraduate career years, providing an opportunity to learn about the basic facts of modern biology. At the same time, this study of biology also provides students an opportunity to develop an understanding of the nature of science and the scientific process so that when they confront issues that involve science and technology, they can solve every-day problems and use evidence and logic to reach sound conclusions. For regardless of their ultimate career paths, all students will need these very basic skills to participate as citizens and thrive in the modern world

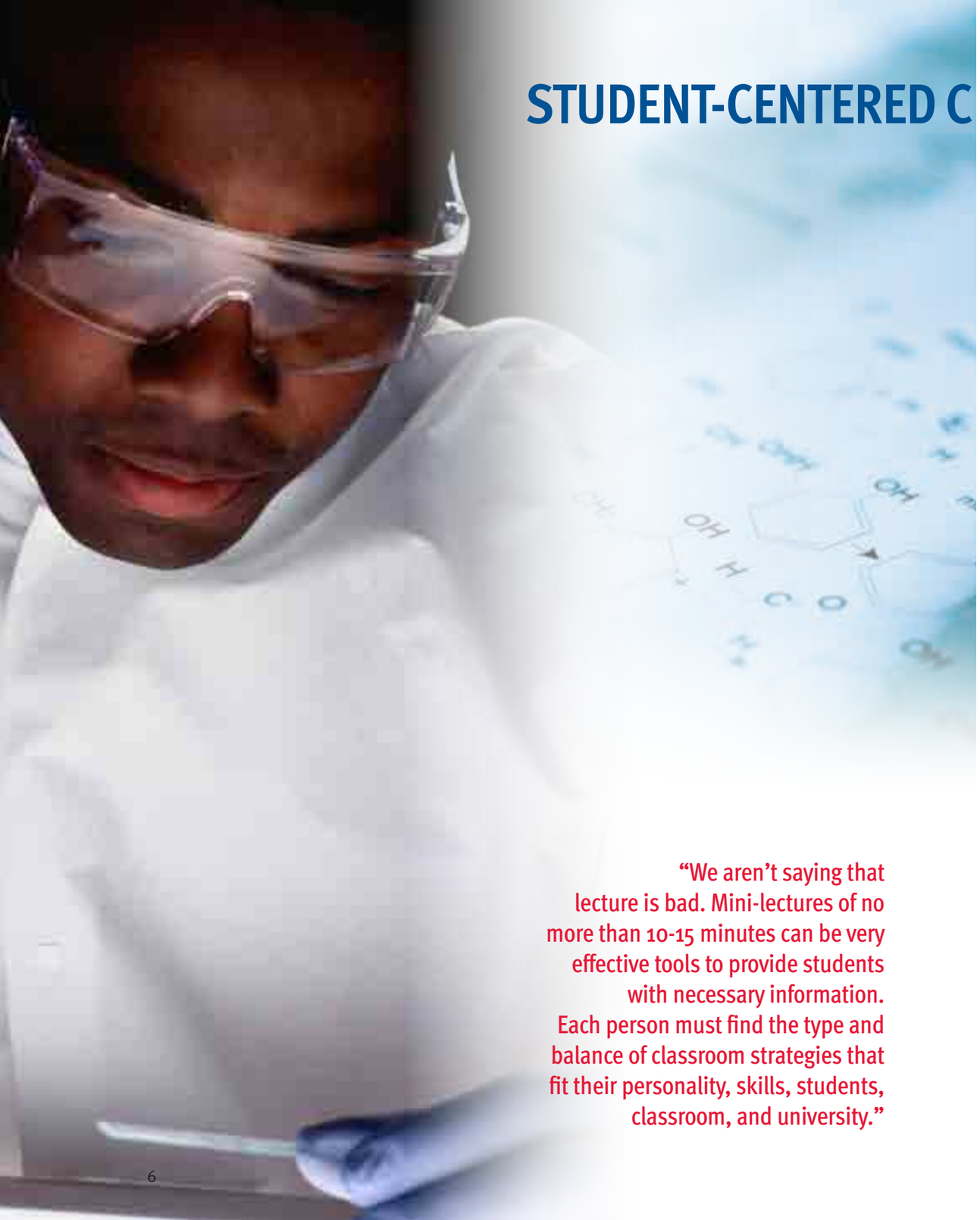
VISION AND CHANGE: A CALL TO NATIONAL SERVICE

In 2007, the American Association for the Advancement of Science (AAAS) and the National Science Foundation (NSF) initiated a series of conversations with more than 200 faculty members, administrators, and other stakeholders from around the country, seeking input on how to improve undergraduate biology education to better prepare all students for the biology-related challenges of the 21st century. They also organized smaller workshops with undergraduates, both biology majors and students majoring in other subjects. An Advisory Board used the results from these conversations to set the agenda for the Vision and Change Conference.

On July 15-17, 2009, more than 500 biology faculty from two- and four-year colleges and universities, researchers, administrators, students and other stakeholders in the future of undergraduate biology education met in Washington, DC. Hosted by the AAAS, with support from the NSF and input from representatives of the Howard Hughes Medical Institute (HHMI) and National Institutes of Health (NIH), the meeting set out to mobilize the nation's educators to ensure that the undergraduate biology they teach in their classrooms reflects the biology they practice in their labs and in the field. The conference also developed recommendations to ensure that all students – biology majors and those majoring in other fields – gain a better understanding of the nature of science and the natural world.

This executive summary provides an overview of some of the meeting's key recommendations and next steps to mobilize the community to respond to what is, in essence, a critical call for national service. A more comprehensive proceedings, discussing these recommendations and action items in more depth, will be available in mid-2010.

http://www.visionandchange.org/james-collins.php



"We aren't saying that lecture is bad. Mini-lectures of no more than 10-15 minutes can be very effective tools to provide students with necessary information. Each person must find the type and balance of classroom strategies that fit their personality, skills, students, classroom, and university."

STUDENT-CENTERED C LASSROOMS AND LEARNING OUTCOMES

My hope is that we can change the focus of introductory courses to cover much less material in order to give students the chance to learn what science is and the opportunity to experience science.

— Bruce Alberts, AAAS, Editor-in-Chief of *Science* and former President, National Academy of Sciences

Research in education and classroom experiences confirm that "covering" a topic does not necessarily result in student learning. Indeed, given the explosion of new knowledge in the biological sciences, attempting to cover it all can be counterproductive and turn away even the most talented and interested students. So instead of providing a list of topics a course will cover, biology faculty need to decide what they want their students to know or be able to do when they have completed a given topic, course, or program of study and then, once these learning goals have been clearly identified, develop assessments to evaluate whether students have achieved those stated goals. These learning outcomes and assessments can then serve as a guide for which teaching strategies will engage students and help them advance their understanding to the desired level of comprehension.

In practice, student-centered classrooms tend to be interactive, inquiry-driven, cooperative, collaborative, and relevant. Classes authentically mirror the scientific process, convey the wonder of the natural world and the passion and curiosity of scientists, and encourage thinking. In addition, classes include both formal and informal assessment and regular feedback to students and faculty to help inform teaching and monitor student learning. And finally, regardless of their majors and eventual careers, students should have opportunities to participate in authentic research experiences and learn how to evaluate complex biological problems from a variety of perspectives, not just recite facts and terminology.

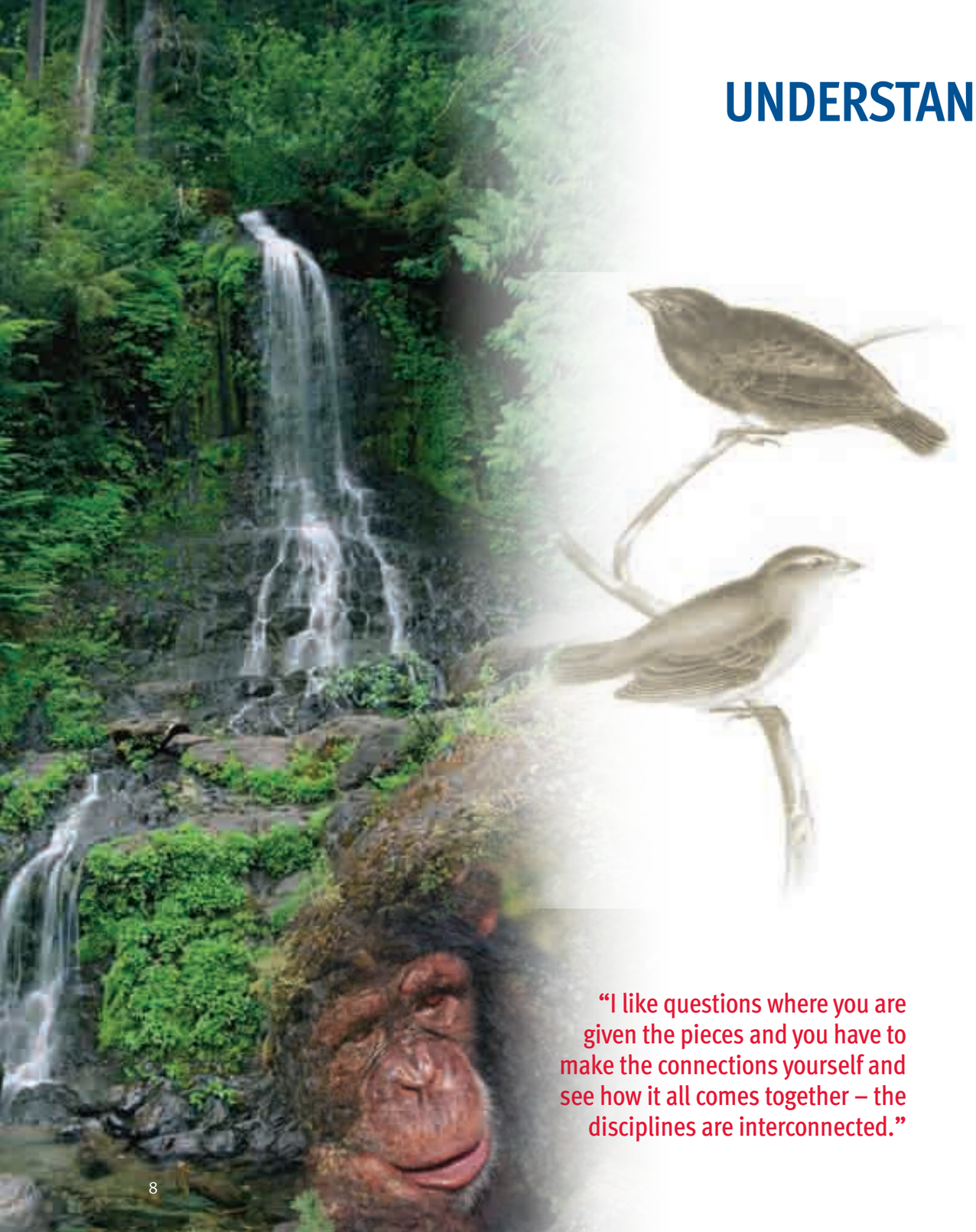
ACTION ITEMS

Introductory biology courses lay the foundation for study in the major, and are often the only college exposure to science for students majoring in other disciplines. Consequently, the scientific process should be introduced to students early in their studies and be integrated throughout all their undergraduate biology courses. To develop an appreciation of the process of science, research experiences should be an integral component of biology education for all students, regardless of their major.

In addition:

- Ensure that undergraduate biology courses are active, outcome-oriented, inquiry-driven and relevant.
- Define learning goals and align assessments to focus on conceptual understanding, not just on covering voluminous content.
- Take biology out of the realm of the abstract and relate it to the real world.
- Give students ongoing, effective, and timely feedback on their progress.
- View assessment of course success as similar to scientific research, centered on the students involved, and apply the assessment data to improve and enhance the learning environment.
- Engage the passion of faculty and ignite the passion of students .

http://www.visionandchange.org/conversations.php



"I like questions where you are given the pieces and you have to make the connections yourself and see how it all comes together – the disciplines are interconnected."

UNDERSTANDING KEY CONCEPTS AND COMPETENCIES

As we think about the content that must be introduced in undergraduate biology education, we really are talking about the need to teach future biologists, doctors, chemists, and poets, and my grandchildren's future science teachers, and US presidents and members of Congress and state legislatures, and school board members.

—Alan Leshner, AAAS, Vision and Change Conference Co-Chair

Many faculty, department heads, and administrators have gained a better appreciation of how students learn, and generally agree that to be biologically literate in today's rapidly changing environment, students need to see biology as an evidence-based science as well as understand the basic connections among sub-disciplines. The curriculum, therefore, needs to engage students in the process of science while presenting biology as a vibrant, active, and relevant field. In the classroom, topics need to be connected to students' lives, experiences, prior knowledge, observations, and interests. The discipline is awash with a sea of facts, so faculty need to help students understand the significance of these facts.

To this end, most faculty agree that to be scientifically literate, students need to understand a few overarching core concepts: evolution; pathways and transformations of energy and matter; information flow, exchange, and storage; structure and function; and systems. As important, undergraduates need to understand the process of science, the interdisciplinary nature of the new biology, and how science is closely integrated within society. Students also should be competent in communication and collaboration, as well as have a certain level of quantitative competency, and a basic ability to understand and interpret data. These concepts and competencies should be woven into the curriculum and reinforced throughout all undergraduate biology coursework.

To be current in biology, students should also have experience with modeling, simulation, and computational and systems-level approaches to biological discovery and analysis, as well as with using large databases. Having a basic understanding of core concepts that form the very basis of life on earth, combined with training in newer approaches to biological research, provides students with insights into the process of scientific discovery, as they develop the tools they will need to succeed in tomorrow's classrooms and board rooms.

ACTION ITEMS

Core concepts and competencies should be fostered throughout the curriculum, with well-defined learning outcomes developed for each. Students should gain competency in all recommended areas but be expected to develop high-level expertise in only a few. Concept maps can be extremely helpful in communicating how students experience the introduction and expansion of these concepts through the curriculum.

In addition:

- Departments, colleges and universities, professional societies and other relevant organizations should provide professional development opportunities for faculty to enhance their scientific and pedagogical expertise.
- Departments and administrators should also encourage, through the reward structure and other means, the development of a community of scholar-educators to share resources and expertise.
- Faculty need to look beyond existing textbooks for course resources since strict adherence to texts can impede reform, and using primary materials and journal articles can often enhance student learning.

http://www.visionandchange.org/bruce-alberts.php

"In the future, teaching will be evidence based, and goals for student learning will be skills based and learner centered rather than just content centered."

STRATEGIES FOR CHANGE

Realizing that the status quo in science education is not achieving the results we need, we have to undertake this bold challenge, breathing new life into our classrooms.

—Arden Bement, Director, National Science Foundation

To ensure a smooth transition to student-centered teaching and learning in undergraduate biology courses, all biology faculty and tenure review committees need to insist that the academic reward system value teaching and mentoring, set clear and concrete guidelines for assessment of these activities, and incorporate regular, formative and adaptive assessment of teaching effectiveness. Faculty need to come to consensus on the overarching, central concepts of biology that should be taught within their division or department, and define learning outcomes for those key concepts so that all faculty are working together toward the same learning goals as students move through their department.

But individual biology faculty cannot do it alone. Departments and administrators need to support and encourage on-going discussions of teaching practice, ensure that all biology faculty have access to — and the resources they need for — regular professional development in educational skills, and regularly engage faculty on curriculum development and pedagogy. Doctoral-granting institutions should create a teaching strand within their programs for graduate students and post-docs preparing to enter academic careers, and provide opportunities for them to work with diverse student groups and learning styles.

The ultimate goal for biology departments should be to develop and grow communities of scholars at all levels of the educational process — from undergraduates to faculty to administrators — all committed to creating, using, assessing, and disseminating effective practices in teaching and learning. This kind of department-wide implementation requires cultural changes by all stakeholders and a commitment to elevate the scholarship of teaching and learning within the discipline as a professional activity.

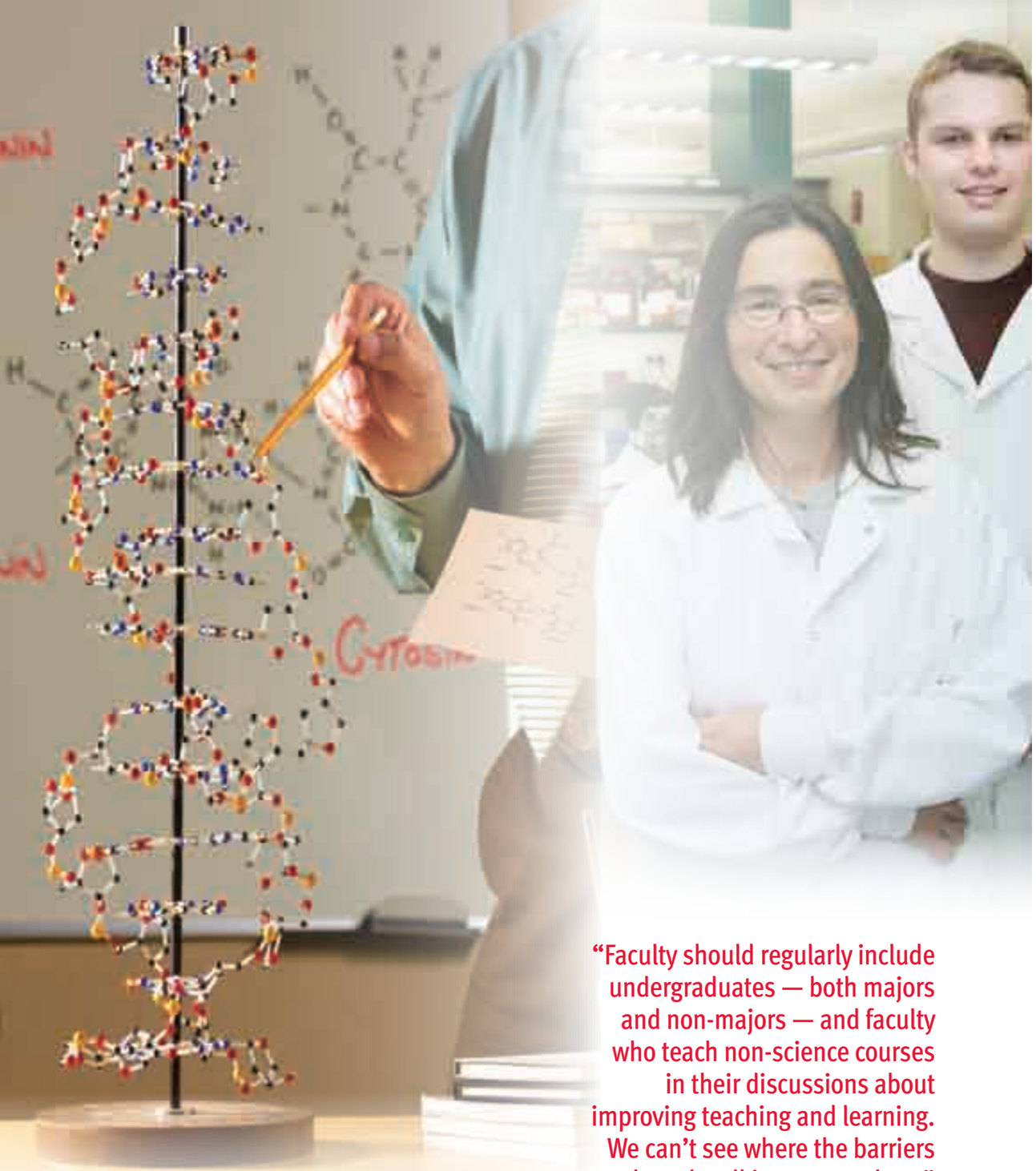
ACTION ITEMS

To meet the educational and societal challenges ahead, all stakeholders need to understand the critical role biology courses play in undergraduate education for all students, and make a commitment to improving the quality of that education.

In addition:

- Students need to become more active, engaged partners in the educational mission of their campus, whether they are at a two-year, four-year, or research-intensive institution.
- Faculty must engage in regular conversations and peer-to-peer mentoring about teaching and learning, and improve, test, and share their own understanding of how students learn.
- Administrators need to emphasize demonstrable excellence in teaching and learning in their strategic plans, provide on-going professional development for all faculty, and value, promote, and reward teaching excellence.
- Professional societies should increase awareness of the critical nature of undergraduate biology education, regularly disseminate science education research, and contribute to the professional development of their members in this arena.
- Funding agencies can help by including the development of teaching and mentoring skills as review criteria in grant applications, particularly those that include graduate and post-doctoral training.

http://www.visionandchange.org/poster-abstracts.php



"Faculty should regularly include undergraduates — both majors and non-majors — and faculty who teach non-science courses in their discussions about improving teaching and learning. We can't see where the barriers are by only talking to ourselves."

NEXT STEPS

For more than twenty years, the National Science Foundation, the American Association for the Advancement of Science, the National Academy of Sciences, the Howard Hughes Medical Institute, and many other organizations have issued calls for change in the way we educate our students in science. The time has come for the biology community to heed those calls and make a commitment to real action.

—James P. Collins, Assistant Director for Biological Sciences, National Science Foundation

While the task may appear formidable, faculty and administrators do not have to start from scratch. Many, if not all, of these ideas and recommendations have been developed, adapted, implemented, and assessed at two-year and four-year colleges and research universities around the country. These include authentic, developmental assessments that measure student understanding and their ability to apply content knowledge. Other assessments help document the learning outcomes of student-centered classes and research experiences.

New course designs have helped students develop critical-thinking skills, while others have resulted in increased interest and/or persistence in science courses. Some new approaches have proven helpful in improving participation of underrepresented groups and increasing these students' confidence in their ability to understand and excel in the study of biology.

Clearly, better communication is needed about the success and effectiveness of these new approaches to designing and implementing a more student-centered and outcomes-oriented undergraduate biology curriculum. One recommendation consistently emerged to help in this effort: the need for a consolidated resource of research and classroom experiences documenting what works and why. Such a database should search like Google, recommend like Amazon, vet like Consumer Reports, and annotate like Wikipedia. This biology education database could disseminate effective practices and provide a centralized location of resources for faculty and others to advance biology education.

ACTION ITEMS

In a great irony, the academy itself may be the last obstacle to improving biology education for all students. Thus, raising the profile of science education within biology departments and ensuring the academic culture values both teaching and learning should be everyone's highest priorities, truly a cultural change on many campuses.

In addition:

- Conference participants were encouraged to organize workshops at their home institutions to disseminate information learned at the meeting.
- Those unable to attend can visit the conference website at http://www.visionandchange.org/ and join the conversation at Facebook (http://www.facebook.com/group.php?gid=129755154551) to explore ways to implement and disseminate conference recommendations.
- Professional societies should convene more sessions and workshops at their annual meetings focused on key strategies to foster excellence in teaching and learning.
- Regularly scheduled conferences to exchange ideas and keep the conversation going would help maintain the momentum needed for making meaningful changes in undergraduate biology education.
- Those still wondering why these action items and recommendations are so critical should watch "Did You Know?" a short video shared by Alan Leshner during his keynote address (http://www.youtube.com/watch?v=jpEnFwiqdx8).

http://www.visionandchange.org/felicia-keesing.php

IN PRACTICE

It is no doubt an incredibly ambitious task. But the conference attendance shows that there is a large body of committed faculty willing to transform biology education.

—Yolanda George, AAAS, Vision and Change Conference Organizer

The following represents a brief sampling of the kinds of quality initiatives designed to improve teaching and learning in undergraduate biology classrooms around the country .

SCIENTIFIC TEACHING, UNIVERSITY OF WISCONSIN, MADISON

Transforming undergraduate classroom teaching

Through the University of Wisconsin's Program for Scientific Teaching, Howard Hughes Medical Institute Teaching Fellows prepare to become more effective life sciences faculty. The year-long sequence introduces graduate students and postdocs to theories of learning, diverse cognitive styles, and practical teaching strategies including effective lecturing, cooperative learning, inquiry-based labs, student assessment, and managing classroom dynamics. As future faculty, Fellows also develop an informed philosophy of teaching as a scholarly endeavor to bring to their own undergraduate biology classrooms. The Wisconsin Program for Scientific Teaching also hosts a week-long summer institute for research university faculty to develop their own teaching skills and transform their undergraduate biology classrooms.

For information, see http://scientificteaching.wisc.edu/

SCIENCE EDUCATION INITIATIVE, UNIVERSITY OF COLORADO, BOULDER

Implementing institutional change

The Science Education Initiative (SEI) at UC-Boulder has enlisted five research-intensive science departments, including Molecular, Cellular, and Developmental Biology, in the process of improving learning outcomes in their undergraduate courses through the development of learning goals and pre- and post-assessment tools to measure learning gains. To help faculty implement this new student-centered approach, the university administration issued a competitive call for proposals for introducing evidence-based science education at the departmental level. The top five proposals were awarded funds to support "Science Teaching Fellows," who have a doctorate in the specific discipline, and an expressed interest in the scholarship of teaching. These SEI Fellows work with departmental faculty to develop learning goals, classroom activities to help students achieve them, and assessments to monitor the results. Since 2006, this five-year program has engaged approximately 10,000 students each year.

For more information, see http://www.colorado.edu/sei/about/index.html

EDUCATION AS KEY TO THE SCIENTIFIC ENTERPRISE, THE ECOLOGICAL SOCIETY OF AMERICA

Contributing to the professional development of their members

Starting in the late-1980s, the Ecological Society of America (ESA) formed committees to improve the quality of undergraduate education and increase diversity within the profession. Based on these early conversations, ESA began offering sessions at its annual meetings focused on what was important to teach about ecology as well as evidence-based strategies to connect teaching with learning. In a complementary effort, education articles began appearing in the Society Bulletin, and now appear regularly in the journal, *Frontiers in Ecology and the Environment*. Since the mid-1990s, ESA annual meetings have included professional development workshops for two days prior to the conference attended by hundreds of ecologists each year, with special attention paid to training opportunities for graduate students and post-docs. In addition, the last two annual meetings had education themes: "Enhancing Ecological Thought by Linking Research and Education" in 2008, and "Ecological Knowledge and a Global Sustainable Society" in 2009.

For more information see http:// www.esa.org/education_diversity/

http://www.visionandchange.org/william-wood.php

VISION AND CHANGE

Innovation in life science will be the major driver of meeting four major societal challenges: challenges of climate, challenges of food, challenges of energy, and challenges of health.

—Phillip A. Sharp, Massachusetts Institute of Technology,
Co-Chair, National Academy of Sciences Committee, A New Biology for the 21st Century

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