

# Mathematical and theoretical biology

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**Mathematical and theoretical biology**, or **biomathematics**, is a branch of biology which employs theoretical analysis, mathematical models and abstractions of the living organisms to investigate the principles that govern the structure, development and behavior of the systems, as opposed to experimental biology which deals with the conduction of experiments to prove and validate the scientific theories.<sup>[1]</sup> The field is sometimes called **mathematical biology** or **biomathematics** to stress the mathematical side, or **theoretical biology** to stress the biological side.<sup>[2]</sup> Theoretical biology focuses more on the development of theoretical principles for biology while mathematical biology focuses on the use of mathematical tools to study biological systems, even though the two terms are sometimes interchanged.<sup>[3][4]</sup>

Mathematical biology aims at the mathematical representation and modeling of biological processes, using techniques and tools of applied mathematics. It can be useful in both theoretical and practical research. Describing systems in a quantitative manner means their behavior can be better simulated, and hence properties can be predicted that might not be evident to the experimenter. This requires precise mathematical models.

Because of the complexity of the living systems, theoretical biology employs several fields of mathematics,<sup>[5]</sup> and has contributed to the development of new techniques.

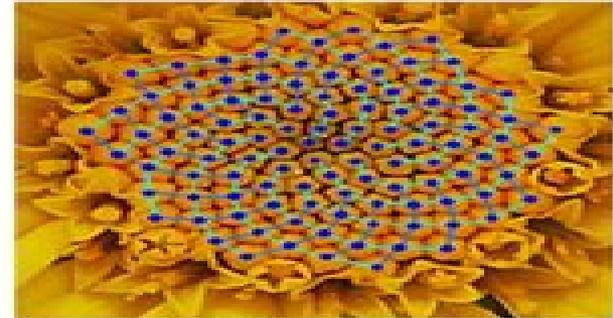
## History

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### Early history

Mathematics has been used in biology as early as the 13th century, when Fibonacci used the famous Fibonacci series to describe a growing population of rabbits. In the 18th century, Daniel Bernoulli applied mathematics to describe the effect of smallpox on the human population. Thomas Malthus' 1789 essay on the growth of the human population was based on the concept of exponential growth. Pierre François Verhulst formulated the logistic growth model in 1836.

Fritz Muller described the evolutionary benefits of what is now called Mullerian mimicry in 1879, in an account notable for being the first use of a mathematical argument in evolutionary ecology to show how powerful the effect of natural selection would be, unless one includes Malthus's discussion of the effects of population growth that influenced Charles Darwin: Malthus argued that growth would be exponential (he uses the word "geometric") while resources (the environment's carrying capacity) could only grow arithmetically.<sup>[6]</sup>



Yellow chamomile head showing the Fibonacci numbers in spirals consisting of 21 (blue) and 13 (aqua). Such arrangements have been noticed since the Middle Ages and can be used to make mathematical models of a wide variety of plants.

# Theoretical Mathematical Biology

**Ei Teramoto, Masaya Yamaguti**



## **Theoretical Mathematical Biology:**

*Mathematical Biology* T. A. Burton, 2016-06-21 *Mathematical Biology A Conference on Theoretical Aspects of Molecular Science* is a collection of papers that covers various investigations in mathematical biology The text tackles a wide range of topics from biological equation models up to electrical phenomena in biological systems The coverage of the text includes existence of a periodic solution for a two predator one prey ecosystem modeled on a chemostat mathematical treatment of nerve conduction and cardiac purkinje fibers and models of positional information The book will be of great interest to students researchers and practitioners of biological sciences

**Theoretical Mathematical Biology** R. L. Hancock, C. K. Zhong, 1994

**The Theoretical Biologist's Toolbox** Marc Mangel, 2006-07-27 Mathematical modelling is widely used in ecology and evolutionary biology and it is a topic that many biologists find difficult to grasp In this new textbook Marc Mangel provides a no nonsense introduction to the skills needed to understand the principles of theoretical and mathematical biology Fundamental theories and applications are introduced using numerous examples from current biological research complete with illustrations to highlight key points Exercises are also included throughout the text to show how theory can be applied and to test knowledge gained so far Suitable for advanced undergraduate courses in theoretical and mathematical biology this book forms an essential resource for anyone wanting to gain an understanding of theoretical ecology and evolution

Game-Theoretical Models in Biology Mark Broom, Jan Rychtář, 2022-08-03 Covering the major topics of evolutionary game theory *Game Theoretical Models in Biology Second Edition* presents both abstract and practical mathematical models of real biological situations It discusses the static aspects of game theory in a mathematically rigorous way that is appealing to mathematicians In addition the authors explore many applications of game theory to biology making the text useful to biologists as well The book describes a wide range of topics in evolutionary games including matrix games replicator dynamics the hawk dove game and the prisoner s dilemma It covers the evolutionarily stable strategy a key concept in biological games and offers in depth details of the mathematical models Most chapters illustrate how to use Python to solve various games Important biological phenomena such as the sex ratio of so many species being close to a half the evolution of cooperative behaviour and the existence of adornments for example the peacock s tail have been explained using ideas underpinned by game theoretical modelling Suitable for readers studying and working at the interface of mathematics and the life sciences this book shows how evolutionary game theory is used in the modelling of these diverse biological phenomena In this thoroughly revised new edition the authors have added three new chapters on the evolution of structured populations biological signalling games and a topical new chapter on evolutionary models of cancer There are also new sections on games with time constraints that convert simple games to potentially complex nonlinear ones new models on extortion strategies for the Iterated Prisoner s Dilemma and on social dilemmas and on evolutionary models of vaccination a timely section given the current Covid pandemic Features Presents a wide range of biological applications of game theory

Suitable for researchers and professionals in mathematical biology and the life sciences and as a text for postgraduate courses in mathematical biology Provides numerous examples exercises and Python code

**Structural Theories for Dynamical Networks in Biology** Atsushi Mochizuki, 2025-06-21 This textbook provides an introduction to theoretical biology using specific topics and explains the main mathematical methods The book also introduces the structural theories developed by the author and his colleagues as new theoretical methods Structural theories are mathematical theories that determine key aspects of the behavior of dynamical systems from network information alone The book details the practical applications of these methods across several biological network systems and shows that they are practically useful for analyzing the behaviors of biological systems The first half of the book focuses on the dynamics that arise from the regulation of biomolecular activity such as gene expression and protein modification The second half of the book approaches the understanding of the dynamics of complex systems composed of many biomolecules Each chapter covers current and important topics in biological research and its description of how biological phenomena are theoretically elucidated effectively conveys the importance and appeal of mathematical methods This book is not only a comprehensive textbook on theoretical biology but also a study guide for learning mathematical methods It also serves as a specialized reference for systematically learning new mathematical theories The Mathematical Methods section at the end of each chapter offers a concise summary and facilitates efficient learning for readers along with the exercises Target readers of this book are from upper undergraduate students to senior researchers interested in the dynamics of complex network systems in biology It appeals to both mathematical and experimental biologists as well as chemists and physicists

**Mathematical Modeling of Biological Systems, Volume II** Andreas Deutsch, Rafael Bravo de la Parra, Rob J. de Boer, Odo Diekmann, Peter Jagers, Eva Kisdi, Mirjam Kretzschmar, Petr Lansky, Hans Metz, 2007-10-12 Volume II of this two volume interdisciplinary work is a unified presentation of a broad range of state of the art topics in the rapidly growing field of mathematical modeling in the biological sciences Highlighted throughout are mathematical and computational approaches to examine central problems in the life sciences ranging from the organization principles of individual cells to the dynamics of large populations The chapters are thematically organized into the following main areas epidemiology evolution and ecology immunology neural systems and the brain and innovative mathematical methods and education The work will be an excellent reference text for a broad audience of researchers practitioners and advanced students in this rapidly growing field at the intersection of applied mathematics experimental biology and medicine computational biology biochemistry computer science and physics

**Mathematical Topics in Population Biology, Morphogenesis and Neurosciences** Ei Teramoto, Masaya Yamaguti, 1987-06-01 This volume represents the edited proceedings of the International Symposium on Mathematical Biology held in Kyoto November 10 15 1985 The symposium was organized by an international committee whose members are E Teramoto M Yamaguti S Amari S A Levin H Matsuda A Okubo L M Ricciardi R Rosen and L A Segel The symposium

included technical sessions with a total of 11 invited papers 49 contributed papers and a poster session where 40 papers were displayed These Proceedings consist of selected papers from this symposium This symposium was the second Kyoto meeting on mathematical topics in biology The first was held in conjunction with the Sixth International Biophysics Congress in 1978 Since then this field of science has grown enormously and the number of scientists in the field has rapidly increased This is also the case in Japan About 80 young Japanese scientists and graduate students participated this time The sessions were divided into 4 categories 1 Mathematical Ecology and Population Biology 2 Mathematical Theory of Developmental Biology and Morphogenesis 3 Theoretical Neurosciences and 4 Cell Kinetics and Other Topics In every session there were stimulating and active discussions among the participants We are convinced that the symposium was highly successful in transmitting scientific information across disciplines and in establishing fruitful contacts among the participants We owe this success to the cooperation of all participants

Theoretical and Mathematical Biology Talbot Howe Waterman, Harold J. Morowitz, 1965

**Philosophy of Science** William Marias Malisoff, 1993

Frontiers in Mathematical Biology Simon A. Levin, 2013-03-13

From a mathematical point of view physiologically structured population models are an underdeveloped branch of the theory of infinite dimensional dynamical systems We have called attention to four aspects i A choice has to be made about the kind of equations one extracts from the predominantly verbal arguments about the basic assumptions and subsequently uses as a starting point for a rigorous mathematical analysis Though differential equations are easy to formulate different mechanisms don't interact in infinitesimal time intervals and so end up as separate terms in the equations they may be hard to interpret rigorously as infinitesimal generators Integral equations constitute an attractive alternative ii The ability of physiologically structured population models to increase our understanding of the relation between mechanisms at the  $i$  level and phenomena at the  $p$  level will depend strongly on the development of dynamical systems lab facilities which are applicable to this class of models iii Physiologically structured population models are ideally suited for the formulation of evolutionary questions Apart from the special case of age see Charlesworth 1980 Yodzis 1989 Caswell 1989 and the references given there hardly any theory exists at the moment This will hopefully change rapidly in the coming years Again the development of appropriate software may turn out to be crucial

**Game-Theoretical Models in Biology** Mark Broom, Jan Rychtar, 2013-03-27

Covering the major topics of evolutionary game theory Game Theoretical Models in Biology presents both abstract and practical mathematical models of real biological situations It discusses the static aspects of game theory in a mathematically rigorous way that is appealing to mathematicians In addition the authors explore many applications of game theory to biology making the text useful to biologists as well The book describes a wide range of topics in evolutionary games including matrix games replicator dynamics the hawk dove game and the prisoner's dilemma It covers the evolutionarily stable strategy a key concept in biological games and offers in depth details of the mathematical models Most chapters illustrate how to use MATLAB to solve various games Important biological phenomena

such as the sex ratio of so many species being close to a half the evolution of cooperative behavior and the existence of adornments for example the peacock's tail have been explained using ideas underpinned by game theoretical modeling Suitable for readers studying and working at the interface of mathematics and the life sciences this book shows how evolutionary game theory is used in the modeling of these diverse biological phenomena Discrete and Topological Models in Molecular Biology Nataša Jonoska, Masahico Saito, 2013-12-23 Theoretical tools and insights from discrete mathematics theoretical computer science and topology now play essential roles in our understanding of vital biomolecular processes The related methods are now employed in various fields of mathematical biology as instruments to zoom in on processes at a molecular level This book contains expository chapters on how contemporary models from discrete mathematics in domains such as algebra combinatorics and graph and knot theories can provide perspective on biomolecular problems ranging from data analysis molecular and gene arrangements and structures and knotted DNA embeddings via spatial graph models to the dynamics and kinetics of molecular interactions The contributing authors are among the leading scientists in this field and the book is a reference for researchers in mathematics and theoretical computer science who are engaged with modeling molecular and biological phenomena using discrete methods It may also serve as a guide and supplement for graduate courses in mathematical biology or bioinformatics introducing nontraditional aspects of mathematical biology

**Mathematical Topics in Population Biology, Morphogenesis and Neurosciences** Ei Teramoto, Masaya Yamaguti, 2013-03-08 This volume represents the edited proceedings of the International Symposium on Mathematical Biology held in Kyoto November 10-15 1985 The symposium was organized by an international committee whose members are E Teramoto M Yamaguti S Amari S A Levin H Matsuda A Okubo L M Ricciardi R Rosen and L A Segel The symposium included technical sessions with a total of 11 invited papers 49 contributed papers and a poster session where 40 papers were displayed These Proceedings consist of selected papers from this symposium This symposium was the second Kyoto meeting on mathematical topics in biology The first was held in conjunction with the Sixth International Biophysics Congress in 1978 Since then this field of science has grown enormously and the number of scientists in the field has rapidly increased This is also the case in Japan About 80 young Japanese scientists and graduate students participated this time The sessions were divided into 4 categories 1 Mathematical Ecology and Population Biology 2 Mathematical Theory of Developmental Biology and Morphogenesis 3 Theoretical Neurosciences and 4 Cell Kinetics and Other Topics In every session there were stimulating and active discussions among the participants We are convinced that the symposium was highly successful in transmitting scientific information across disciplines and in establishing fruitful contacts among the participants We owe this success to the cooperation of all participants **The Principles of Psychology** William James, 1918 Towards a Mathematical Theory of Complex Biological Systems Carlo Bianca, Concetta Bianca, N. Bellomo, 2011 This monograph has the ambitious aim of developing a mathematical theory of complex biological systems with special attention to the phenomena of

ageing degeneration and repair of biological tissues under individual self repair actions that may have good potential in medical therapy The approach to mathematically modeling biological systems needs to tackle the additional difficulties generated by the peculiarities of living matter These include the lack of invariance principles abilities to express strategies for individual fitness heterogeneous behaviors competition up to proliferative and or destructive actions mutations learning ability evolution and many others Applied mathematicians in the field of living systems especially biological systems will appreciate the special class of integro differential equations offered here for modeling at the molecular celular and tissue scales A unique perspective is also presented with a number of case studies in biological modeling

*The Principles of Psychology* William James, 1918

**Pattern Recognition by Humans and Machines** Eileen C. Schwab, Howard C. Nusbaum, 2013-09-11 Pattern Recognition by Humans and Machines Volume 1 Speech Perception covers perception from the perspectives of cognitive psychology artificial intelligence and brain theory The book discusses on the research theory and the principal issues of speech perception the auditory and phonetic coding of speech and the role of the lexicon in speech perception The text also describes the role of attention and active processing in speech perception the suprasegmental in very large vocabulary word recognition and the adaptive self organization of serial order in behavior The cognitive science and the study of cognition and language are also considered Psychologists will find the book invaluable

*Theoretical Models in Biology* Glenn W. Rowe, 1994 This book surveys theoretical models in three broad areas of biology the origin of life the immune system and memory in the brain introducing mathematical and mainly computational models that have been used to construct simulations Most current books on theoretical biology fall into one of two categories a books that specialize in one area of biology and treat theoretical models in considerable depth and b books that concentrate on purely mathematical models with computers used only to find numerical solutions to differential equations for example Although some mathmatical models are considered in this book the main emphasis is on stochastic computer modles of biological systems Such techniques have a much greater potential for producing detailed realistic models of individual systems and are likely to be the preferred modelling methods of the future By considering three different areas in biology the book shows how several of these modelling techniques have been successfully applied in diverse areas Put simply this book is important becuase it shows how the power of modern computers is allowing researchers in theoretical biology to break free of the constraints on modelling that were imposed by the traditional differential equation approach Anyone who is interested in the theoretical models of complicated living systems should have this in his or her library

G B Ermentrout *Bulletin of Mathematical Biology*

*Integrodifference Equations in Spatial Ecology* Frithjof Lutscher, 2019-10-30 This book is the first thorough introduction to and comprehensive treatment of the theory and applications of integrodifference equations in spatial ecology Integrodifference equations are discrete time continuous space dynamical systems describing the spatio temporal dynamics of one or more populations The book contains step by step model construction explicitly solvable models

abstract theory and numerical recipes for integrodifference equations The theory in the book is motivated and illustrated by many examples from conservation biology biological invasions pattern formation and other areas In this way the book conveys the more general message that bringing mathematical approaches and ecological questions together can generate novel insights into applications and fruitful challenges that spur future theoretical developments The book is suitable for graduate students and experienced researchers in mathematical ecology alike **From the Catalpa Tree to the Elm Tree** Ronald Lee Hancock, 2014-10-15 This book is a quick fun read in poetic prose that gives insights into the personal life of a Missouri boy who becomes a MD Biochemist publishing over 130 scientific papers on the biochemistry of Cancer and is presently involved in a great many areas

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