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Vision and Change in Biology Undergraduate Education, A Call for Action—Initial Responses

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INTRODUCTION

Last July, as a culmination of a year of conversations among biology faculty and students, university administrators, and biology professional societies, more than 500 biologists met to discuss the needs of undergraduate biology in light of the exciting changes in the discipline itself and what we are learning about how people learn (American Association for the Advancement of Science [AAAS], 2009; Woodin *et al*., 2009). This effort had major financial support from the National Science Foundation (NSF) and input from representatives of the Howard Hughes Medical Institute (HHMI), the National Institutes of Health (NIH), the National Academy of Sciences (NAS), and the AAAS, the convener of the meetings.

On February 20, at the 2010 annual meeting of the AAAS, the executive summary of the findings of the conference, *Vision and Change in Undergraduate Education, A Call to Action* (AAAS, 2010), was released at a session highlighting the recommendations from Vision and Change (V&C), presented by Carol Brewer,[1] the cochair of that event (George, 2010). Brewer set down the challenge to the community: "*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 twenty-first century. I am confident our community is up to the challenge. Because, after all, if not now, when? And if not us, then who?*"[2]

Keith Yamamoto[3] presented the principle findings of the New Biology committee (NAS, 2010) within the context of V&C:

- the increasingly interdisciplinary nature of research within the biological sciences and attention to its societal context,
- the growing complexity of the data generated and the need for computational and modeling skills to deal with that complexity, and
- the amazing power new technologies have brought to the discipline, allowing new questions to be posed and new approaches designed that were not possible before.

He noted that the confluence and synergy of the V&C and the New Biology reports is striking and that "*each will strengthen the impact of the other*."

Joann Roskoski (Acting Assistant Director of the NSF Directorate for Biological Sciences) set out next steps contemplated by NSF, many of them in concert with other principal funders such as NIH and HHMI. Among NSF's efforts to "*move the agenda forward*," she mentioned the following:

- increased support for existing programs to support course reform (NSF, 2010) and to encourage formation of networks of people funded to work on similar aspects of educational change (NSF, 2009b); and
- establishing initiatives to support institutional reform and to create an online resource of well-tested educational materials (to be done in concert with HHMI and NIH).

Below, we highlight six of the key findings in the V&C Executive Summary, note some of the recent documents that resonate with those findings, and give a few examples of actions under way to implement these findings.

KEY CONCEPTS AND COMPETENCIES

The report notes 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;*"

and that undergraduates should master the following competencies:

- "*understand the process of science, the interdisciplinary nature of the new biology and how science is closely integrated within society;*

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[1] Carol Brewer is Associate Dean of the College of Arts and Sciences, University of Montana, and Associate Editor of *Conservation Biology*.
[2] All quotes are from the Vision and Change Executive Summary (AAAS, 2010).
[3] Keith R. Yamamoto is Executive Vice Dean for Research in the School of Medicine and a Professor in the Cellular/Molecular Pharmacology and Biochemistry/Biophysics Department at the University of California at San Francisco.

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- *be competent in communication and collaboration;*
- *have quantitative competency and a basic ability to interpret data; and*
- *have some experience with modeling, simulation and computational and systems level approaches as well as with using large databases.*"

These recommendations mirror those for revision of Advanced Placement courses and exams (College Board, 2009) and for the preparation of future physicians (AAMC-HHMI Committee, 2009; Long, 2010). As part of the next steps, we are currently contemplating convening a meeting of the various biology professional societies to discuss how their views of important concepts and competencies fit within the overarching goals given above.

ENGAGING STUDENTS IN THE SCIENTIFIC PROCESS

"*Students should have opportunities to participate in authentic research experiences and learn how to evaluate complex biology problems from a variety of perspectives, not just recite facts and terminology.*" Historically, research scientists have welcomed undergraduate students into their laboratories to be part of their research teams. Recently, these efforts have been expanded to serve more students by incorporating authentic research experiences directly into student laboratories (e.g., see Lopatto *et al*., 2008) or engaging students in both introductory and upper-division courses in an in-depth discussion of research articles (Hoskins and Stevens, 2009). In the past 3 years, within its Transforming Undergraduate Education in STEM (formerly Course, Curriculum, and Laboratory Improvement Program), NSF has funded 29 classroom-centered undergraduate research projects. The institutions involved are as varied as Finger Lakes Community Colleges (Hewlett, 2008) and Stanford University (Simoni, 2009). HHMI has established an exciting undergraduate laboratory experience that unites students across the country in a joint effort to identify and characterize phage from soil bacteria, generating new findings and at the same time producing a set of engaged undergraduate students knowledgeable in the ways of science (HHMI, 2009).

COMMUNITY BUILDING—CULTURAL CHANGE

"*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.*" This need for a community approach, including senior research scientists and science educators, was echoed by Keith Yamamoto in his discussion of twenty-first century biology. A relatively new program within NSF, Research Coordination Networks-Undergraduate Biology Education (RCN-UBE), established in response to early V&C conversations, supports such collaborations. Since its inception in 2009, four full projects (up to $100,000/year for up to 5 years) and seven incubator projects ($50,000 for 1 year) have been funded, with more in progress. Projects range from a large consortium of ethnobiologists working to combine their various information bases and to tailor them for use in undergraduate courses (Harrison, 2009) to an incubator-level effort to establish communities to address the need for useful instruments and techniques to assess conceptual learning (Fisher, 2010).

DEVELOPING COMPUTATIONAL COMPETENCE

"*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 data bases.*" A recently established NSF program (NSF, 2009a) supports projects that involve teams of mathematics and biology majors and their professors in courses and research projects that emphasize the application of mathematical techniques to the solution of biological problems. That program is beginning to reap results: in a cadre of students who are comfortable with interdisciplinary approaches to biology, a series of peer-reviewed articles describing research results, and a new approach to biology education on many of the participating campuses. During the recent mathematical/biology symposia at the 2010 AAAS annual meeting, the organizer challenged each speaker to elucidate the way in which their research projects had been incorporated into undergraduate education, and each had activities in progress (Gross, 2010).

FACULTY DEVELOPMENT

Several initiatives have emerged in response to the need to help present and future faculty develop effective approaches to undergraduate biology education. The Scientific Teaching Institutes at the University of Wisconsin–Madison (UW) work with UW postdoctoral fellows and graduate students during the academic year and with teams of research university faculty during an intense 1-week summer institute for this purpose (Pfund *et al*., 2009). The Science Education Initiative at the University of Colorado, Boulder (www.colorado.edu/sei) uses Science Teaching Fellows as the vehicle to help interested and committed departments change their teaching approaches to be more student centered, interactive, and assessment-based (www.visionandchange.org/wp-content/themes/simpla_widgetized/files/William%20Wood_V&C%20PPT.ppt). The NIH Institutional Research and Academic Career Development Awards help postdoctoral students develop teaching skills and pedagogical knowledge as they work with established faculty in minority-serving institutions with the aim of facilitating the progress of postdoctoral candidates toward research and teaching careers in academia (NIH, 2010).

DEVELOPING A WEBSITE IN RESPONSE TO V&C

"*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. This biology education database could disseminate effective practices and provide a centralized location*

of resources for faculty and others to advance biology education." A partnership with representatives from NIH, NSF, and HHMI is currently exploring the feasibility of such a site, and we welcome your advice (send suggestions to twoodin@nsf.gov).

SUMMARY

The executive summary provides an overview of some of V&C's key recommendations regarding next steps in the effort to mobilize the biology community. It is, in essence, a call for national service. A publication discussing these recommendations and action items in more depth will be available later this year. Meanwhile, we highly recommend reading the Executive Summary of V&C, the NAS report (NAS, 2010), and a seminal article by Labov *et al*. (2010) summarizing the synergy created by these several reports on the changing nature of studies in biology and concomitant need to change biology education. Then, take action! Our hope is to see the formation of a community of biologists, similar to that forming in geology (Manduca *et al*., 2010): one that will advance biology undergraduate education so it truly reflects the discipline it serves.

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