MODELS – Introduction

One reason for the diversity of curriculum ideas for biology is that there are only a small number of slots, perhaps only two or three, available in the packed curriculum of biology majors. A second reason is the lack of uniformity in the biology curriculum that the mathematics curriculum is supposed to support. Physicists are generally in agreement about what constitutes introductory learning in physics, which has led to a mathematics curriculum that varies little among institutions, with no issues more serious than the order of linear algebra and differential equations. Biologists, in contrast, have not yet reached a consensus on what constitutes introductory learning in biology. Accordingly, there is no single mathematics curriculum for biology that can be applied in all institutions.

In the past decade, a number of approaches to the problem of replacing the standard calculus sequence with something more appropriate for biologists have been made by mathematicians, with connections to various areas of biology. This broad issue of mathematics curricula for lower-division biology students is addressed in eight of the thirteen papers in the Modeling section, which fall into three classes.

The simplest approach, as seen in the first three papers, is to modify the courses that biology students are already taking, but to leave them compatible with the standard sequence so that students can move between the traditional physics-based and alternative biology-based courses. These three papers are arranged in order of increasing scope. We begin with a paper by Jerry Uhl and Judy Holdener that describes a one-semester biocalculus course at the University of Illinois that grew out of Jerry's well-known Calculus with Mathematica project and features significant use of a computer algebra system. Next is a paper by Tim Comar that describes the two-semester biocalculus sequence at Benedictine University. The courses incorporate dynamical systems and biology applications into the standard calculus sequence and also use computer laboratory projects. This group concludes with a paper by Laura Kubatko and colleagues that describes a two-quarter sequence of biology-oriented calculus courses, along with a one-quarter biology-oriented statistics course, at the Ohio State University. This group of papers offers a variety of options for modifying the standard curriculum.

A second approach, also represented by three papers, is to create a biology-based curriculum that does not try to be compatible with the standard curriculum. We can gain flexibility by diverging from the standard curriculum at the beginning, but at the cost of immediate tracking of students. The three papers in this group illustrate the variety that is made possible by abandoning the requirement of compatibility with standard courses. We have arranged these papers in order of decreasing seniority, beginning with a paper by Fred Adler that describes the one-year mathematics-for-biology curriculum he created at the University of Utah in the early 1990s. The Utah curriculum focuses on dynamical systems and probability/statistics, packaged to be accessible to students who have not previously taken a calculus couorse. Calculus topics are developed as needed. Next is a paper by several faculty at Macalester College that describes their Applied Calculus and Statistical Modeling sequence. Do not be mislead by the word "Applied." Whereas the title Applied Calculus normally is used for the brief treatments designed for business students and often foisted on biology students, the Macalester Applied Calculus course is designed for students who have already had some exposure to calculus. It begins with a treatment of functions and differential calculus and concludes with material on differential equations and linear algebra. The Statistical Modeling course offers a calculus-based curriculum designed around statistical problems in biology. In the final paper of this group, Lester Caudill describes the Scientific Calculus sequence and a biomedical modeling course at the University of Richmond. The first semester in the Scientific Calculus sequence adds modeling, regression, and multivariable optimization to a first-semester calculus core, while the second semester focuses on probability, Taylor series, and dynamical systems. The third course focuses on modeling and dynamical systems. Having a third course makes it possible for the Richmond curriculum to retain more topics from standard calculus than the other projects in this group. Readers interested in full-year freshman curricula will also want to look at the article by Lou Gross in the Processes section of this volume.

Recently, there has been some interest in the intermediate strategy of a standard-curriculum-compatible one-semester calculus course followed by a terminal one-semester course designed for biology students. This approach offers more flexibility than the first approach without the immediate tracking of the second. In the first paper of this group, I describe the Mathematical Methods for Biology and Medicine course that I created at the University of Nebraska. It begins with basics of mathematical modeling, with a focus on working with parameters and fitting data to models, before turning to probability distributions and concluding with dynamical systems. In the second paper of this group, Claudia Neuhauser describes a course at the University of Minnesota called Modeling Nature and the Nature of Modeling. This course focuses on discrete and continuous dynamical systems before turning to some partial differential equation models and stochastic processes, with an emphasis on computer modeling in Excel and Matlab.

The remaining papers in the Models section concern projects that fill specific niches identified at their institutions. Each is highly interdisciplinary and taught by a team that includes life science and mathematics faculty. Many include student research. Three focus on topics that do not normally appear in the mathematics curriculum and one encompasses basic biology as well as basic mathematics. They are examples of creative curriculum development in mathematical biology.

The papers by Rohan Attele and Dan Hrozencik of Chicago State University and by Glenn Ledder, Brigitte Tenhumberg, and Travis Adams of the University of Nebraska describe two approaches to designing a course based more on research than on specific content. Attele and Hrozencik describe a sophomore-level course in which students learn computational linear algebra and matrix population models before studying molecular evolution and phylogenetic trees. Students work in interdisciplinary teams on a research problem in population demographics. Ledder, Tenhumberg, and Adams describe a pre-college or freshman-level course centered on a research project in theoretical ecology. The students collect data on rates of aphid birth, growth, and death, which they use to parameterize a matrix model of aphid population growth. Another experiment collects population data used to test the predictions of the model. The lecture portion of the course supplements the laboratory portion by teaching students the methods and concepts needed for modeling and data analysis.

The next paper, by Raina Robeva, Robin Davies, and Michael Johnson, describes a Biomathematics course taught at Sweet Briar College by a team of one mathematician and one biologist to mathematics and biology majors who have taken courses in calculus, statistics, and general biology. The course employs mathematical methods to treat problems chosen for their biological content. These include Boolean network analysis, a topic that is nicely described in a paper by Martins, Vera-Licona, and Laubenbacher that appears in the Directions section of this volume.

In the next paper of the Models section, Steven Deckelman describes the bioinformatics program of the mathematics department at the University of Wisconsin-Stout. It is built from courses in computer science, biology, chemistry, and mathematics, and features a capstone course called Mathematical and Computational Foundations of Bioinformatics.

The final paper in the Models section describes an integrated year-long freshman sequence at East Tennessee State University that is equivalent to one statistics course, one calculus course, and three biology courses. The reader interested in interdisciplinary courses should also look at the paper by Mark MacLean in the Processes section.

The thirteen papers in the Models section do not provide a comprehensive listing of curriculum projects in mathematics for biology students, but they do contain a rich variety of projects that represent solutions to pedagogical problems that are partly general and partly dependent on the institutional setting. Readers who do not find a model here that they can adapt to their institution will at least find elements to incorporate into their own innovative model. Three additional papers in the Processes section (one by Lee and Boyd, one by Ardis and Subramanian, and one by Hom, Leaver, and Wilson) also contain significant descriptions of curriculum models.