Education for a Biocomplex Future

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Perusing the recent *Science* classified ads is highly edifying to those who have long been arguing for the importance of quantitative methods in the biological sciences. In the workshops I organized on quantitative training for life scientists over the past decade, young academic biologists commonly lamented the unwillingness of the "old guard" in their departments to appreciate the importance of mathematics in biology. The great increase in computational biology and bioinformatics positions clearly indicates a phase shift in the attention paid to quantitative approaches in the modern life sciences. The growth across the spectrum of biology in the application of mathematical and computational approaches provides explicit evidence that educators worldwide need to take account of new market forces if they wish to train their students to be adequately prepared for the demands of modern research.

How do we go about encouraging students to develop the range of skills needed to be competitive in the emerging fields of quantitative biology? Colleagues from many countries have expressed concern at Society for Mathematical Biology meetings about their biology students' poor comprehension of basic quantitative concepts. Difficulties in developing truly interdisciplinary training programs are rampant at institutions that designate resources along disciplinary lines. Despite numerous appeals for new approaches, essentially all undergraduate training in the United States and elsewhere, and much graduate training, occurs within discipline-based departments. Exposure to the benefits of quantitative approaches early in the educational process could encourage more students to broaden their courses beyond the very limited requirements of particular life science curricula and to take advantage of research experiences to augment their formal education with projects involving interdisciplinary activities.

The majority of U.S. life science undergraduates wish to pursue careers in health-related fields, and a major factor affecting their course selection is medical school entrance requirements. Only 39% of U.S. medical schools have any explicit quantitative requirements for entrance. Although this percentage is slightly higher than a few years ago, clearly medical school faculty do not believe that quantitative training at the undergraduate level is as critical to success in medicine as exposure to chemistry and physics. Few undergraduate life science degrees require more than two quantitative courses, typically both calculus. Yet much of computational biology requires understanding of discrete mathematics, not calculus. Given that exposure to the diversity of mathematical fields applicable in biology is critical to training in modern biology, how do we encourage this without requiring more courses within an already packed curriculum?

First, teach entry-level quantitative courses that entice life science students through meaningful applications of diverse mathematics to biology, not just calculus with a few simple biological examples. Second, include quantitative approaches throughout biology courses, don't just isolate the subject in a couple of quantitative courses that students often perceive as peripheral to their interests in biology. Such efforts could entice more of the best undergraduates into double majors or quantitative minors, as has been the case for many students pursuing graduate work in mathematical ecology in the United States. Federally funded programs are encouraging the development of undergraduate courses and curricula that focus on the nonlinear problems that arise in biocomplexity. Further efforts to disseminate the materials from these projects will help this process along.

At the graduate level, programs in computational biology are just starting to develop. The successes in mathematical ecology over the past several decades may be informative here. Two quite distinct groups of students are drawn to such interdisciplinary research: those with strong quantitative backgrounds (computer science, math, and statistics), who wish to contribute to biology, and those trained primarily in biology, who realize the importance of math to the biological questions that fascinate them. Routes for training both types of students are needed. New computational biology programs must be sufficiently diverse and flexible to accommodate the different backgrounds of potential students.

See, for example, www.tiem.utk.edu/bioed/

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