Chapter 1
Introduction

The progress in the biological sciences over the last several decades has been revolutionary, and it is reasonable to expect that this pace of progress, facilitated by huge advances in technology, will continue in the following decades. Mathematics has historically contributed to, as well as benefited from, progress in the natural sciences, and it can play the same role in the biological sciences. For this reason we believe that it is important to introduce students very early, already at the freshman or sophomore level, with just basic knowledge in Calculus, to the interdisciplinary field of mathematical biology. A typical case study in mathematical biology consists of several steps. The initial step is a description of a biological process which gives rise to several biological questions where mathematics could be helpful in providing answers. The second step is to develop a mathematical model that represents the relevant biological process. The next step is to use mathematical theories and computational methods in order to derive mathematical predictions from the model. The final step is to check that the mathematical predictions provide answers to the biological question. One can then further explore related biological questions by using the mathematical model.

This book is based on a one semester course that we have been teaching for several years. We chose two sets of case studies. The first set includes chemostat models, predator–prey interaction, competition among species, the spread of infectious diseases, and oscillations arising from bifurcations. In developing these topics we also introduced the students to the basic theory of ordinary differential equations, and taught them how to work and program with MATLAB without any prior programming experience. The students also learned how to use codes to test biological hypotheses.

The second set of case studies were cases adapted from recent and current research papers to the level of the students. We selected topics that are of great public health interest. These include the risk of atherosclerosis associated with high

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cholesterol level, cancer and immune interactions, cancer therapy, and tuberculosis. Throughout these case studies the student will experience how mathematical models and their numerical simulations can provide explanations that may actually guide biological and biomedical research. Toward this goal we have also included in our course "projects" for the students. We divided the students into small groups, and each group was assigned a research paper which they were to present to the entire class at the end of the course.

Another special feature of this book is that in addition to teach students how to use MATLAB to solve differential equations, we also introduce some very basic numerical methods to familiarize the students with some numerical techniques. That will greatly help their understanding in using different MATLAB functions, and can further help them when they try to use other computer languages in the future. Overall, our book is quite different from traditional mathematical biology textbooks in many aspects.

We believe that the book will help demonstrate to undergraduate students, even those with little mathematical background and no biological background, that mathematics can be a powerful tool in furthering biological understanding, and that there are both challenge and excitement in the interface between mathematics and biology.

This book is the undergraduate companion to the more advanced book "Mathematical Modeling of Biological Process" by A. Friedman and C.-Y. Kao (Springer, 2014), and there is some overlap with Chapters 1, 4–6 of that book. We would like to thank Chiu-Yen Kao who taught the very first version of this undergraduate course.

The MATLAB codes (in M-files) for the sample codes printed on the book are available in the Supplementary Material. The supplementary material can be downloaded from http://link.springer.com/book/10.1007/978-3-319-29638-8.