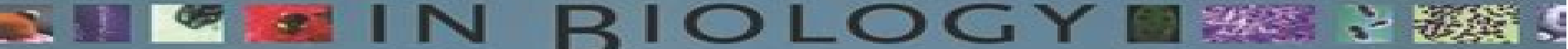


# DYNAMIC MODELS IN BIOLOGY



STEPHEN P. ELLNER AND  
JOHN GUCKENHEIMER



# Dynamic Models In Biology Dynamic Models In Biology

**Ensheng Dong**



## **Dynamic Models In Biology Dynamic Models In Biology:**

Dynamic Models in Biology Stephen P. Ellner, John Guckenheimer, 2011-09-19 From controlling disease outbreaks to predicting heart attacks dynamic models are increasingly crucial for understanding biological processes Many universities are starting undergraduate programs in computational biology to introduce students to this rapidly growing field In *Dynamic Models in Biology* the first text on dynamic models specifically written for undergraduate students in the biological sciences ecologist Stephen Ellner and mathematician John Guckenheimer teach students how to understand build and use dynamic models in biology Developed from a course taught by Ellner and Guckenheimer at Cornell University the book is organized around biological applications with mathematics and computing developed through case studies at the molecular cellular and population levels The authors cover both simple analytic models the sort usually found in mathematical biology texts and the complex computational models now used by both biologists and mathematicians Linked to a Web site with computer lab materials and exercises *Dynamic Models in Biology* is a major new introduction to dynamic models for students in the biological sciences mathematics and engineering

***Dynamical Models in Biology*** Miklós Farkas, 2001-06-15 *Dynamic Models in Biology* offers an introduction to modern mathematical biology This book provides a short introduction to modern mathematical methods in modeling dynamical phenomena and treats the broad topics of population dynamics epidemiology evolution immunology morphogenesis and pattern formation Primarily employing differential equations the author presents accessible descriptions of difficult mathematical models Recent mathematical results are included but the author's presentation gives intuitive meaning to all the main formulae Besides mathematicians who want to get acquainted with this relatively new field of applications this book is useful for physicians biologists agricultural engineers and environmentalists Key Topics Include Chaotic dynamics of populations The spread of sexually transmitted diseases Problems of the origin of life Models of immunology Formation of animal hide patterns The intuitive meaning of mathematical formulae explained with many figures Applying new mathematical results in modeling biological phenomena Miklos Farkas is a professor at Budapest University of Technology where he has researched and instructed mathematics for over thirty years He has taught at universities in the former Soviet Union Canada Australia Venezuela Nigeria India and Columbia Prof Farkas received the 1999 Bolyai Award of the Hungarian Academy of Science and the 2001 Albert Szentgyorgyi Award of the Hungarian Ministry of Education A down to earth introduction to the growing field of modern mathematical biology Also includes appendices which provide background material that goes beyond advanced calculus and linear algebra

*Dynamical Models in Biology* Miklós Farkas, 2001-06-06 *Dynamic Models in Biology* offers an introduction to modern mathematical biology This book provides a short introduction to modern mathematical methods in modeling dynamical phenomena and treats the broad topics of population dynamics epidemiology evolution immunology morphogenesis and pattern formation Primarily employing differential equations the author presents accessible descriptions of difficult mathematical models Recent mathematical

results are included but the author's presentation gives intuitive meaning to all the main formulae. Besides mathematicians who want to get acquainted with this relatively new field of applications, this book is useful for physicians, biologists, agricultural engineers, and environmentalists. Key Topics Include: Chaotic dynamics of populations, The spread of sexually transmitted diseases, Problems of the origin of life, Models of immunology, Formation of animal hide patterns, The intuitive meaning of mathematical formulae explained with many figures, Applying new mathematical results in modeling biological phenomena. Miklos Farkas is a professor at Budapest University of Technology where he has researched and instructed mathematics for over thirty years. He has taught at universities in the former Soviet Union, Canada, Australia, Venezuela, Nigeria, India, and Columbia. Prof. Farkas received the 1999 Bolyai Award of the Hungarian Academy of Science and the 2001 Albert Szentgyorgyi Award of the Hungarian Ministry of Education. A down-to-earth introduction to the growing field of modern mathematical biology. Also includes appendices which provide background material that goes beyond advanced calculus and linear algebra.

**Dynamical Models of Biology and Medicine** Yang Kuang, Meng Fan, Shengqiang Liu, Wanbiao Ma, 2019-10-04. Mathematical and computational modeling approaches in biological and medical research are experiencing rapid growth globally. This Special Issue Book intends to scratch the surface of this exciting phenomenon. The subject areas covered involve general mathematical methods and their applications in biology and medicine with an emphasis on work related to mathematical and computational modeling of the complex dynamics observed in biological and medical research. Fourteen rigorously reviewed papers were included in this Special Issue. These papers cover several timely topics relating to classical population biology, fundamental biology, and modern medicine. While the authors of these papers dealt with very different modeling questions, they were all motivated by specific applications in biology and medicine and employed innovative mathematical and computational methods to study the complex dynamics of their models. We hope that these papers detail case studies that will inspire many additional mathematical modeling efforts in biology and medicine.

**Dynamic Models and Control of Biological Systems** Vadrevu Sree Hari Rao, Ponnada Raja Sekhara Rao, 2009-07-30. Mathematical Biology has grown at an astonishing rate and has established itself as a distinct discipline. Mathematical modeling is now being applied in every major discipline in the biological sciences. Though the field has become increasingly large and specialized, this book remains important as a text that introduces some of the exciting problems which arise in the biological sciences and gives some indication of the wide spectrum of questions that modeling can address.

**Dynamical Models of Biology and Medicine** Meng Fan, Yang Kuang, Shengqiang Liu, Wanbiao Ma, 2019. Mathematical and computational modeling approaches in biological and medical research are experiencing rapid growth globally. This Special Issue Book intends to scratch the surface of this exciting phenomenon. The subject areas covered involve general mathematical methods and their applications in biology and medicine with an emphasis on work related to mathematical and computational modeling of the complex dynamics observed in biological and medical research. Fourteen rigorously reviewed papers were

included in this Special Issue. These papers cover several timely topics relating to classical population biology, fundamental biology, and modern medicine. While the authors of these papers dealt with very different modeling questions, they were all motivated by specific applications in biology and medicine and employed innovative mathematical and computational methods to study the complex dynamics of their models. We hope that these papers detail case studies that will inspire many additional mathematical modeling efforts in biology and medicine.

**Modeling Dynamic Biological Systems** Bruce Hannon, Matthias Ruth, 2014-07-05. Many biologists and ecologists have developed models that find widespread use in theoretical investigations and in applications to organism behavior, disease control, population and metapopulation theory, ecosystem dynamics, and environmental management. This book captures and extends the process of model development by concentrating on the dynamic aspects of these processes and by providing the tools such that virtually anyone with basic knowledge in the Life Sciences can develop meaningful dynamic models. Examples of the systems modeled in the book range from models of cell development, the beating heart, the growth and spread of insects, spatial competition and extinction, to the spread and control of epidemics, including the conditions for the development of chaos. Key features: easy to learn and easy to use; software examples from many subdisciplines of biology covering models of cells, organisms, populations, and metapopulations; no prior computer or programming experience required. Key benefits: learn how to develop modeling skills and system thinking on your own rather than use models developed by others; be able to easily run models under alternative assumptions and investigate the implications of these assumptions for the dynamics of the biological system being modeled; develop skills to assess the dynamics of biological systems.

**Modeling Dynamic Phenomena in Molecular and Cellular Biology** Lee A. Segel, 1984-03-30. The dynamic development of various processes is a central problem of biology and indeed of all the sciences. The mathematics describing that development is in general complicated because the models that are realistic are usually nonlinear. Consequently, many biologists may not notice a possible application of theory. They may be unable to decide whether a particular model captures the essence of a system or to appreciate that analysis of a model can reveal important aspects of biological problems and may even describe in detail how a system works. The aim of this textbook is to remedy the situation by adopting a general approach to model analysis and applying it several times to problems drawn primarily from molecular and cellular biology of gradually increasing biological and mathematical complexity. Although material of considerable sophistication is included, little mathematical background is required; only some exposure to elementary calculus. Appendixes supply the necessary mathematics, and the author concentrates on concepts rather than techniques. He also emphasizes the role of computers in giving a full picture of model behavior and complementing more qualitative analysis. Some problems suitable for computer analysis are also included. This is a class-tested textbook suitable for a one-semester course for advanced undergraduate and beginning graduate students in biology or applied mathematics. It can also be used as a source book for teachers and a reference for specialists.

Dynamic Systems Biology Modeling and

Simulation Joseph DiStefano III, 2015-01-10 Dynamic Systems Biology Modeling and Simulation consolidates and unifies classical and contemporary multiscale methodologies for mathematical modeling and computer simulation of dynamic biological systems from molecular cellular organ system on up to population levels The book pedagogy is developed as a well annotated systematic tutorial with clearly spelled out and unified nomenclature derived from the author's own modeling efforts publications and teaching over half a century Ambiguities in some concepts and tools are clarified and others are rendered more accessible and practical The latter include novel qualitative theory and methodologies for recognizing dynamical signatures in data using structural multicompartmental and network models and graph theory and analyzing structural and measurement data models for quantification feasibility The level is basic to intermediate with much emphasis on biomodeling from real biodata for use in real applications Introductory coverage of core mathematical concepts such as linear and nonlinear differential and difference equations Laplace transforms linear algebra probability statistics and stochastics topics The pertinent biology biochemistry biophysics or pharmacology for modeling are provided to support understanding the amalgam of math modeling with life sciences Strong emphasis on quantifying as well as building and analyzing biomodels includes methodology and computational tools for parameter identifiability and sensitivity analysis parameter estimation from real data model distinguishability and simplification and practical bioexperiment design and optimization Companion website provides solutions and program code for examples and exercises using Matlab Simulink VisSim SimBiology SAAMII AMIGO Copasi and SBML coded models A full set of PowerPoint slides are available from the author for teaching from his textbook He uses them to teach a 10 week quarter upper division course at UCLA which meets twice a week so there are 20 lectures They can easily be augmented or stretched for a 15 week semester course Importantly the slides are editable so they can be readily adapted to a lecturer's personal style and course content needs The lectures are based on excerpts from 12 of the first 13 chapters of DSBMS They are designed to highlight the key course material as a study guide and structure for students following the full text content The complete PowerPoint slide package 25 MB can be obtained by instructors or prospective instructors by emailing the author directly at joed cs ucla edu

**Dynamic Modeling in Behavioral Ecology** Marc Mangel, Colin Whitcomb Clark, 2019-12-31 This book describes a powerful and flexible technique for the modeling of behavior based on evolutionary principles The technique employs stochastic dynamic programming and permits the analysis of behavioral adaptations wherein organisms respond to changes in their environment and in their own current physiological state Models can be constructed to reflect sequential decisions concerned simultaneously with foraging reproduction predator avoidance and other activities The authors show how to construct and use dynamic behavioral models Part I covers the mathematical background and computer programming and then uses a paradigm of foraging under risk of predation to exemplify the general modeling technique Part II consists of five applied chapters illustrating the scope of the dynamic modeling approach They treat hunting behavior in lions reproduction in insects

migrations of aquatic organisms clutch size and parental care in birds and movement of spiders and raptors Advanced topics including the study of dynamic evolutionarily stable strategies are discussed in Part III

**Dynamic Models of Infectious Diseases** Vadrevu Sree Hari Rao, Ravi Durvasula, 2012-11-07 Despite great advances in public health worldwide insect vector borne infectious diseases remain a leading cause of morbidity and mortality Diseases that are transmitted by arthropods such as mosquitoes sand flies fleas and ticks affect hundreds of millions of people and account for nearly three million deaths all over the world In the past there was very little hope of controlling the epidemics caused by these diseases but modern advancements in science and technology are providing a variety of ways in which these diseases can be handled Clearly the process of transmission of an infectious disease is a nonlinear not necessarily linear dynamic process which can be understood only by appropriately quantifying the vital parameters that govern these dynamics

**Dynamical System Models in the Life Sciences and Their Underlying Scientific Issues** Frederic Y. M. Wan, 2018 Broadly speaking there are two general approaches to teaching mathematical modeling 1 The case study approach focusing on different specific modeling problems familiar to the particular author and 2 The methods approach teaching some useful mathematical techniques accessible to the targeted student cohort with different models introduced to illustrate the application of the methods taught The goal and approach of this new text differ from these two conventional approaches in that its emphasis is on the scientific issues that prompt the mathematical modeling and analysis of a particular phenomenon For example in the study of a fish population we may be interested in the growth and evolution of the population whether the natural growth or harvested population reaches a steady state equilibrium or periodically changing population in a particular environment is a steady state stable or unstable with respect to a small perturbation from the equilibrium state whether a small change in the environment would lead to a catastrophic change etc Each of these scientific issues requires the introduction of a different kind of model and a different set of mathematical tools to extract information about the same biological organisms or phenomena Volume I of this three volume set limits its scope to phenomena and scientific issues that can be modeled by ordinary differential equations ODE that govern the evolution of the phenomena with time The scientific issues involved include evolution equilibrium stability bifurcation feedback optimization and control Scientific issues such as signal and wave propagation diffusion and shock formation pertaining to phenomena involving spatial dynamics are to be modeled by partial differential equations PDE and will be treated in Volume II Scientific issues involving randomness and uncertainty are deferred to Volume III

*Stochastic Chemical Reaction Systems in Biology* Hong Qian, Hao Ge, 2021-10-19 This book provides an introduction to the analysis of stochastic dynamic models in biology and medicine The main aim is to offer a coherent set of probabilistic techniques and mathematical tools which can be used for the simulation and analysis of various biological phenomena These tools are illustrated on a number of examples For each example the biological background is described and mathematical models are developed following a unified set of principles These models are then analyzed and

finally the biological implications of the mathematical results are interpreted The biological topics covered include gene expression biochemistry cellular regulation and cancer biology The book will be accessible to graduate students who have a strong background in differential equations the theory of nonlinear dynamical systems Markovian stochastic processes and both discrete and continuous state spaces and who are familiar with the basic concepts of probability theory A *Mathematical Treatment of Dynamical Models in Biological Science* Kristína Smítalová, Štefan Šujan, 1991 Providing a comprehensive introduction to mathematical modelling in biology and ecology this book presents numerous results and developments The basic mathematical facts on the theory of the dynamics of biological communities are presented with emphasis placed on the quantitative aspects *Dynamical Modeling of Biological Systems* Stilianos Louca, 2023-06-07 This book introduces concepts and practical tools for dynamical mathematical modeling of biological systems Dynamical models describe the behavior of a system over time as a result of internal feedback loops and external forcing based on mathematically formulated dynamical laws similarly to how Newton's laws describe the movement of celestial bodies Dynamical models are increasingly popular in biology as they tend to be more powerful than static regression models This book is meant for undergraduate and graduate students in physics applied mathematics and data science with an interest in biology as well as students in biology with a strong interest in mathematical methods The book covers deterministic models for example differential equations stochastic models for example Markov chains and autoregressive models and model independent aspects of time series analysis Plenty of examples and exercises are included often taken or inspired from the scientific literature and covering a broad range of topics such as neuroscience cell biology genetics evolution ecology microbiology physiology epidemiology and conservation The book delivers generic modeling techniques used across a wide range of situations in biology and hence readers from other scientific disciplines will find that much of the material is also applicable in their own field Proofs of most mathematical statements are included for the interested reader but are not essential for a practical understanding of the material The book introduces the popular scientific programming language MATLAB as a tool for simulating models fitting models to data and visualizing data and model predictions The material taught is current as of MATLAB version 2022b The material is taught in a sufficiently general way that also permits the use of alternative programming languages *Dynamical models in biology*, 1990 *Dynamical Models in Biology* Nicolas Farkas, 2001 *Modeling Biological Systems* James W. Haefner, 1996-07-31 This book is intended as a text for a first course on creating and analyzing computer simulation models of biological systems The expected audience for this book are students wishing to use dynamic models to interpret real data much as they would use standard statistical techniques It is meant to provide both the essential principles as well as the details and equations applicable to a few particular systems and subdisciplines Biological systems however encompass a vast diverse array of topics and problems This book discusses only a select number of these that I have found to be useful and interesting to biologists just beginning their appreciation of



computer simulation The examples chosen span classical mathematical models of well studied systems to state of the art topics such as cellular automata and artificial life I have stressed the relationship between the models and the biology over mathematical analysis in order to give the reader a sense that mathematical models really are useful to biologists In this light I have sought examples that address fundamental and I think interesting biological questions Almost all of the models are directly compared to quantitative data to provide at least a partial demonstration that some biological models can accurately predict

**Dynamic Models of Energy, Robotic, and Biological Systems** Jose de Jesus Rubio,Alejandro Zacarias,Jaime Pacheco,2025-05-30 Dynamic models are essential for understanding the system dynamics It is of importance because one mistake in experiments could cause accidents or damages while one mistake in the simulation of dynamic models could cause nothing Each system has a different dynamic model hence this book presents the designs of 10 dynamic models which are mainly classified in two ways The first kind of dynamic models are mainly obtained by the Euler Lagrange method and described by differential equations The second kind of dynamic models are mainly obtained by the neural networks and described by difference equations Topics and features Contains the dynamic models of energy systems Derives dynamic models of energy systems by the Euler Lagrange method Includes the dynamic models of robotic systems Contains the dynamic models of biological systems Derives dynamic models of robotic systems by the Euler Lagrange method Obtains dynamic models of biological systems by neural networks This book is expected to be used primary by researchers and secondary by students and in the areas of control robotics energy biological mechanical mechatronics and computing systems Jose de Jesus Rubio Alejandro Zacarias and Jaime Pacheco are full Professors affiliated with the ESIME Azcapotzalco Instituto Polit cnico Nacional Secci n de Estudios de Posgrado e Investigaci n Ciudad de M xico M xico

**Computational Systems Biology** Reinhard Laubenbacher,Pedro Mendes,2013-11-26 Mathematical and statistical network modeling is an important step toward uncovering the organizational principles and dynamic behavior of biological networks This chapter focuses on methods to construct discrete dynamic models of gene regulatory networks from experimental data sets also sometimes referred to as top down modeling or reverse engineering Time discrete dynamical systems models have long been used in biology particularly in population dynamics The models mainly focused on here are also assumed to have a finite set of possible states for each variable That is the modeling framework discussed in this chapter is that of time discrete dynamical systems over a finite state set

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