DIRECTIONS – Introduction

Each of the papers in the Directions section addresses some perceived, but largely unmet, need in curricular development for undergraduate mathematical biology. Of course the question of what developments ought to occur is a matter of opinion. Each of these papers lays out a strong case and offers insights on how to introduce and develop the topics. As editors, we endorse these calls for a change in emphasis.

The section begins with the paper *Integrating Statistics into College Algebra to Meet the Needs of Biology Students***,** by Sheldon Gordon of Farmingdale State University and Florence Gordon of the New York Institute of Technology. These authors are well known for their efforts to revitalize college algebra and precalculus courses. They argue for an algebra course designed to prepare students for statistics rather than calculus. The course would be more relevant to the life science students who constitute a large portion of the enrollment. The authors offer many suggestions for ways to bring statistical ideas and methods into the college algebra course while recommending a greater focus on concepts rather than techniques. Readers interested in precalculus courses should also see the paper by Ardis and Subramanian in the Processes section.

In *Motivating Calculus with Biology*, Sebastian Schreiber of the University of California at Davis argues that mathematics for biology should emphasize mathematical modeling. While all mathematics books contain word problems, some with biological themes, the typical word problem falls short of providing students with experience in mathematical modeling. A word problem provides just enough data to uniquely determine parameter values, while a modeling problem provides an excess of stochastic data that requires statistical methods to match to model parameters. Where a word problem ends with a quantitative answer, a modeling investigation continues with a comparison of the mathematical answer with biological data. Other issues important in mathematical modeling are similarly missing from the typical word problem. Schreiber offers examples with two common themes: scaling laws and population growth.

In *Computational Systems Biology: Discrete Models of Gene Regulation Networks*, Ana Martins, Paulo Vera-Licona, and Reinhard Laubenbacher of the Virginia Biomathematics Institute present a primer on molecular biology and Boolean network analysis, focusing on the *lac* operon found in *Escherichia coli.* This operon consists of a collection of genes that allow the cell to adjust to changes in the environment. While the biological system can be modeled using a variety of tools, Boolean network analysis has the advantage of being accessible to students who do not have any calculus background—the material presented in this paper forms a portion of a workshop the authors have conducted for high school teachers. Boolean network analysis could therefore be used to introduce mathematical modeling ideas much earlier in the curriculum than is currently the case. The reader interested in computational biology should also look at the papers by Attele and Hrozencik and by Robeva, Davies, and Johnson in the Models section and the paper by Lee and Boyd in the Processes section.

The Directions section concludes with the paper *Creating Quantitative Biologists: The Immediate Future of SYMBIOSIS* by Darrell Moore and colleagues at East Tennessee State University. SYMBIOSIS is an interdisciplinary curriculum project that focuses on linked mathematics and biology courses at the freshman level. The authors offer a critique of standard biology textbooks and discuss how to make biology courses more quantitative and more conceptual. While the focus of the paper is more on biology education than mathematics education, the issues are also relevant to mathematicians. Students who take mathematics courses with applications in physics take concurrent or subsequent physics courses that make use of the mathematics. In contrast, students whose mathematics courses have applications in biology are generally unable to take a concurrent or subsequent course in biology that uses the mathematics. No amount of success in mathematics curriculum development will matter unless the shoots propagated in a mathematics course ultimately flower in a biology course. The reader interested in interdisciplinary freshman courses will also want to read the article by Mark MacLean in the Processes section.

We hope that the four papers in this section will stimulate further discussion of these topics and other broader issues of curriculum reform. Biology is a diverse area, as are the mathematical needs of biologists. The last word on what mathematical topics should be offered to biologists and when they should be offered will not be spoken for a long time. It is best to emphasize these discussions now, before a consensus on curriculum needs has formed. As is obvious in other areas of curriculum development, it is harder to renovate a curriculum area that has crystallized into a rigid form than it is to innovate in an area that is still being shaped.