

## Evolutionary Dynamics Exploring The Equations Of Life Ma Nowak

At a time of unprecedented expansion in the life sciences, evolution is the one theory that transcends all of biology. Any observation of a living system must ultimately be interpreted in the context of its evolution. Evolutionary change is the consequence of mutation and natural selection, which are two concepts that can be described by mathematical equations. Evolutionary Dynamics is concerned with these equations of life. In this book, Martin A. Nowak draws on the languages of biology and mathematics to outline the mathematical principles according to which life evolves. His work introduces readers to the powerful yet simple laws that govern the evolution of living systems, no matter how complicated they might seem. Evolution has become a mathematical theory, Nowak suggests, and any idea of an evolutionary process or mechanism should be studied in the context of the mathematical equations of evolutionary dynamics. His book presents a range of analytical tools that can be used to this end: fitness landscapes, mutation matrices, genomic sequence space, random drift, quasispecies, replicators, the Prisoner's Dilemma, games in finite and infinite populations, evolutionary graph theory, games on grids, evolutionary kaleidoscopes, fractals, and spatial chaos. Nowak then shows how evolutionary dynamics applies to critical real-world problems, including the progression of viral diseases such as AIDS, the virulence of infectious agents, the unpredictable mutations that lead to cancer, the evolution of altruism, and even the evolution of human language. His book makes a clear and compelling case for understanding every living system—and everything that arises as a consequence of living systems—in terms of evolutionary dynamics.

Galileo Unbound traces the journey that brought us from Galileo's law of free fall to today's geneticists measuring evolutionary drift, entangled quantum particles moving among many worlds, and our lives as trajectories traversing a health space with thousands of dimensions. Remarkably, common themes persist that predict the evolution of species as readily as the orbits of planets or the collapse of stars into black holes. This book tells the history of spaces of expanding dimension and increasing abstraction and how they continue today to give new insight into the physics of complex systems. Galileo published the first modern law of motion, the Law of Fall, that was ideal and simple, laying the foundation upon which Newton built the first theory of dynamics. Early in the twentieth century, geometry became the cause of motion rather than the result when Einstein envisioned the fabric of space-time warped by mass and energy, forcing light rays to bend past the Sun. Possibly more radical was Feynman's dilemma of quantum particles taking all paths at once — setting the stage for the modern fields of quantum field theory and quantum computing. Yet as concepts of motion have evolved, one thing has remained constant, the need to track ever more complex changes and to capture their essence, to find patterns in the chaos as we try to predict and control our world.

Fractional evolution inclusions are an important form of differential inclusions within nonlinear mathematical analysis. They are generalizations of the much more widely developed fractional evolution equations (such as time-fractional diffusion equations) seen through the lens of multivariate analysis. Compared to fractional evolution equations, research on the theory of fractional differential inclusions is however only in its initial stage of development. This is important because differential models with the fractional derivative providing an excellent instrument for the description of memory and hereditary properties, and have recently been proved valuable tools in the modeling of many physical phenomena. The fractional order models of real systems are always more adequate than the classical integer order models, since the description of some systems is more accurate when the fractional derivative is used. The advantages of fractional derivatization become evident in modeling mechanical and electrical properties of real materials, description of rheological properties of rocks and in various other fields. Such models are interesting for engineers and physicists as well as so-called pure mathematicians. Phenomena investigated in hybrid systems with dry friction, processes of controlled heat transfer, obstacle problems and others can be described with the help of various differential inclusions, both linear and nonlinear. Fractional Evolution Equations and Inclusions is devoted to a rapidly developing area of the research for fractional evolution equations & inclusions and their applications to control theory. It studies Cauchy problems for fractional evolution equations, and fractional evolution inclusions with Hille-Yosida operators. It discusses control problems for systems governed by fractional evolution equations. Finally it provides an investigation of fractional stochastic evolution inclusions in Hilbert spaces. Systematic analysis of existence theory and topological structure of solution sets for fractional evolution inclusions and control systems. Differential models with fractional derivative provide an excellent instrument for the description of memory and hereditary properties, and their description and working will provide valuable insights into the modelling of many physical phenomena suitable for engineers and physicists. The book provides the necessary background material required to go further into the subject and explore the rich research literature.

The theme of this volume is to discuss Eco-evolutionary Dynamics. Updates and informs the reader on the latest research findings. Written by leading experts in the field. Highlights areas for future investigation.

Evolution and Contextual Behavioral Science

Evolutionary Games and Population Dynamics

The History of Symmetry

Harmonic Analysis Method for Nonlinear Evolution Equations, I

Altruism, Evolution, and Why We Need Each Other to Succeed

Evolution and the Theory of Games

This volume is a collection of notes from lectures given at the 2008 Clay Mathematics Institute Summer School, held in Zürich, Switzerland. The lectures were designed for graduate students and mathematicians within five years of the Ph.D., and the main focus of the program was on recent progress in the theory of evolution equations. Such equations lie at the heart of many areas of mathematical physics and arise not only in situations with a manifest time evolution (such as linear and nonlinear wave and Schrödinger equations) but also in the high energy or semi-classical limits of elliptic problems. The three main courses focused primarily on microlocal analysis and spectral and scattering theory, the theory of the nonlinear Schrödinger and wave equations, and evolution problems in general relativity. These major topics were supplemented by several mini-courses reporting on the derivation of effective evolution equations from microscopic quantum dynamics; on wave maps with and without symmetries; on quantum N-body scattering, diffraction of waves, and symmetric spaces; and on nonlinear Schrödinger equations at critical regularity. Although highly detailed treatments of some of these topics are now available in the published literature, in this collection the reader can learn the fundamental ideas and tools with a minimum of technical machinery. Moreover, the treatment in this volume emphasizes common themes and techniques in the field, including exact and approximate conservation laws, energy methods, and positive commutator arguments. Titles in this series are co-published with the Clay Mathematics Institute (Cambridge, MA).

Charles Darwin changed the course of scientific thinking by showing how evolution accounts for the stunning diversity and biological complexity of life on earth. Recently, there has also been increased interest in the social sciences in how Darwinian theory can explain human culture. Covering a wide range of topics, including fads, public policy, the spread of religion, and herd behavior in markets, Alex Mesoudi shows that human culture is itself an evolutionary process that exhibits the key Darwinian mechanisms of variation, competition, and inheritance. This cross-disciplinary volume focuses on the ways cultural phenomena can be studied scientifically—from theoretical modeling to lab experiments, archaeological fieldwork to ethnographic studies—and shows how apparently disparate methods can complement one another to the mutual benefit of the various social science disciplines. Along the way, the book reveals how new insights arise from looking at culture from an evolutionary angle. Cultural Evolution provides a thought-provoking argument that Darwinian evolutionary theory can both unify different branches of inquiry and enhance understanding of human behavior.

Draws on the languages of biology and mathematics to outline the mathematical principles according to which life evolves in an intriguing study that makes a clear and compelling case for understanding every living system in terms of evolutionary dynamics.

This book develops the mathematical tools essential for students in the life sciences to describe interacting systems and predict their behavior. From predator-prey populations in an ecosystem, to hormone regulation within the body, the natural world abounds in dynamical systems that affect us profoundly. Complex feedback relations and counter-intuitive responses are common in nature; this book develops the quantitative skills needed to explore these interactions. Differential equations are the natural mathematical tool for quantifying change, and are the driving force throughout this book. The use of Euler's method makes nonlinear examples tractable and accessible to a broad spectrum of early-stage undergraduates, thus providing a practical alternative to the procedural approach of a traditional Calculus curriculum. Tools are developed within numerous, relevant examples, with an emphasis on the construction, evaluation, and interpretation of mathematical models throughout. Encountering these concepts in context, students learn not only quantitative techniques, but how to bridge between biological and mathematical ways of thinking. Examples range broadly, exploring the dynamics of neurons and the immune system, through to population dynamics and the Google PageRank algorithm. Each scenario relies only on an interest in the natural world; no biological expertise is assumed of student or instructor. Building on a single prerequisite of Precalculus, the book suits a two-quarter sequence for first or second year undergraduates, and meets the mathematical requirements of medical school entry. The later material provides opportunities for more advanced students in both mathematics and life sciences to revisit theoretical knowledge in a rich, real-world framework. In all cases, the focus is clear: how does the math help us understand the science?

Dynamical Systems and Evolution Equations

The Mathematical Foundations of Music

Population Games and Evolutionary Dynamics

An Integrated Framework for Understanding, Predicting, and Influencing Human Behavior

Evolutionary Game Theory

Examines the importance of cooperation in human beings and in nature, arguing that this social tool is as an important aspect of evolution as mutation and natural selection.

The first complete overview of evolutionary computing, the collective name for a range of problem-solving techniques based on principles of biological evolution, such as natural selection and genetic inheritance. The text is aimed directly at lecturers and graduate and undergraduate students. It is also meant for those who wish to apply evolutionary computing to a particular problem or within a given application area. The book contains quick-reference information on the current state-of-the-art in a wide range of related topics, so it is of interest not just to evolutionary computing specialists but to researchers working in other fields.

An enthralling account of the arguments about altruism and sexual selection raging since Darwin's day.

An instant New York Times Bestseller! "Unreasonably entertaining . . . reveals how geometric thinking can allow for everything from fairer American elections to better pandemic planning." —The New York Times From the New York Times-bestselling author of How Not to Be Wrong—himself a world-class geometer—a far-ranging exploration of the power of geometry, which turns out to help us think better about practically everything. How should a democracy choose its representatives? How can you stop a pandemic from sweeping the world? How do computers learn to play Go, and why is learning Go so much easier for them than learning to read a sentence? Can ancient Greek proportions predict the stock market? (Sorry, no.) What should your kids learn in school if they really want to learn to think? All these are questions about geometry. For real. If you're like most people, geometry is a sterile and dimly remembered exercise you gladly left behind in the dust of ninth grade, along with your braces and active romantic interest in pop singers. If you recall any of it, it's plodding through a series of miniscule steps only to prove some fact about triangles that was obvious to you in the first place. That's not geometry. Okay, it is geometry, but only a tiny part, which has as much to do with geometry in all its flush modern richness as conjugating a verb has to do with a great novel. Shape reveals the geometry underneath some of the most important scientific, political, and philosophical problems we face. Geometry asks: Where are things? Which things are near each other? How can you get from one thing to another thing? Those are important questions. The word "geometry" comes from the Greek for "measuring the world." If anything, that's an undersell. Geometry doesn't just measure the world—it explains it. Shape shows us how.

Exploring Mathematical Modeling in Biology Through Case Studies and Experimental Activities

Cultural Evolution

Solar System Dynamics

Mathematical and Conceptual Foundations

Dynamics of Evolutionary Equations

## Evolutionary Theory

The world's most revered and eloquent interpreter of evolutionary ideas offers here a work of explanatory force unprecedented in our time—a landmark publication, both for its historical sweep and for its scientific vision. With characteristic attention to detail, Stephen Jay Gould first describes the content and discusses the history and origins of the three core commitments of classical Darwinism: that natural selection works on organisms, not genes or species; that it is almost exclusively the mechanism of adaptive evolutionary change; and that these changes are incremental, not drastic. Next, he examines the three critiques that currently challenge this classic Darwinian edifice: that selection operates on multiple levels, from the gene to the group; that evolution proceeds by a variety of mechanisms, not just natural selection; and that causes operating at broader scales, including catastrophes, have figured prominently in the course of evolution. Then, in a stunning tour de force that will likely stimulate discussion and debate for decades, Gould proposes his own system for integrating these classical commitments and contemporary critiques into a new structure of evolutionary thought. In 2001 the Library of Congress named Stephen Jay Gould one of America's eighty-three Living Legends—people who embody the “quintessentially American ideal of individual creativity, conviction, dedication, and exuberance.” Each of these qualities finds full expression in this peerless work, the likes of which the scientific world has not seen—and may not see again—for well over a century.

Introduces current evolutionary game theory--where ideas from evolutionary biology and rationalistic economics meet--emphasizing the links between static and dynamic approaches and noncooperative game theory. This text introduces current evolutionary game theory--where ideas from evolutionary biology and rationalistic economics meet--emphasizing the links between static and dynamic approaches and noncooperative game theory. Much of the text is devoted to the key concepts of evolutionary stability and replicator dynamics. The former highlights the role of mutations and the latter the mechanisms of selection. Moreover, set-valued static and dynamic stability concepts, as well as processes of social evolution, are discussed. Separate background chapters are devoted to noncooperative game theory and the theory of ordinary differential equations. There are examples throughout as well as individual chapter summaries. Because evolutionary game theory is a fast-moving field that is itself branching out and rapidly evolving, Jörgen Weibull has judiciously focused on clarifying and explaining core elements of the theory in an up-to-date, comprehensive, and self-contained treatment. The result is a text for second-year graduate students in economic theory, other social sciences, and evolutionary biology. The book goes beyond filling the gap between texts by Maynard-Smith and Hofbauer and Sigmund that are currently being used in the field. Evolutionary Game Theory will also serve as an introduction for those embarking on research in this area as well as a reference for those already familiar with the field. Weibull provides an overview of the developments that have taken place in this branch of game theory, discusses the mathematical tools needed to understand the area, describes both the motivation and intuition for the concepts involved, and explains why and how it is relevant to economics.

The book aims to provide an introduction to mathematical models that describe the dynamics of tumor growth and the evolution of tumor cells. It can be used as a textbook for advanced undergraduate or graduate courses, and also serves as a reference book for researchers. The book has a strong evolutionary component and reflects the viewpoint that cancer can be understood rationally through a combination of mathematical and biological tools. It can be used both by mathematicians and biologists. Mathematically, the book starts with relatively simple ordinary differential equation models, and subsequently explores more complex stochastic and spatial models. Biologically, the book starts with explorations of the basic dynamics of tumor growth, including competitive interactions among cells, and subsequently moves on to the evolutionary dynamics of cancer cells, including scenarios of cancer initiation, progression, and treatment. The book finishes with a discussion of advanced topics, which describe how some of the mathematical concepts can be used to gain insights into a variety of questions, such as epigenetics, telomeres, gene therapy, and social interactions of cancer cells. Contents:Teaching GuideCancer and Somatic EvolutionMathematical Modeling of TumorigenesisBasic Growth Dynamics and Deterministic Models:Single Species GrowthTwo-Species Competition DynamicsCompetition Between Genetically Stable and Unstable CellsChromosomal Instability and Tumor GrowthAngiogenesis Inhibitors, Promoters, and Spatial GrowthEvolutionary Dynamics and Stochastic Models:Evolutionary Dynamics of Tumor Initiation Through Oncogenes: The Gain-of-Function ModelEvolutionary Dynamics of Tumor Initiation Through Tumor-Suppressor Genes: The Loss-of-Function Model and Stochastic TunnelingMicrosatellite and Chromosomal Instability in Sporadic and Familial Colorectal CancersEvolutionary Dynamics in Hierarchical PopulationsSpatial Evolutionary Dynamics of Tumor InitiationComplex Tumor Dynamics in SpaceStochastic Modeling of Cellular Growth, Treatment, and Resistance GenerationEvolutionary Dynamics of Drug Resistance in Chronic Myeloid LeukemiaAdvanced Topics:Evolutionary Dynamics of Stem-Cell Driven Tumor GrowthTumor Growth Kinetics and Disease ProgressionEpigenetic Changes and the Rate of DNA MethylationTelomeres and Cancer ProtectionGene Therapy and Oncolytic Virus TherapyImmune Responses, Tumor Growth, and TherapiesTowards Higher Complexities: Social Interactions Readership: Researchers in mathematical biology, mathematical modeling, biology, mathematical oncology. Keywords:Mathematical Oncology;Dynamics;Evolution;Evolutionary Dynamics;Cancer;Mathematical Models;Somatic Evolution;TeachingKey Features:Both a reference book for the topic, and provides material for undergraduate and graduate coursesTries to bridge the divide between mathematicians and biologists, which is also reflected in the backgrounds of the two authorsShows how mathematical concepts can be translated into experimentally and clinically useful insightsRooted in evolutionary biology, the book handles this very complex phenomenon in an intuitive and mathematically elegant wayContains problems and research projects for each topic10 pages of figures in color

All of life is a game, and evolution by natural selection is no exception. The evolutionary game theory developed in this 2005 book provides the tools necessary for understanding many of nature's mysteries, including co-evolution, speciation, extinction and the major biological questions regarding fit of form and function, diversity, procession, and the distribution and abundance of life. Mathematics for the evolutionary game are developed based on Darwin's postulates leading to the concept of a fitness generating function (G-function). G-function is a tool that simplifies notation and plays an important role developing Darwinian dynamics that drive natural selection. Natural selection may result in special outcomes such as the evolutionarily stable strategy (ESS). An ESS maximum principle is formulated and its graphical representation as an adaptive landscape illuminates concepts such as adaptation, Fisher's Fundamental Theorem of Natural Selection, and the nature of life's evolutionary game.

Shape

Fundamentals of Evolutionary Game Theory and its Applications

A Path Across Life, the Universe and Everything

The Hidden Geometry of Information, Biology, Strategy, Democracy, and Everything Else

The Ant and the Peacock

Analysis and Control

***This open access book chronicles the rise of a new scientific paradigm offering novel insights into the age-old enigmas of existence. Over 300 years ago, the human mind discovered the machine code of reality: mathematics. By utilizing abstract thought systems, humans began to decode the workings of the cosmos. From this understanding, the current scientific paradigm emerged, ultimately discovering the gift of technology. Today, however, our island of knowledge is surrounded by ever longer shores of ignorance. Science appears to***

**have hit a dead end when confronted with the nature of reality and consciousness. In this fascinating and accessible volume, James Glattfelder explores a radical paradigm shift uncovering the ontology of reality. It is found to be information-theoretic and participatory, yielding a computational and programmable universe.**

**This text offers a systematic, rigorous, and unified presentation of evolutionary game theory, covering the core developments of the theory from its inception in biology in the 1970s through recent advances. Evolutionary game theory, which studies the behavior of large populations of strategically interacting agents, is used by economists to make predictions in settings where traditional assumptions about agents' rationality and knowledge may not be justified. Recently, computer scientists, transportation scientists, engineers, and control theorists have also turned to evolutionary game theory, seeking tools for modeling dynamics in multiagent systems. Population Games and Evolutionary Dynamics provides a point of entry into the field for researchers and students in all of these disciplines. The text first considers population games, which provide a simple, powerful model for studying strategic interactions among large numbers of anonymous agents. It then studies the dynamics of behavior in these games. By introducing a general model of myopic strategy revision by individual agents, the text provides foundations for two distinct approaches to aggregate behavior dynamics: the deterministic approach, based on differential equations, and the stochastic approach, based on Markov processes. Key results on local stability, global convergence, stochastic stability, and nonconvergence are developed in detail. Ten substantial appendixes present the mathematical tools needed to work in evolutionary game theory, offering a practical introduction to the methods of dynamic modeling. Accompanying the text are more than 200 color illustrations of the mathematics and theoretical results; many were created using the Dynamo software suite, which is freely available on the author's Web site. Readers are encouraged to use Dynamo to run quick numerical experiments and to create publishable figures for their own research.**

**"In this accessible and well-written text, Martin Nowak and Robert May describe the emerging field of theoretical immunology. Using mathematical and computational models, the authors explore how populations of viruses and immune cells interact in various circumstances, and how infectious diseases spread with-in patients."--Page 4 de la couverture.**

**What do evolutionary science and contextual behavioral science have in common? Edited by David Sloan Wilson and Steven C. Hayes, this groundbreaking book offers a glimpse into the histories of these two schools of thought, and provides a sound rationale for their reintegration. Evolutionary science (ES) provides a unifying theoretical framework for the biological sciences, and is increasingly being applied to the human-related sciences. Meanwhile, contextual behavioral science (CBS) seeks to understand the history and function of human behavior in the context of everyday life where behaviors occur, and to influence behavior in a practical sense. This volume seeks to integrate these two bodies of knowledge that have developed largely independently. In Evolution and Contextual Behavioral Science, two renowned experts in their fields argue why ES and CBS are intrinsically linked, as well as why their reintegration—or, reunification—is essential. The main purpose of this book is to continue to move CBS under the umbrella of ES, and to help evolutionary scientists understand how working alongside contextual behavioral scientists can foster both the development of ES principles and their application to practical situations. Rather than the sequential relationship that is typically imagined between these two schools of thought, this volume envisions a parallel relationship between ES and CBS, where science can best influence positive change in the real world.**

**Bayesian Evolutionary Analysis with BEAST**

**Mathematical Principles of Immunology and Virology**

**Introduction to Evolutionary Computing**

**Dynamics of Cancer**

**Eco-Evolutionary Dynamics**

**Modeling Life**

*Galaxies, along with their underlying dark matter halos, constitute the building blocks of structure in the Universe. Of all fundamental forces, gravity is the dominant one that drives the evolution of structures from small density seeds at early times to the galaxies we see today. The interactions among myriads of stars, or dark matter particles, in a gravitating structure produce a system with fascinating connotations to thermodynamics, with some analogies and some fundamental differences. Ignacio Ferreras presents a concise introduction to extragalactic astrophysics, with emphasis on stellar dynamics, and the growth of density fluctuations in an expanding Universe. Additional chapters are devoted to smaller systems (stellar clusters) and larger ones (galaxy clusters). Fundamentals of Galaxy Dynamics, Formation and Evolution is written for advanced undergraduates and beginning postgraduate students, providing a useful tool to get up to speed in a starting research career. Some of the derivations for the most important results are presented in detail to enable students appreciate the beauty of maths as a tool to understand the workings of galaxies. Each chapter includes a set of problems to help the student advance with the*

material.

*This book both summarizes the basic theory of evolutionary games and explains their developing applications, giving special attention to the 2-player, 2-strategy game. This game, usually termed a "2x2 game" in the jargon, has been deemed most important because it makes it possible to posit an archetype framework that can be extended to various applications for engineering, the social sciences, and even pure science fields spanning theoretical biology, physics, economics, politics, and information science. The 2x2 game is in fact one of the hottest issues in the field of statistical physics. The book first shows how the fundamental theory of the 2x2 game, based on so-called replicator dynamics, highlights its potential relation with nonlinear dynamical systems. This analytical approach implies that there is a gap between theoretical and reality-based prognoses observed in social systems of humans as well as in those of animal species. The book explains that this perceived gap is the result of an underlying reciprocity mechanism called social viscosity. As a second major point, the book puts a sharp focus on network reciprocity, one of the five fundamental mechanisms for adding social viscosity to a system and one that has been a great concern for study by statistical physicists in the past decade. The book explains how network reciprocity works for emerging cooperation, and readers can clearly understand the existence of substantial mechanisms when the term "network reciprocity" is used. In the latter part of the book, readers will find several interesting examples in which evolutionary game theory is applied. One such example is traffic flow analysis. Traffic flow is one of the subjects that fluid dynamics can deal with, although flowing objects do not comprise a pure fluid but, rather, are a set of many particles. Applying the framework of evolutionary games to realistic traffic flows, the book reveals that social dilemma structures lie behind traffic flow.*

*Introduction to Mathematical Oncology presents biologically well-motivated and mathematically tractable models that facilitate both a deep understanding of cancer biology and better cancer treatment designs. It covers the medical and biological background of the diseases, modeling issues, and existing methods and their limitations. The authors introduce mathematical and programming tools, along with analytical and numerical studies of the models. They also develop new mathematical tools and look to future improvements on dynamical models. After introducing the general theory of medicine and exploring how mathematics can be essential in its understanding, the text describes well-known, practical, and insightful mathematical models of avascular tumor growth and mathematically tractable treatment models based on ordinary differential equations. It continues the topic of avascular tumor growth in the context of partial differential equation models by incorporating the spatial structure and physiological structure, such as cell size. The book then focuses on the recent active multi-scale modeling efforts on prostate cancer growth and treatment dynamics. It also examines more mechanistically formulated models, including cell quota-based population growth models, with applications to real tumors and validation using clinical data. The remainder of the text presents abundant additional historical, biological, and medical background materials for advanced and specific treatment modeling efforts. Extensively classroom-tested in undergraduate and graduate courses, this self-contained book allows instructors to emphasize specific topics relevant to clinical cancer biology and treatment. It can be used in a variety of ways, including a single-semester undergraduate course, a more ambitious graduate course, or a full-year sequence on mathematical oncology.*

*What are the models used in phylogenetic analysis and what exactly is involved in Bayesian evolutionary analysis using Markov chain Monte Carlo (MCMC) methods? How can you choose and apply these models, which parameterisations and priors make sense, and how can you diagnose Bayesian MCMC when things go wrong? These are just a few of the questions answered in this comprehensive overview of Bayesian approaches to phylogenetics. This practical guide:*

- Addresses the theoretical aspects of the field
- Advises on how to prepare and perform phylogenetic analysis
- Helps with interpreting analyses and visualisation of phylogenies
- Describes the software architecture
- Helps developing BEAST 2.2 extensions to allow these models to be extended further.

*With an accompanying website providing example files and tutorials (<http://beast2.org/>), this one-stop reference to applying the latest phylogenetic models in BEAST 2 will provide essential guidance for all users – from those using phylogenetic tools, to computational biologists and Bayesian statisticians.*

*Evolution of the Social Contract*

*Fundamentals of Galaxy Dynamics, Formation and Evolution*

*The Structure of Evolutionary Theory*

*Virus Dynamics*

*Altruism and Sexual Selection from Darwin to Today*

*Why Beauty Is Truth*

**Evolutionary Theory is for graduate students, researchers, and advanced undergraduates who want an understanding of the mathematical and biological reasoning that underlies evolutionary theory. The book covers all of the major theoretical approaches used to study the mechanics of evolution, including classical one- and two-locus models, diffusion theory, coalescent theory, quantitative genetics, and game theory. There are also chapters on theoretical approaches to the evolution of development and on multilevel selection theory. Each subject is illustrated by focusing on those results that have the greatest power to influence the way that we think about how evolution works. These major results are developed in detail, with many accompanying illustrations, showing exactly how they are derived and how the mathematics relates to the biological insights that they yield. In this way, the reader learns something of the actual machinery of different branches of theory while gaining a deeper understanding of the evolutionary process. Roughly half of the book focuses on gene-based models, the other half being concerned with general phenotype-based theory. Throughout, emphasis is placed on the fundamental relationships between the different branches of theory, illustrating how all of these branches are united by a few basic, universal, principles. The only mathematical background assumed is basic calculus. More advanced mathematical methods are explained, with the help of an extensive appendix, when they are needed. This 1982 book is an account of an alternative way of thinking about evolution and the theory of games.**

**Exploring ODEs is a textbook of ordinary differential equations for advanced undergraduates, graduate students, scientists, and**

engineers. It is unlike other books in this field in that each concept is illustrated numerically via a few lines of Chebfun code. There are about 400 computer-generated figures in all, and Appendix B presents 100 more examples as templates for further exploration.?

In this new edition of *Evolution of the Social Contract*, Brian Skyrms uses evolutionary game theory to analyze the genesis of social contracts and investigates social phenomena including justice, communication, altruism, and bargaining. Featuring new material on evolution and information transfer, and including recent developments in game theory and evolution literature, his book introduces and applies appropriate concepts of equilibrium and evolutionary dynamics, showing how key issues can be modeled as games and considering the ways in which evolution sometimes supports, and sometimes does not support, rational choice. He discusses topics including how bargaining with neighbors promotes sharing of resources, the diversity of behavior in ultimatum bargaining in small societies, the Prisoner's Dilemma, and an investigation into signaling games and the spontaneous emergence of meaningful communication. His book will be of great interest to readers in philosophy of science, social science, evolutionary biology, game and decision theory, and political theory.

Theory and Applications

Galileo Unbound

A Discovery-Based Laboratory Course

Evolution, Games, and God

Evolution Equations

A Biologist's Guide to Mathematical Modeling in Ecology and Evolution

Evolutionary Dynamics Exploring the Equations of Life Harvard University Press

Physics.

This book grew out of a nine-month course first given during 1976-77 in the Division of Engineering Mechanics, University of Texas (Austin), and repeated during 1977-78 in the Department of Engineering Sciences and Applied Mathematics, Northwestern University. Most of the students were in their second year of graduate study, and all were familiar with Fourier series, Lebesgue integration, Hilbert space, and ordinary differential equations in finite-dimensional space. This book is primarily an exposition of certain methods of topological dynamics that have been found to be very useful in the analysis of physical systems but appear to be well known only to specialists. The purpose of the book is twofold: to present the material in such a way that the applications-oriented reader will be encouraged to apply these methods in the study of those physical systems of personal interest, and to make the coverage sufficient to render the current research literature intelligible, preparing the more mathematically inclined reader for research in this particular area of applied mathematics. We present only that portion of the theory which seems most useful in applications to physical systems. Adopting the view that the world is deterministic, we consider our basic problem to be predicting the future for a given physical system. This prediction is to be based on a known equation of evolution, describing the forward-time behavior of the system, but it is to be made without explicitly solving the equation.

The Solar System is a complex and fascinating dynamical system. This is the first textbook to describe comprehensively the dynamical features of the Solar System and to provide students with all the mathematical tools and physical models they need to understand how it works. It is a benchmark publication in the field of planetary dynamics and destined to become a classic. Clearly written and well illustrated, *Solar System Dynamics* shows how a basic knowledge of the two- and three-body problems and perturbation theory can be combined to understand features as diverse as the tidal heating of Jupiter's moon Io, the origin of the Kirkwood gaps in the asteroid belt, and the radial structure of Saturn's rings. Problems at the end of each chapter and a free Internet Mathematica® software package are provided. *Solar System Dynamics* provides an authoritative textbook for courses on planetary dynamics and celestial mechanics. It also equips students with the mathematical tools to tackle broader courses on dynamics, dynamical systems, applications of chaos theory and non-linear dynamics.

Exploring the Equations of Life

Integrated Genomics

Mathematical Foundations of Oncology

Introduction to Mathematical Oncology

Information—Consciousness—Reality

Exploring ODEs

**A commonsense, self-contained introduction to the mathematics and physics of music; essential reading for musicians, music engineers, and anyone interested in the intersection of art and science. “Mathematics can be as effortless as humming a tune, if you know the tune,” writes Gareth Loy. In *Musimathics*, Loy teaches us the tune, providing a friendly and spirited tour of the mathematics of music—a commonsense, self-contained introduction for the nonspecialist reader. It is designed for musicians who find their art increasingly mediated by technology, and for anyone who is interested in the intersection of art and science. In Volume 1, Loy presents the materials of music (notes, intervals, and scales); the physical properties of music (frequency, amplitude, duration, and timbre); the perception of music and sound (how we hear); and music composition. Calling himself “a composer seduced into mathematics,” Loy provides answers to foundational questions about the mathematics of music accessibly yet rigorously. The examples given are all practical problems in music and audio. Additional material can be found at <http://www.musimathics.com>.**

***Evolution, Games, and God* explores how cooperation and altruism, alongside mutation and natural selection, play a critical role in evolution, from microbes to human societies. Inheriting a tendency to cooperate**

and self-sacrifice on behalf of others may be as beneficial to a population's survival as the self-preserving instincts of individuals.

How to understand evolution in mathematical terms, i.e. how to model natural selection by game theory.

The theory and applications of infinite dimensional dynamical systems have attracted the attention of scientists for quite some time. This book serves as an entrée for scholars beginning their journey into the world of dynamical systems, especially infinite dimensional spaces. The main approach involves the theory of evolutionary equations.

How a New Understanding of the Universe Can Help Answer Age-Old Questions of Existence

Fractional Evolution Equations and Inclusions

The Mathematics of Biological Systems

Musimathics, Volume 1

Evolutionary Dynamics

SuperCooperators

*Exploring Mathematical Modeling in Biology through Case Studies and Experimental Activities* provides supporting materials for courses taken by students majoring in mathematics, computer science or in the life sciences. The book's cases and lab exercises focus on hypothesis testing and model development in the context of real data. The supporting mathematical, coding and biological background permit readers to explore a problem, understand assumptions, and the meaning of their results. The experiential components provide hands-on learning both in the lab and on the computer. As a beginning text in modeling, readers will learn to value the approach and apply competencies in other settings. Included case studies focus on building a model to solve a particular biological problem from concept and translation into a mathematical form, to validating the parameters, testing the quality of the model and finally interpreting the outcome in biological terms. The book also shows how particular mathematical approaches are adapted to a variety of problems at multiple biological scales. Finally, the labs bring the biological problems and the practical issues of collecting data to actually test the model and/or adapting the mathematics to the data that can be collected. Presents a single volume on mathematics and biological examples, with data and wet lab experiences suitable for non-experts Contains three real-world biological case studies and one wet lab for application of the mathematical models Includes R code templates throughout the text, which are also available through an online repository, along with the necessary data files to complete all projects and labs

Thirty years ago, biologists could get by with a rudimentary grasp of mathematics and modeling. Not so today. In seeking to answer fundamental questions about how biological systems function and change over time, the modern biologist is as likely to rely on sophisticated mathematical and computer-based models as traditional fieldwork. In this book, Sarah Otto and Troy Day provide biology students with the tools necessary to both interpret models and to build their own. The book starts at an elementary level of mathematical modeling, assuming that the reader has had high school mathematics and first-year calculus. Otto and Day then gradually build in depth and complexity, from classic models in ecology and evolution to more intricate class-structured and probabilistic models. The authors provide primers with instructive exercises to introduce readers to the more advanced subjects of linear algebra and probability theory. Through examples, they describe how models have been used to understand such topics as the spread of HIV, chaos, the age structure of a country, speciation, and extinction. Ecologists and evolutionary biologists today need enough mathematical training to be able to assess the power and limits of biological models and to develop theories and models themselves. This innovative book will be an indispensable guide to the world of mathematical models for the next generation of biologists. A how-to guide for developing new mathematical models in biology Provides step-by-step recipes for constructing and analyzing models Interesting biological applications Explores classical models in ecology and evolution Questions at the end of every chapter Primers cover important mathematical topics Exercises with answers Appendixes summarize useful rules Labs and advanced material available

*Integrated Genomics: A Discovery-Based Laboratory Course* introduces the excitement of discovery to the basic molecular biology laboratory. Utilizing up-to-date molecular biology protocols and a basic experimental design, this text offers experience with three different model systems. Students will become familiar with the simplicity and power of single-celled organisms, *Escherichia coli* and *Saccharomyces cerevisiae*, as they search for genes that interact and function within the nematode *Caenorhabditis elegans*. Incorporated throughout the course are exercises designed to offer students familiarity with the wealth of bioinformatics data

that can be accessed on the World Wide Web. Following completion of interaction studies within the yeast, the course is designed to allow students to examine the functional consequences of reducing a gene's function within the multicellular worm that is both simple and inexpensive to maintain within a laboratory. The inclusion of alternative experiments allow for flexibility in determining the ending date or goal of the laboratory, as well as working within the available budget and resources of most any classroom environment. Further striking features of this title are: An accompanying Web site providing PowerPoint slides, plus links to the internet, and regular updates as bioinformatics databases evolve and methods improve. [www.wiley.com/go/caldwell](http://www.wiley.com/go/caldwell) Inclusion of modern genomic/proteomic technologies such as the yeast two-hybrid system and RNAi Detailed experimental protocols and easy access to instructional materials This discovery-based laboratory course provides excellent practical training for those pursuing career paths in biomedicine, pharmacy, and biotechnology.

This monograph provides a comprehensive overview on a class of nonlinear evolution equations, such as nonlinear Schrödinger equations, nonlinear Klein-Gordon equations, KdV equations as well as Navier-Stokes equations and Boltzmann equations. The global wellposedness to the Cauchy problem for those equations is systematically studied by using the harmonic analysis methods. This book is self-contained and may also be used as an advanced textbook by graduate students in analysis and PDE subjects and even ambitious undergraduate students.

How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences  
Evolutionary Game Theory, Natural Selection, and Darwinian Dynamics