# Undergraduate Mathematics for the Life Sciences: Models, Processes, and Directions

ed. Glenn Ledder

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# Preface

This volume contains 26 articles on mathematics pedagogy for life science students, representing 22 different institutions ranging from large research universities to community colleges. While many of the articles discuss projects designed to fit a particular niche at a particular institution, each emphasizes lessons learned that could be applied to other projects at different institutions. The articles are sorted into three themes, ***Models***, ***Processes***, and ***Directions***, as described in more detail in the General Introduction, which follows the table of contents, and the separate editorial introductions to each of the three parts. Curricular development in mathematics for biology is occurring at a variety of levels, including advanced undergraduate courses, interdisciplinary courses, alternatives to the standard calculus sequence, and complete curricula. Articles in the ***Models*** and ***Processes*** sections focus on specific curriculum projects at one of these levels. The division of these articles into two groups was motivated by the observation, common to many of the authors, that successful innovation in mathematics pedagogy for biology requires much more than a good pedagogical idea. Several excellent projects have failed to become established because they could not attract sufficient enrollment or have fallen into disuse because they could not be institutionalized. We wanted to present these projects as outstanding models and also address the reasons for their eventual failure.

For the most part, articles in the ***Models*** section focus on the details of a curricular model while articles in the ***Processes*** section focus on the issues involved in implementing a curricular model. Some articles were written as companion pieces, one in each section, while other articles address both themes and were placed in whichever section seemed most appropriate; these connections are noted in the general introduction and in the editorial introductions to the three parts. Articles in the ***Directions*** section focus on potential changes in emphasis and topic selection. Our hope was that we would also have articles on assessment of curricular projects to put in the ***Directions*** section; however, at the time articles were chosen for this volume, we were unable to find any assessment results that we thought sufficiently robust and exemplary for inclusion as separate articles. A few of the articles do contain limited assessment results, but there is clearly a need for assessment of curriculum projects that is only beginning to be met.

Each article begins with a brief summary of the institution and the students involved in the associated project; where possible, each directs the reader to additional information accessible on the web. Readers interested in other web resources could start with the BIO SIGMAA and Bioquest web sites.

Many of the curriculum projects discussed in this volume had their genesis in the response of the mathematics and biology communities to the publication in 2003 of the BIO2010 report of the National Academies. Incorporating perspectives from leading biology researchers with mathematics expertise, the report recommended significant improvements in the quantitative education of research biologists. While the report received some criticism from a small number of biologists who believed (incorrectly, in my opinion) that it was aimed primarily at medical research, it was largely endorsed by the biology community and thoroughly embraced by the mathematics community. “All” that remained was to implement its recommendations.

The Mathematics Association of America (MAA) published a follow-up volume in 2005, called *Math and BIO2010*, edited by Lynn Arthur Steen. This volume contained a number of essays with suggestions for mathematics curriculum reform, but there were very few concrete examples of successful programs. Simultaneously, a growing number of mathematics faculties began addressing problems of curriculum reform for their own institutions, and a small number of associated textbooks were published in the first few years after *BIO2010*.

Mathematics curriculum development for biology went mainstream in 2006 with two developments that were initially unrelated. The first was that the planners for the Joint Mathematics Meetings (JMM) of 2007 found themselves with three distinct proposals for contributed paper sessions on mathematics education for biology. Two of these were combined together, resulting in two distinct sessions. One of these was organized by Elton Graves of Rose-Hulman Institute of Technology; I organized the other in conjunction with Jack Bookman, James Fulton, and Yajun Yang. The second development was the founding of the Biology Special Interest Group of the MAA (BIO SIGMAA) by Eric Marland of Appalachian State University. I was among the people originally invited by Eric to help form the group. I suggested that BIO SIGMAA's first official action should be to sponsor my contributed paper session, which resulted in my selection as the first Program Director of BIO SIGMAA.

The mathematics-for-biology sessions at JMM 2007 proved to be a great success. My session had so many contributors that it had to be broken into three parts. In spite of the necessity for some of these parts to be scheduled at undesirable times, these talks were very well attended, with audiences ranging from 20 participants to more than 50. The mathematics-for-biology sessions also caught the interest of people involved in publishing. Shortly after JMM 2007, I received offers for publications from PRIMUS editor Brian Winkel and MAA Notes editor Steve Maurer. After some preliminary discussions with the other JMM contributors, we arrived at a plan – I would edit a PRIMUS issue focused on ideas of small scope that could be implemented within the context of an individual course, and Jenna Carpenter and Tim Comar would join me in editing an MAA Notes volume focused on projects at the course and curriculum levels. The PRIMUS issue, published in January 2008, consisted of invited papers based on talks in my JMM session.

Jenna, Tim, and I initially planned this volume with help from Eric Marland. It was Eric who suggested that we should look for articles that would describe curricular models, discuss the curriculum change process, and suggest directions for the future. This led to the conception of the volume as having separate parts devoted to models, processes, and directions.

Some of the contributions for this volume were specifically solicited from leaders in mathematics education for biology, but we also wanted to cast a wide net. We used the BIO SIGMAA listserv to send out a call for papers. This brought us a large number of proposals for articles, eventually resulting in the 26 papers in this volume. Taken together, these papers offer the reader a wealth of accumulated experience.

It appears likely that mathematics curriculum development for biology students will impact an increasing number of educational institutions.  However, it is difficult to move from a good idea to an accepted course or curriculum.  Models that meet the needs of one institution may not work for other institutions.  New courses or curricula need to be tested in the context of their own institution to inform subsequent improvement.  For this reason, each article begins with a capsule summary of the key facts about the program described in the paper and the associated institution.  To the reader who is struggling with mathematics curriculum development for biology students, these articles offer an opportunity to make use of the experiences of those who have already faced the same challenges with varying degrees of success.

My co-editors and I want to acknowledge the valuable assistance of Steve Maurer and the team of reviewers that read through the articles.  The reviewers had a lot of work to do with the first draft, owing to the lack of experience of the volume editors, but their critiques resulted in extensive changes for the better.  While this volume has taken a long time to reach print – owing to the large number of people and revisions involved – the extra time has allowed many articles to discuss how the projects changed over time in response to changing needs and varying degrees of initial success.  We hope that the information presented in this volume will inspire a new generation of successful curriculum models.

Glenn Ledder
May, 2012

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## General Introduction

The mathematics curriculum as we know it grew out of the mathematical needs of physical science. We start with a full course in calculus, which requires three semesters at most institutions. This is followed by courses in linear algebra, differential equations, and calculus-based probability/statistics in some order. These latter subjects are the ones with the broadest applications in biology, along with several discrete topics that do not occupy a place in the physics-based mathematics curriculum. Biological applications in these courses have been rare until recently, but many authors are incorporating biological examples in updated editions. There are some books in these traditional areas that are geared toward life science students, but there is no clear mathematics curriculum specifically designed for life science.

Meanwhile, the biology curriculum coalesced into a form that includes very little mathematics, in spite of the development, beginning in the 1920's, of several important mathematical models for biology. The typical curriculum for biology majors includes just one course in calculus and one in non-calculus-based statistics, and anything beyond two courses is rare.

The combined result of the large gap between the mathematics background that is beneficial to biologists and the mathematics background biology students acquire through mathematics courses is an undergraduate education in biology with very little quantitative content. Mathematics could certainly be incorporated into biology courses such as genetics and ecology; however, this is very difficult to accomplish unless the biologist who teaches the course can count on students having previously acquired the necessary mathematics background.

The obvious answer, from a mathematician's point of view, is for biology students to take the full calculus sequence followed by courses in linear algebra, differential equations, and probability/statistics. There are two problems with this answer. First, the biology content of these courses is minimal, as the courses still generally cater to the needs of the physical or social sciences. This problem could be addressed without a major curriculum change. More serious is the problem of fitting all of these courses into a biology student's program. As it is, all biology students are essentially double majors, with enough courses in mathematics, physics, general chemistry, and organic chemistry to encompass a major in general science, along with the major in biology. The addition of four more mathematics courses to this load of requirements is impractical, even for biology students who have the interest and aptitude.

In this volume, a variety of authors from a variety of institutions address some of the problems involved in reforming mathematics curricula for biology students. These problems are sorted into three themes. We begin by examining curriculum ***Models.*** It is relatively straight-forward for mathematicians to generate curriculum ideas for the training of mathematicians, but it is much more difficult to generate curriculum ideas for the training of biologists, owing to the difficulties noted above. A number of different curriculum models have been introduced at various institutions, and a selection of these comprise the Models section. The second theme is ***Processes***. Suppose we have created an outstanding course that clearly meets the needs of its students. This course amounts to nothing unless it is institutionalized in both the biology department (as a curricular requirement) and in the mathematics department (as a course that will be staffed even after the creator of the course is no longer on the faculty). The final theme is ***Directions***. Here we look to the future, with each paper laying out a case for pedagogical developments that the authors would like to see gain traction.

There is a significant overlap between the ***Models*** and ***Processes*** themes. All of the ***Processes*** papers are in reference to some model, although the role played by the curriculum model is peripheral in some cases. Many of the ***Models*** papers make some mention of process issues. Some contributors, such as Kubatko and Nance of Ohio State University, have companion pieces in both parts. Other papers were placed in whichever part seemed to be the better fit, but in some cases this was almost arbitrary. The papers by MacLean, Lee and Boyd, and Joplin *et al* combine almost equal doses of model and process; the first two appear in the ***Processes*** part and the latter in the ***Models*** part.