Cell Biology Education
Vol. 2, 224–227, Winter 2003

Points of View: Is *Bio2010* the Right Blueprint for the Biology of the Future?

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Submitted October 7, 2003; Accepted October 29, 2003

NOTE FROM THE EDITORS:

CBE is pleased to launch a new feature called Points of View (POV). POVs address issues faced by many people within the life sciences education realm. We will present two or more opposing POVs back-to-back on a particular topic to promote discussion on the selected topic. Readers are encouraged to participate in the online discussion forum hosted by *CBE* at www.cellbioed.org/discussion/public/main.cfm. We consider POVs "Op-Ed" pieces to stimulate thought and dialog on significant educational issues.

In the first POV, we have asked the question, "Is *Bio2010* the Right Blueprint for the Biology of the Future?" *Bio2010* is a set of recommendations from the National Research Council proposing ways to modify the biology curriculum to meet the changing needs of future biomedical researchers. (For a comprehensive assessment of this report, you can read three accounts in the Summer 2003 issue of *CBE*, http://www.cellbioed.org/articles/vol2no2/toc.cfm.) To open debate on this question, we have asked Donald Kennedy (*CBE* Editorial Board member and Editor-in-Chief of *Science*) and James Gentile (*CBE* Editorial Board member and a member of the Bio2010 committee) to present their points of view.

"Is Bio2010 the Right Blueprint for the Biology of the Future?"

Point of View by Donald Kennedy
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A remarkable project was completed early in 2003 by a committee of the National Academies of Science (NAS)/National Research Council, chaired by Professor Lubert Stryer. The publication is called *Biology 2010: Transforming Undergraduate Education for Research Biologists*, and it is a document worth serious attention by all who teach undergraduate biology, serve on curriculum committees, or are simply interested in what's happening to the field. A report in the summer issue of *Cell Biology Education* by Kerry Brenner, who staffed the NAS committee, gave a useful overview of the report, saving me the trouble of doing a summary. Here are some additional reasons for giving *Biology 2010* your attention.

First, it is yet another welcome sign of wakefulness on this subject at the National Academies. Bruce Alberts has brought a passionate interest in science teaching at all levels to an establishment that has, in the past, often found such matters beneath notice. The sad state of K–12 education has gotten much of the attention, but the Center for Science, Mathematics and Engineering at the NAS spent some time on undergraduate teaching during the late 1990s when I was involved with its Advisory Committee. Lubert Stryer, a distinguished Stanford University colleague who could have been excused for spending all his time in the lab, or for resting on his research laurels, has now brought an admirable personal commitment to the important challenge of curricular renovation.

Second, the *2010* report recognizes—as many biologists have not—the reality that our discipline has been transformed into an interdiscipline. Watching the flow of exciting papers that I encounter in the review process at *Science* makes this septuagenarian biologist feel a little like Rip van Winkle. Consider, for example, a few of the things that happened while I was figuratively asleep in the Catskills. Genomics happened; not only did the genomic revolution require more chemical sophistication than biologists used to get; hard on its heels was bioinformatics, a new interdiscipline requiring an entirely new level of mathematical training. Physics now gets linked with structural biology: We are seeing analyses of the thermodynamics of protein folding and unfolding, and optical tweezers are being used to uncoil DNA. Surely no one can doubt that it will take a lot more to prepare an embryonic biomedical researcher for graduate work than it once did.

Third, the Stryer report is an elegant document. It makes a persuasive case, not merely for including these other disciplines in a biologist's education but for integrating them fully, so the student sees the application of these other disciplines to real biological concepts. Instead of merely paying the customary respect to assessment and evaluation, the report takes the trouble to specify important concepts so that a teacher may verify progress toward the goal. The report emphasizes the need for integrating the disciplines in laboratory instruction and stresses the excitement that can be generated by independent research experiences and by seminars that focus on "cutting-edge developments" in biological research. Finally, to my unalloyed delight, it takes a hard shot

DOI: 10.1187/cbe.03-10-0039

the Medical College Admissions Test for canalizing and reifying the undergraduate biology curriculum.

Having delivered some well-deserved praise, what should I say about what isn't there? Here are a few of my own concerns; perhaps they will rouse some thoughts in others.

To begin with, the title talks about training "research biologists." Consistent with this, the term *biology* and *biologist* are used exclusively throughout the recommendations section. However, in a few places, the text lets the reader in on a little secret by saying that the real target clientele is *biomedical researchers*. Indeed, the explicit charge to the drafting committee was to examine a curriculum for the undergraduate training of future biomedical scientists. There are various efforts to remind the reader that the plant sciences and even ecology are not meant to be excluded, but somehow these come off as afterthoughts, leaving little doubt about what is really important. The recommended curriculum is interdisciplinary, to be sure, but it is also reductionist, with a strongly implied emphasis on the molecular and cellular levels of organization.

The interdisciplinary nature of the proposed curriculum endows *Biology 2010* with some real advantages. However, it also loses a few opportunities. Many students in introductory courses are uncommitted as to future specialization; many others derived their initial affection for biology from real-world experiences in natural settings. On the other side of Campus Drive from Lubert Stryer's laboratory, there are a number of undergraduates who caught the biology bug on an Oregon farm or on a field trip to Yosemite. Capturing the interest of children who (to quote one distinguished biologist) "came the butterfly route," or who fought forest fires in Arizona during the summer, may require more attention to the higher levels of biological organization. That doesn't amount to an argument against cellular and molecular biology. However, it does suggest that for many students there should be more, at least in the early years.

This raises a different issue, one that I regularly encountered as an undergraduate adviser and later as a provost with some responsibility for curriculum requirements. This plan is pretty demanding. If one adds up all the recommended courses, the total number of hours that would be required exceeds the present set of major and cognate science requirements substantially, at least at institutions with which I am familiar. The plea for more of this and more of that makes sense in terms of what will be required of this generation of biomedical researchers. The case is strengthened by the claim that it is interdisciplinary. However, taken a little farther, a claim of that kind would also suggest including substantial exposure to the social sciences and perhaps especially the humanities—the core disciplines of a liberal education. I'd like to be sure there's time for that.

I expect that these topics were beyond the charge of the committee. However, researchers in the NAS and professional biomedical societies should hope to produce a new generation of investigators who will have some characteristics that don't automatically emerge from the *Biology 2010* curriculum. I hope, for example, that this new generation will be able to explain what they are doing and why they are doing it to nonspecialists—and many of the young biomedical researchers I encounter don't write very well. I want them to be thoughtful interpreters and advocates for the application of their science to public policy, and too many of the biomedical researchers I see don't care much for that. I want them to have a high human regard for students, colleagues, and competitors, but I am troubled by the sociological portrait of the highly competitive, "tournament" society in our field so convincingly drawn by Richard Freeman and his colleagues under ASCB auspices (*Science* 294: 2293, 2001). In summary, I think there is a solid rationale for extending the interdisciplinary mandate beyond the limits set by, or maybe for, the committee.

There's a story about Ross Perot's efforts to reform K–12 education in Texas. A "don't pass, don't play" rule was enacted, disturbing high-school football fans. Perot's next step was to get failing students barred from 4-H competition. That tore it. When an outraged Texan approached Perot at a social occasion, he said, "Ross, you've left off preachin' and gone to meddlin' now!" I am afraid I may have come to that in this review.

Nevertheless, in closing I shall meddle some more by suggesting two new NAS committees. The first of these should explore what should be done for all those biology majors who aren't headed for biomedical careers. They may be bound for agricultural science, paleontology, restoration ecology, wildlife management, environmental policy—complete your own list. However, there should be a curriculum for them also. The second suggestion contends with the appalling level of scientific illiteracy that exists in the United States today. When the committee I chaired at the NAS produced *Teaching about Evolution and the Nature of Science*, we were told at a press conference that half the people in America don't believe in evolution and that half do believe in astrology. All I could say was that I hoped it was the same half! With frequent challenges to teaching evolution in a different states, there is not a moment to lose!

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Point of View by James Gentile
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The headline reads loud and clear: "Information Overload Hampers Biology Reform" (*Science* 293: 1609, 2001). Indeed, reform of undergraduate science curricula in general face uphill battles from faculty who teach, administrators who govern, and often accreditation agencies that demand. However, nowhere, perhaps, has the issue of "What to do?" been as challenging as in the biological sciences. Reform efforts over the years in biology have generally been, as noted by Roy Pollack, "more like rearranging the deck chairs than steering a ship. They end up being minor rearrangements of credits or sequences without any substantial change in direction" (Pollock, R.V.H. 1989. *Intervet* 24: 8). There is too much to know, too much to teach, too many "factoids" to jam into any given lecture session, too few days in a semester (or academic career of a student for that matter), few agreements on what the "key elements" are that all biologists should know, and too much reliance on colleagues from cognate disciplines to teach "all that stuff" (such as chemistry, physics, mathematics, computer science, and so forth) that biologists need to take (know?) but are too complex or take up too much space and time to include in biology courses themselves.

So it was against this background that the National Academies of Sciences challenged the National Research

Council Board on Life Sciences to examine the formal undergraduate education, training, and experience required to prepare the next generation of life science majors, with a particular emphasis on the preparation of students for careers in biomedical research. That charge led to the formation of a committee under the leadership of Lubert Stryer (Stanford University), who ultimately produced the report *Biology 2010: Transforming Undergraduate Education for Future Research Biologists* (2003, National Academies Press, Washington, DC, 191 pp.).

As noted in the *Biology 2010* report, the biological sciences have been revolutionized, not only in the ways in which research is conducted but also how research findings are disseminated among professionals and to the public. However, the undergraduate programs that strive to educate future biology researchers remain much the same as they were before these fundamental changes occurred. *Biology 2010* challenges the education and research communities in the biological sciences to work jointly to bring "up to speed" the education of students so as to take fuller advantage of the evolving knowledge base, and tools, now found in the life sciences. This includes:

- building a strong interdisciplinary curriculum that integrates physical science, informational technology, and mathematics into the life sciences in a more profound and direct manner;
- focusing on the new challenges found in understanding of complex systems in the life sciences (for more here see *Nature* 420: 205, 2002)
- creating early opportunities for undergraduate students to engage in meaningful research;
- designing research-focused, theme-centered laboratory experiences for all students; and
- promoting *and* rewarding teaching excellence at *all* institutions and finding ways to overcome the barriers that keep excellent research scientists from becoming equally excellent teachers.

The result of an educational approach for the biological sciences that took fuller advantage of the physical sciences and mathematics would virtually mandate that those who teach courses in the biological sciences would have to:

- seriously reduce through thoughtful triage the number of factoids that currently are offered to students in standard courses; and
- work collaboratively with colleagues in cognate disciplines to evolve ways in which the physical science and mathematics courses can teach life science concepts and, most important, biology courses more effectively integrate the physical sciences and mathematics as critical components of the curriculum.

For the above to occur, university and college administrators must not only reduce the barriers (real and imagined) to cross-departmental collaborations but must also promote and expect faculty to collaborate in education endeavors with the same enthusiasm and expectations for success that occur within research teams that use all the tools of science to address critical questions. Administrative expectations for success are essential, because it is well documented that curriculum reform efforts, no matter how well intentioned or well conceived they may be, often fall short of their primary objectives during implementation when unanticipated or unaddressed organizational resistance surfaces (Bowe *et al. Medical Education*, 37: 723, 2003). Therefore, the resources necessary for success must be put into place, both by the institutions themselves as well as private and public foundations that seek to catalyze educational reform.

Biology 2010 does *not* provide all of the answers. In fact, I believe that there may not be any institution, large or small, in our great nation that could adopt or adapt all of the recommendations placed forth for consideration. However, the process for thoughtful consideration for local reform of the biological science education process on every campus is there and local institutional environments will eventually dictate what approaches will work best for their students, faculty, and program. I do not know what factoids should stay or go in any given course or set of courses, but I strongly believed that the encyclopedic, noncontextual mode with which biology factoids are presented to students in many courses is tedious and ineffectual at best and discouraging for many students as they consider the pursuit of further studies in biological sciences. There has to be a better and more effective way, and *Biology 2010* helps to point a path (with a multitude of side paths) for science educators to ponder with an open mind and sincerity.

What *Biology 2010* does not say is important as well. It is crucial to remember that, although aspects of this book point out unique approaches for all life science education, the original charge to the *Biology 2010* committee was to make recommendations for the education and training of biomedical scientists. It has been disquieting for me to hear that on some campuses this has been taken to mean that there is no support for the other areas of the biology sciences, such as ecology, evolution, and so forth. This is *not* the case, and almost all aspects of the curriculum reform articulated in *Biology 2010* are adaptable for all components of the life sciences, and for good measure in the physical sciences and mathematics as well. I also think that *Biology 2010* did not articulate with enough clarity that not only must the pedagogies of teaching change but that research about student learning and the impact of pedagogical change on learning must also be part of the package. Teaching must never become static but remain like the fluid mosaic model of cell membrane structure. Teaching is not intended to merely "box something into a discreet package" but to promote meaningful exchanges and ways to grow and expand the knowledge base, and applicability of that knowledge, for students and educators alike. *Biology 2010* stimulates action that was taken to leverage off the ideas presented in the report. This past August, the NAS held its inaugural Summer Institute on Teaching in the Biological Sciences (at the University of Wisconsin). This institute promoted undergraduate teaching and, therefore. enhanced opportunities for student learning, among preeminent research faculty from around the nation. Future courses, to be called National Academies Summer Institutes for Undergraduate Education in Biology, will add another important stimulus to reform efforts in undergraduate life sciences education. Each year these courses will bring together a small group of prominent researcher–educators (faculty) with both junior and senior life sciences faculty members (students) who wish to become more effective teachers. This is clearly a step in the right direction, and I believe that this may be one of many initiatives that will be stimulated by the challenges put forth by *Biology 2010*.

In closing, I want to thank the Editors of *Cell Biology Education* for giving me this opportunity to share my perspectives; to the NAS for taking the initiative to bring the issues discussed on *Biology 2010* for consideration, conversation and debate; to the Howard Hughes Medical Institute and the National Institutes of Health for their support of the *Biology 2010* initiative; and to my colleagues on the *Biology 2010* committee. If indeed those individuals were together in a single institution, the current crisis in biological science education would be well addressed.