

Evolutionary Dynamics Exploring The Equations Of Life

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.

Introduces readers to key case studies that illustrate how theory and data can be integrated to understand wildlife disease ecology.

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. Praise for the first edition: ... superb, beautifully written and organized work that

takes an engineering approach to systems biology. Alon provides nicely written appendices to explain the basic mathematical and biological concepts clearly and succinctly without interfering with the main text. He starts with a mathematical description of transcriptional activation and then describes some basic transcription-network motifs (patterns) that can be combined to form larger networks. – Nature [This text deserves] serious attention from any quantitative scientist who hopes to learn about modern biology ... It assumes no prior knowledge of or even interest in biology ... One final aspect that must be mentioned is the wonderful set of exercises that accompany each chapter. ...

Alon's book should become a standard part of the training of graduate students.

– Physics Today Written for students and researchers, the second edition of this best-selling textbook continues to offer a clear presentation of design principles that govern the structure and behavior of biological systems. It highlights simple, recurring circuit elements that make up the regulation of cells and tissues.

Rigorously classroom-tested, this edition includes new chapters on exciting advances made in the last decade. Features: Includes seven new chapters The new edition has 189 exercises, the previous edition had 66 Offers new examples relevant to human physiology and disease

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.

The concept of macroscopic waves and patterns developing from chemical reaction coupling with diffusion was presented, apparently for the first time, at the Main Meeting of the Deutsche Bunsengesellschaft für Angewandte Physikalische Chemie, held in Dresden, Germany from May 21 to 24, 1906. Robert Luther, Director of the Physical Chemistry Laboratory in Leipzig, read his paper on the discovery and analysis of propagating reaction-diffusion fronts in autocatalytic chemical reactions [1, 2]. He presented an equation for the velocity of these new waves, $V = a(KDC)^{1/2}$, and asserted that they might have features in common with propagating action potentials in nerve cell axons. During the discussion period, a skeptic in the audience voiced his objections to this notion. It was none other than the great physical chemist Walther Nernst, who believed that nerve impulse propagation was far too rapid to be akin to the propagating fronts. He was also not willing to accept Luther's wave velocity equation without a derivation. Luther stood his ground, saying his equation was "a simple consequence of the corresponding differential equation." He described several different autocatalytic reactions that exhibit propagating fronts (recommending gelling the solution to prevent convection) and even presented a demonstration: the autocatalytic permanganate oxidation of oxalate was carried out in a test tube with the image of the front projected onto a screen for the audience.

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

This book highlights cutting-edge research in the field of network science, offering scientists, researchers, students and practitioners a unique update on the latest advances in theory and a multitude of applications. It presents the peer-reviewed proceedings of the VI International Conference on Complex Networks and their Applications (COMPLEX NETWORKS 2017), which took place in Lyon on November 29 – December 1, 2017. The carefully selected papers cover a wide range of theoretical topics such as network models and measures; community structure, network dynamics; diffusion, epidemics and spreading processes; resilience and control as well as all the main network applications, including social and political networks; networks in finance and economics; biological and ecological networks and technological networks.

A pioneer in evolutionary game theory looks at selfishness and cooperation How does cooperation emerge among selfish individuals? When do people share resources, punish those they consider unfair, and engage in joint enterprises? These questions fascinate philosophers, biologists, and economists alike, for the "invisible hand" that should turn selfish efforts into public benefit is not always at work. The Calculus of Selfishness looks at social dilemmas where cooperative motivations are subverted and self-interest becomes self-defeating. Karl Sigmund, a pioneer in evolutionary game theory, uses simple and well-known game theory models to examine the foundations of collective action and the

effects of reciprocity and reputation. Focusing on some of the best-known social and economic experiments, including games such as the Prisoner's Dilemma, Trust, Ultimatum, Snowdrift, and Public Good, Sigmund explores the conditions leading to cooperative strategies. His approach is based on evolutionary game dynamics, applied to deterministic and probabilistic models of economic interactions. Exploring basic strategic interactions among individuals guided by self-interest and caught in social traps, *The Calculus of Selfishness* analyzes to what extent one key facet of human nature—selfishness—can lead to cooperation. The million copy international bestseller, critically acclaimed and translated into over 25 languages. As influential today as when it was first published, *The Selfish Gene* has become a classic exposition of evolutionary thought. Professor Dawkins articulates a gene's eye view of evolution - a view giving centre stage to these persistent units of information, and in which organisms can be seen as vehicles for their replication. This imaginative, powerful, and stylistically brilliant work not only brought the insights of Neo-Darwinism to a wide audience, but galvanized the biology community, generating much debate and stimulating whole new areas of research. Forty years later, its insights remain as relevant today as on the day it was published. This 40th anniversary edition includes a new epilogue from the author discussing the continuing relevance of these ideas in evolutionary biology today, as well as the original prefaces and foreword, and extracts from early reviews. Oxford Landmark Science books are 'must-read' classics of modern science writing which have crystallized big ideas, and shaped the way we think.

How did life start? Is the evolution of life describable by any physics-like laws? Stuart Kauffman's latest book offers an explanation-beyond what the laws of physics can explain-of the progression from a complex chemical environment to molecular reproduction, metabolism and to early protocells, and further evolution to what we recognize as life. Among the estimated one hundred billion solar systems in the known universe, evolving life is surely abundant. That evolution is a process of "becoming" in each case. Since Newton, we have turned to physics to assess reality. But physics alone cannot tell us where we came from, how we arrived, and why our world has evolved past the point of unicellular organisms to an extremely complex biosphere. Building on concepts from his work as a complex systems researcher at the Santa Fe Institute, Kauffman focuses in particular on the idea of cells constructing themselves and introduces concepts such as "constraint closure." Living systems are defined by the concept of "organization" which has not been focused on in enough in previous works. Cells are autopoietic systems that build themselves: they literally construct their own constraints on the release of energy into a few degrees of freedom that constitutes the very thermodynamic work by which they build their own self creating constraints. Living cells are "machines" that construct and assemble their own working parts. The emergence of such systems-the origin of life problem-was probably a spontaneous phase transition to self-reproduction in

complex enough prebiotic systems. The resulting protocells were capable of Darwin's heritable variation, hence open-ended evolution by natural selection. Evolution propagates this burgeoning organization. Evolving living creatures, by existing, create new niches into which yet further new creatures can emerge. If life is abundant in the universe, this self-constructing, propagating, exploding diversity takes us beyond physics to biospheres everywhere.

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.

Ecology and Evolution of Cancer is a timely work outlining ideas that not only represent a substantial and original contribution to the fields of evolution, ecology, and cancer, but also goes beyond by connecting the interfaces of these disciplines. This work engages the expertise of a multidisciplinary research team to collate and review the latest knowledge and developments in this exciting research field. The evolutionary perspective of cancer has gained significant international recognition and interest, which is fully understandable given that somatic cellular selection and evolution are elegant explanations for carcinogenesis. Cancer is now generally accepted to be an evolutionary and ecological process with complex interactions between tumor cells and their environment sharing many similarities with organismal evolution. As a critical contribution to this field of research the book is important and relevant for the applications of evolutionary biology to understand the origin of cancers, to control neoplastic progression, and to prevent therapeutic failures. Covers all aspects of the evolution of cancer, appealing to researchers seeking to understand its origins and effects of treatments on its progression, as well as to lecturers in evolutionary medicine Functions as both an introduction to cancer and evolution and a review of the current research on this burgeoning, exciting field, presented by an international group of leading editors and contributors Improves understanding of the origin and the evolution of cancer, aiding efforts to determine how this disease interferes with biotic interactions that govern ecosystems Highlights research that intends to apply evolutionary principles to help predict emergence and metastatic progression with the aim of improving therapies

This groundbreaking book describes the emerging field of theoretical immunology, in particular the use of mathematical models to describe the spread of infectious diseases within patients. It reveals fascinating insights into the dynamics of viral and other infections, and the interactions between infectious agents and immune responses. Structured around the examples of HIV/AIDS and hepatitis B, Nowak and May show how mathematical models can help researchers to understand the detailed dynamics of infection and the effects of antiviral therapy. Models are developed to describe the dynamics of drug resistance, immune responses, viral evolution and mutation, and to optimise the

design of therapy and vaccines. - ;We know, down to the tiniest details, the molecular structure of the human immunodeficiency virus (HIV). Yet despite this tremendous accomplishment, and despite other remarkable advances in our understanding of individual viruses and cells of the immune system, we still have no agreed understanding of the ultimate course and variability of the pathogenesis of AIDS. Gaps in our understanding like these impede our efforts towards developing effective therapies and preventive vaccines. Martin Nowak and Robert M May describe the emerging field of theoretical immunology in this accessible and well- written text. Using mathematical modelling techniques, the authors set out their ideas about how populations of viruses and populations of immune system cells may interact in various circumstances, and how infectious diseases spread within patients. They explain how this approach to understanding infectious diseases can reveal insights into the dynamics of viral and other infections, and the interactions between infectious agents and immune responses. The book is structured around the examples of HIV/AIDS and Hepatitis B virus, although the approaches described will be more widely applicable. The authors use mathematical tools to uncover the detailed dynamics of the infection and the effects of antiviral therapy. Models are developed to describe the emergence of drug resistance, and the dynamics of immune responses, viral evolution, and mutation. The practical implications of this work for optimisation of the design of therapy and vaccines are discussed. The book concludes with a glance towards the future of this fascinating, and potentially highly useful, field of study. - ;... an excellent introduction to a field that has the potential to advance substantially our understanding of the complex interplay between virus and host - Nature

Have you ever wondered how birds flock or forest fires spread? For thousands of years people - from DaVinci to Einstein - have created models to help them better understand patterns and processes in the world around them. Computers make it easier for novices to build and explore their own models - and learn new scientific ideas in the process. Adventures in Modeling introduces you and your students to designing, creating, and investigating models in StarLogo. Computer modeling, the use of computer programs to simulate complex, dynamic systems or events (like population growth or environmental conservation), is a powerful learning tool that is finding a rapidly growing audience among teachers in middle and high school science and mathematics classes, especially since the NCTM Standards 2000 advocates its use in the curriculum. This valuable resource: Provides educators with a rich and accessible introduction to the use of computer modeling in the classroom using the popular StarLogo computer programming language; Takes readers step-by-step through the process of using computer models to simulate complex relationships; Shows how and why computer modeling can lead to powerful and enduring learning outcomes for all students. Provides explicit links between various state and national math and science content standards and the use of computer models, to enable educators to see

how this work may enhance standards-based instruction; As computer use gains in currency and value in the middle and high school classroom, *Adventures in Modeling* will give teachers and students a very effective way to build curiosity and boost learning outcomes in a standards-based curriculum.

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.

In recent years, scientists have realized that evolution can occur on timescales much shorter than the 'long lapse of ages' emphasized by Darwin - in fact, evolutionary change is occurring all around us all the time. This work provides an authoritative and accessible introduction to eco-evolutionary dynamics, a cutting-edge new field that seeks to unify evolution and ecology into a common conceptual framework focusing on rapid and dynamic environmental and evolutionary change.

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. *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.

Highly effective thinking is an art that engineers and scientists can be taught to develop. By presenting actual experiences and analyzing them as they are described, the author conveys the developmental thought processes employed and shows a style of thinking that leads to successful results is something that can be learned. Along with spectacular successes, the author also conveys how failures contributed to shaping the thought processes. Provides the reader with a style of thinking that will enhance a person's ability to function as a problem-solver of complex technical issues. Consists of a collection of stories about the author's participation in significant discoveries, relating how those discoveries came about and, most importantly, provides analysis about the thought processes and reasoning that took place as the author and his associates progressed through engineering problems.

A groundbreaking argument for why alien life will evolve to be much like life here on Earth We are all familiar with the popular idea of strange alien life wildly different from life on earth inhabiting other planets. Maybe it's made of silicon! Maybe it has wheels! Or maybe it doesn't. In *The Equations of Life*, biologist Charles S. Cockell makes the forceful argument that the laws of physics narrowly constrain how life can evolve, making evolution's outcomes predictable. If we were to find on a distant planet something very much like a lady bug eating something like an aphid, we shouldn't be surprised. The forms of life are guided by a limited set of rules, and as a result, there is a narrow set of solutions to the challenges of existence. A remarkable scientific contribution breathing new life into Darwin's theory of evolution, *The Equations of Life* makes a radical argument about what life can--and can't--be.

Evolutionary Dynamics Exploring the Equations of Life Harvard University Press
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. 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.

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. 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.

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.

Thorough and accessible, this book presents the design principles of biological systems, and highlights the recurring circuit elements that make up biological networks. It provides a simple mathematical framework which can be used to understand and even design biological circuits. The text avoids specialist terms, focusing instead on several well-studied biological systems that concisely demonstrate key principles. An Introduction to Systems Biology: Design Principles of Biological Circuits builds a solid foundation for the intuitive understanding of general principles. It encourages the reader to ask why a

system is designed in a particular way and then proceeds to answer with simplified models.

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

This 1982 book is an account of an alternative way of thinking about evolution and the theory of games.

Popular understanding holds that genetic changes create cancer. James DeGregori uses evolutionary principles to propose a new way of thinking about cancer's occurrence. Cancer is as much a disease of evolution as it is of mutation, one in which mutated cells outcompete healthy cells in the ecosystem of the body's tissues. His theory ties cancer's progression, or lack thereof, to evolved strategies to maximize reproductive success. Through natural selection, humans evolved genetic programs to maintain bodily health for as long as necessary to increase the odds of passing on our genes—but not much longer. These mechanisms engender a tissue environment that favors normal stem cells over precancerous ones. Healthy tissues thwart cancer cells' ability to outcompete their precancerous rivals. But as our tissues age or accumulate damage from exposures such as smoking, normal stem cells find themselves less optimized to their ecosystem. Cancer-causing mutations can now help cells adapt to these altered tissue environments, and thus outcompete normal cells. Just as changes in a species' habitat favor the evolution of new species, changes in tissue environments favor the growth of cancerous cells. DeGregori's perspective goes far in explaining who gets cancer, when it appears, and why. While we cannot avoid mutations, it may be possible to sustain our tissues' natural and effective system of defense, even in the face of aging or harmful exposures. For those interested in learning how cancers arise within the human body, the insights in Adaptive Oncogenesis offer a compelling perspective. 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.

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).

This concise introduction addresses the theories behind population genetics and relevant empirical evidence, genetic drift, natural selection, nonrandom mating, quantitative genetics, and the evolutionary advantage of sex.

Wide-ranging and inclusive, this text provides an invaluable review of an expansive selection of topics in human evolution, variation and adaptability for professionals and students in biological anthropology, evolutionary biology, medical sciences and psychology. The chapters are organized around four broad themes, with sections devoted to phenotypic and genetic variation within and between human populations, reproductive physiology and behavior, growth and development, and human health from evolutionary and ecological perspectives. An introductory section provides readers with the historical, theoretical and methodological foundations needed to understand the more complex ideas presented later. Two hundred discussion questions provide starting points for class debate and assignments to test student understanding.

This volume is based on lectures delivered at the 2011 AMS Short Course on Evolutionary Game Dynamics, held January 4-5, 2011 in New Orleans, Louisiana. Evolutionary game theory studies basic types of social interactions in populations of players. It combines the strategic viewpoint of classical game theory (independent rational players trying to outguess each other) with

population dynamics (successful strategies increase their frequencies). A substantial part of the appeal of evolutionary game theory comes from its highly diverse applications such as social dilemmas, the evolution of language, or mating behaviour in animals. Moreover, its methods are becoming increasingly popular in computer science, engineering, and control theory. They help to design and control multi-agent systems, often with a large number of agents (for instance, when routing drivers over highway networks or data packets over the Internet). While these fields have traditionally used a top down approach by directly controlling the behaviour of each agent in the system, attention has recently turned to an indirect approach allowing the agents to function independently while providing incentives that lead them to behave in the desired way. Instead of the traditional assumption of equilibrium behaviour, researchers opt increasingly for the evolutionary paradigm and consider the dynamics of behaviour in populations of agents employing simple, myopic decision rules. Genetic algorithms are playing an increasingly important role in studies of complex adaptive systems, ranging from adaptive agents in economic theory to the use of machine learning techniques in the design of complex devices such as aircraft turbines and integrated circuits. *Adaptation in Natural and Artificial Systems* is the book that initiated this field of study, presenting the theoretical foundations and exploring applications. In its most familiar form, adaptation is a biological process, whereby organisms evolve by rearranging genetic material to survive in environments confronting them. In this now classic work, Holland presents a mathematical model that allows for the nonlinearity of such complex interactions. He demonstrates the model's universality by applying it to economics, physiological psychology, game theory, and artificial intelligence and then outlines the way in which this approach modifies the traditional views of mathematical genetics. Initially applying his concepts to simply defined artificial systems with limited numbers of parameters, Holland goes on to explore their use in the study of a wide range of complex, naturally occurring processes, concentrating on systems having multiple factors that interact in nonlinear ways. Along the way he accounts for major effects of coadaptation and coevolution: the emergence of building blocks, or schemata, that are recombined and passed on to succeeding generations to provide, innovations and improvements.

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 mechanics 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.

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

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