Preface

When I tried to design output feedback controllers for nonlinear control systems, I found that design methods are limited. I thought that a cellular process in living organisms, such as the blood glucose control system, would be a perfect feedback control system because the cellular process should be tightly controlled so that cells in the living organism can carry out numerous tasks to survive. Thus I was wondering whether I can get inspiration from cells to design feedback controllers and started to read biology books. As I read more and more in biology, I found that there are numerous perfect feedback control mechanisms in life, for instance, enzyme feedback inhibition, blood glucose regulation, and store-operated calcium entry in cells, to mention a few. This motivated me to open a class to teach mathematical modeling in biology with a focus on cellular processes and motivated me to write this textbook for my class.

Because the general idea of establishing a model for every cellular control system is similar, I have selected a number of cellular control systems that I have understood most, such as the blood glucose control system and intracellular calcium control system, to demonstrate how to model them mathematically in the setting of control theory. Once one masters the methods of modeling these selected cellular systems, one will be able to use them to handle other cellular systems.

This textbook contains the essential knowledge in modeling, simulation, analysis, and applications in dealing with biological cellular control systems. In particular, the book shows how to use the law of mass balance and the law of mass action to derive an enzyme kinetic model - the Michaelis-Menten function or the Hill function, how to use a current-voltage relation, Nernst potential equilibrium equation, and Hodgkin and Huxley's models to model an ionic channel or pump, and how to use the law of mass balance to integrate these enzyme or channel models into a complete feedback control system. The book also illustrates how to use data to estimate parameters in a model, how to use MATLAB to solve a model numerically, how to do computer simulations, and how to provide model predictions. Furthermore, the book demonstrates how to conduct a stability and sensitivity analysis on a model.

This textbook is self-contained and easy to read. Modeling, simulation, and applications are explained in details. Whenever possible, a schematic diagram is drawn to help understand the biology in a cellular process. A good background in ordinary differential equations and molecular biology is sufficient to understand the materials in this textbook.

This text is designed as a textbook for a one-semester course in mathematical modeling in biology with a focus on cellular processes in living organisms. There are exercises in the end of each chapter and preliminary MATLAB is introduced in Appendix A.

Although all models in this textbook are ordinary differential equation (ODE) models, a diffusion term can be easily added to these ODE models for some cellular systems such as the intracellular calcium control system to lead to partial differential equation (PDE) models. However, the PDE models will greatly increase the complexity and difficulty of computer simulation.

Although I tried hard to make the text error-free, there are certainly still numerous errors and mistakes of different types, such as typos, grammatical errors, and even scientific mistakes. I apologize for making these mistakes and you are welcome to send your comments and criticisms to me at weijiul@uca.edu or liuweijiu@hotmail.com.

I thank Dr. Fusheng Tang for collaborative work on mathematical biology, constant inspirational discussions on biology, and insightful comments on this manuscript. I thank the reviewer for evaluating this text and giving constructive comments. I thank my students for using this text and correcting mistakes.

Conway (Arkansas), July 2011 *Weijiu Liu*

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