Modeling and Simulation in Science, Engineering and Technology

Mathematical Modeling of Biological Systems, Volume I

Cellular Biophysics, Regulatory Networks, Development, Biomedicine, and Data Analysis

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Mathematical Modeling In Biomedicine

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Mathematical Modeling In Biomedicine:

Mathematical Methods and Models in Biomedicine Urszula Ledzewicz,Heinz Schättler,Avner Friedman,Eugene Kashdan,2012-10-20 Mathematical biomedicine is a rapidly developing interdisciplinary field of research that connects the natural and exact sciences in an attempt to respond to the modeling and simulation challenges raised by biology and medicine There exist a large number of mathematical methods and procedures that can be brought in to meet these challenges and this book presents a palette of such tools ranging from discrete cellular automata to cell population based models described by ordinary differential equations to nonlinear partial differential equations representing complex time and space dependent continuous processes Both stochastic and deterministic methods are employed to analyze biological phenomena in various temporal and spatial settings This book illustrates the breadth and depth of research opportunities that exist in the general field of mathematical biomedicine by highlighting some of the fascinating interactions that continue to develop between the mathematical and biomedical sciences It consists of five parts that can be read independently but are arranged to give the reader a broader picture of specific research topics and the mathematical tools that are being applied in its modeling and analysis The main areas covered include immune system modeling blood vessel dynamics cancer modeling and treatment and epidemiology The chapters address topics that are at the forefront of current biomedical research such as cancer stem cells immunodominance and viral epitopes aggressive forms of brain cancer or gene therapy The presentations highlight how mathematical modeling can enhance biomedical understanding and will be of interest to both the mathematical and the biomedical communities including researchers already working in the field as well as those who might consider entering it Much of the material is presented in a way that gives graduate students and young researchers a starting point for their own work Mathematical Modelling in Biomedicine Vitaly Volpert,2021-01-26 Mathematical modelling in biomedicine is a rapidly developing scientific discipline at the intersection of medicine biology mathematics physics and computer science Its progress is stimulated by fundamental scientific questions and by the applications to public health This book represents a collection of papers devoted to mathematical modelling of various physiological problems in normal and pathological conditions It covers a broad range of topics including cardiovascular system and diseases heart and brain modelling tumor growth viral infections and immune response Computational models of blood circulation are used to study the influence of heart arrhythmias on coronary blood flow and on operating modes for left ventricle assisted devices Wave propagation in the cardiac tissue is investigated in order to show the influence of tissue heterogeneity and fibrosis The models of tumor growth are used to determine optimal protocols of antiangiogenic and radiotherapy The models of viral hepatitis kinetics are considered for the parameter identification and the evolution of viral quasi species is investigated The book presents the state of the art in mathematical modelling in biomedicine and opens new perspectives in this passionate field of research **Mathematical Modelling in Biomedicine** Vitaly Volpert,2021 Mathematical modelling in biomedicine is a rapidly developing scientific discipline at the intersection of medicine biology mathematics physics and computer science Its progress is stimulated by fundamental scientific questions and by the applications to public health This book represents a collection of papers devoted to mathematical modelling of various physiological problems in normal and pathological conditions It covers a broad range of topics including cardiovascular system and diseases heart and brain modelling tumor growth viral infections and immune response Computational models of blood circulation are used to study the influence of heart arrhythmias on coronary blood flow and on operating modes for left ventricle assisted devices Wave propagation in the cardiac tissue is investigated in order to show the influence of tissue heterogeneity and fibrosis The models of tumor growth are used to determine optimal protocols of antiangiogenic and radiotherapy The models of viral hepatitis kinetics are considered for the parameter identification and the evolution of viral quasi species is investigated The book presents the state of the art in mathematical modelling in biomedicine and opens new perspectives in this passionate field of research

Mathematical Modelling in Biomedicine Y. Cherruault,2012-12-06 Approach your problems from the right It isn t that they can t see the solution It end and begin with the answers Then is that they can t see the problem one day perhaps you will find the final question G K Chesterton The Scandal of Father Brown The point of a Pin The Hermit Clad in Crane Feathers in R van Gulik s The Chinese Maze Murders Growing specialization and diversification have brought a host of monographs and textbooks on increasingly specialized topics However the tree of knowledge of mathematics and related fields does not grow only by putting forth new branches It also happens quite often in fact that branches which were thought to be completely disparate are suddenly seen to be related Further the kind and level of sophistication of mathematics applied in various sciences has changed drastically in recent years measure theory is used non trivially in regional and theoretical economics algebraic geometry interacts with physics the Minkowsky lemma cod ing theory and the structure of water meet one another in packing and covering theory quantum fields crystal defects and mathematical pro gramming profit from homotopy theory Lie algebras are relevant to filtering and prediction and electrical engineering can use Stein spaces

Mathematical Models in Biomedical Science Duncan Chambers,2020-09-15 The field of biomedical science studies the mechanisms that are at the core of the function and formation of living organisms It ranges in scope from the study of individual molecules to complex human functions This contributes to our understanding of how different diseases traumas and genetic defects alter physiological and behavioral processes Modern biomedical science works at the cellular molecular and systems level with the aid of techniques of molecular biology and genome characterization Such studies have implications on potential medical therapies and clinical studies and the understanding of disease mechanisms The integration of mathematics with biomedical sciences has led to many such applications and innovations Mathematical modeling and analysis optimization techniques and computational methods numerical analysis applied statistics or a combination of these are used for solving problems in this field Mathematical models and methods also form the basis for the construction of imaging techniques in biomedical science This has transformed the practice of medicine and furthered the scope of non invasive diagnosis and surgical planning for guiding surgery biopsy and radiation therapy The field of biomedical science and engineering has undergone rapid development over the past few decades This book elucidates the mathematical concepts and models that have led to advancements in biomedical science It is an essential guide for both academicians and those who wish to pursue this discipline further *Mathematical Models for Biomedicine* Luca Mesin,2017 *Mathematical Methods and Models in Biomedicine* Urszula Ledzewicz,Heinz Schättler,Avner Friedman,Eugene Kashdan,2012-10-21 Mathematical biomedicine is a rapidly developing interdisciplinary field of research that connects the natural and exact sciences in an attempt to respond to the modeling and simulation challenges raised by biology and medicine There exist a large number of mathematical methods and procedures that can be brought in to meet these challenges and this book presents a palette of such tools ranging from discrete cellular automata to cell population based models described by ordinary differential equations to nonlinear partial differential equations representing complex time and space dependent continuous processes Both stochastic and deterministic methods are employed to analyze biological phenomena in various temporal and spatial settings This book illustrates the breadth and depth of research opportunities that exist in the general field of mathematical biomedicine by highlighting some of the fascinating interactions that continue to develop between the mathematical and biomedical sciences It consists of five parts that can be read independently but are arranged to give the reader a broader picture of specific research topics and the mathematical tools that are being applied in its modeling and analysis The main areas covered include immune system modeling blood vessel dynamics cancer modeling and treatment and epidemiology The chapters address topics that are at the forefront of current biomedical research such as cancer stem cells immunodominance and viral epitopes aggressive forms of brain cancer or gene therapy The presentations highlight how mathematical modeling can enhance biomedical understanding and will be of interest to both the mathematical and the biomedical communities including researchers already working in the field as well as those who might consider entering it Much of the material is presented in a way that gives graduate students and young researchers a starting point for their own work

Biomathematics J. C. Misra,2006 Will be invaluable to researchers who are interested in emerging areas of the field

Mathematical Modeling of Biological Systems, Volume I Andreas Deutsch,Lutz Brusch,Helen Byrne,Gerda de Vries,Hanspeter Herzel,2007-06-15 Volume I of this two volume interdisciplinary work is a unified presentation of a broad range of state of the art topics in the rapidly growing field of mathematical modeling in the biological sciences The chapters are thematically organized into the following main areas cellular biophysics regulatory networks developmental biology biomedical applications data analysis and model validation The work will be an excellent reference text for a broad audience of researchers practitioners and advanced students in this rapidly growing field at the intersection of applied mathematics experimental biology and medicine computational biology biochemistry computer science and physics Complex Systems in Biomedicine A. Quarteroni,L. Formaggia,A. Veneziani,2007-03-20 Mathematicalmodelingofhumanphysiopathologyisatremendouslyambitioustask It encompasses the modeling of most diverse compartments such as the cardiovas lar respiratory skeletalandnervoussystems aswellasthemechanicalandbioch ical interaction between blood ow and arterial walls and electrocardiac processes and electric conduction in biological tissues Mathematical models can be set up to simulate both vasculogenesis the aggregation and organization of endothelial cells dispersed in a given environment and angiogenesis the formation of new vessels sprouting from an existing vessel that are relevant to the formation of vascular networks and in particular to the description of tumor growth The integration of models aimed at simulating the cooperation and interrelation of different systems is an even more dif cult task It calls for the setting up of for instance interaction models for the integrated cardio vascular system and the interplay between the central circulation and peripheral compartments models for the mid to long range cardiovascular adjustments to pathological conditions e g to account for surgical interventions congenital malformations or tumor growth models for integration among circulation tissue perfusion biochemical and thermal regulation models for parameter identi cation and sensitivity analysis to parameter changes or data uncertainty and many others **Model-Based Hypothesis Testing in Biomedicine** Rikard Johansson,2017-10-03 The utilization of mathematical tools within biology and medicine has traditionally been less widespread compared to other hard sciences such as physics and chemistry However an increased need for tools such as data processing bioinformatics statistics and mathematical modeling have emerged due to advancements during the last decades These advancements are partly due to the development of high throughput experimental procedures and techniques which produce ever increasing amounts of data For all aspects of biology and medicine these data reveal a high level of inter connectivity between components which operate on many levels of control and with multiple feedbacks both between and within each level of control However the availability of these large scale data is not synonymous to a detailed mechanistic understanding of the underlying system Rather a mechanistic understanding is gained first when we construct a hypothesis and test its predictions experimentally Identifying interesting predictions that are quantitative in nature generally requires mathematical modeling This in turn requires that the studied system can be formulated into a mathematical model such as a series of ordinary differential equations where different hypotheses can be expressed as precise mathematical expressions that influence the output of the model Within specific sub domains of biology the utilization of mathematical models have had a long tradition such as the modeling done on electrophysiology by Hodgkin and Huxley in the 1950s However it is only in recent years with the arrival of the field known as systems biology that mathematical modeling has become more commonplace The somewhat slow adaptation of mathematical modeling in biology is partly due to historical differences in training and terminology as well as in a lack of awareness of showcases illustrating how modeling can make a difference or even be required for a correct analysis of the experimental data In this work I provide such showcases by demonstrating the universality and applicability of mathematical modeling and hypothesis testing in three disparate biological systems In Paper II we demonstrate how mathematical modeling is necessary for the correct interpretation and analysis of dominant negative inhibition data in insulin signaling in primary human adipocytes In Paper III we use modeling to determine transport rates across the nuclear membrane in yeast cells and we show how this technique is superior to traditional curve fitting methods We also demonstrate the issue of population heterogeneity and the need to account for individual differences between cells and the population at large In Paper IV we use mathematical modeling to reject three hypotheses concerning the phenomenon of facilitation in pyramidal nerve cells in rats and mice We also show how one surviving hypothesis can explain all data and adequately describe independent validation data Finally in Paper I we develop a method for model selection and discrimination using parametric bootstrapping and the combination of several different empirical distributions of traditional statistical tests We show how the empirical log likelihood ratio test is the best combination of two tests and how this can be used not only for model selection but also for model discrimination In conclusion mathematical modeling is a valuable tool for analyzing data and testing biological hypotheses regardless of the underlying biological system Further development of modeling methods and applications are therefore important since these will in all likelihood play a crucial role in all future aspects of biology and medicine especially in dealing with the burden of increasing amounts of data that is made available with new experimental techniques Anv ndandet av matematiska verktyg har inom biologi och medicin traditionellt sett varit mindre utbredd j mf rt med andra mnen inom naturvetenskapen s som fysik och kemi Ett kat behov av verktyg som databehandling bioinformatik statistik och matematisk modellering har tr tt fram tack vare framsteg under de senaste decennierna Dessa framsteg r delvis ett resultat av utvecklingen av storskaliga datainsamlingstekniker Inom alla omr den av biologi och medicin s har dessa data avsl jat en h g niv av interkonnektivitet mellan komponenter verksamma p m nga kontrollniv er och med flera terkopplingar b de mellan och inom varje niv av kontroll Tillg ng till storskaliga data r emellertid inte synonymt med en detaljerad mekanistisk f rst else f r det underliggande systemet Snarare uppn s en mekanisk f rst else f rst n r vi bygger en hypotes vars prediktioner vi kan testa experimentellt Att identifiera intressanta prediktioner som r av kvantitativ natur kr ver generellt sett matematisk modellering Detta kr ver i sin tur att det studerade systemet kan formuleras till en matematisk modell s som en serie ordin ra differentialekvationer d r olika hypoteser kan uttryckas som precisa matematiska uttryck som p verkar modellens output Inom vissa delomr den av biologin har utnyttjandet av matematiska modeller haft en l ng tradition s som den modellering gjord inom elektrofysiologi av Hodgkin och Huxley p 1950 talet Det r emellertid just p senare r med ankomsten av f ltet systembiologi som matematisk modellering har blivit ett vanligt inslag Den n got l ngsamma adapteringen av matematisk modellering inom biologi r bl a grundad i historiska skillnader i tr ning och terminologi samt brist p medvetenhet om exempel som illustrerar hur modellering kan g ra skillnad och faktiskt ofta r ett krav f r en korrekt analys av experimentella data I detta arbete tillhandah ller jag s dana exempel och demonstrerar den matematiska modelleringens och hypotestestningens allm ngiltighet och till mpbarhet i tre olika biologiska system I Arbete II visar vi hur matematisk modellering r n dv ndig f r en korrekt tolkning och analys av dominant negativ inhiberingsdata vid insulinsignalering i prim ra humana adipocyter I Arbete III anv nder vi modellering f r att best mma transporthastigheter ver cellk rnmembranet i j stceller och vi visar hur denna teknik r verl gsen traditionella kurvpassningsmetoder Vi demonstrerar ocks fr gan om populationsheterogenitet och behovet av att ta h nsyn till individuella skillnader mellan celler och befolkningen som helhet I Arbete IV anv nder vi matematisk modellering f r att f rkasta tre hypoteser om hur fenomenet facilitering uppst r i pyramidala nervceller hos r ttor och m ss Vi visar ocks hur en verlevande hypotes kan beskriva all data inklusive oberoende valideringsdata Slutligen utvecklar vi i Arbete I en metod f r modellselektion och modelldiskriminering med hj lp av parametrisk bootstrapping samt kombinationen av olika empiriska f rdelningar av traditionella statistiska tester Vi visar hur det empiriska log likelihood ratio testet r den b sta kombinationen av tv tester och hur testet r applicerbart inte bara f r modellselektion utan ocks f r modelldiskriminering Sammanfattningsvis r matematisk modellering ett v rdefullt verktyg f r att analysera data och testa biologiska hypoteser oavsett underliggande biologiskt system Vidare utveckling av modelleringsmetoder och till mpningar r d rf r viktigt eftersom dessa sannolikt kommer att spela en avg rande roll i framtiden f r biologi och medicin s rskilt n r det g ller att hantera belastningen fr n kande datam ngder som blir tillg nglig med nya experimentella tekniker Biomedical Mass Transport and Chemical Reaction James S. Ultman,Harihara Baskaran,Gerald M. Saidel,2016-04-29 Teaches the fundamentals of mass transport with a unique approach emphasizing engineering principles in a biomedical environment Includes a basic review of physiology chemical thermodynamics chemical kinetics mass transport fluid mechanics and relevant mathematical methods Teaches engineering principles and mathematical modelling useful in the broad range of problems that students will encounter in their academic programs as well as later on in their careers Illustrates principles with examples taken from physiology and medicine or with design problems involving biomedical devices Stresses the simplification of problem formulations based on key geometric and functional features that permit practical analyses of biomedical applications Offers a web site of homework problems associated with each chapter and solutions available to instructors Homework problems related to each chapter are available from a supplementary website *Simple Mathematical Models of Gene Regulatory Dynamics* Michael C. Mackey,Moisés Santillán,Marta Tyran-Kamińska,Eduardo S. Zeron,2016-11-09 This is a short and self contained introduction to the field of mathematical modeling of gene networks in bacteria As an entry point to the field we focus on the analysis of simple gene network dynamics The notes commence with an introduction to the deterministic modeling of gene networks with extensive reference to applicable results coming from dynamical systems theory The second part of the notes treats extensively several approaches to the study of gene network dynamics in the presence of noise either arising from low numbers of molecules involved or due to noise external to the regulatory process The third and final part of the notes gives a detailed treatment of three well studied and concrete examples of gene network dynamics by considering the lactose operon the tryptophan operon and the lysis lysogeny switch The notes contain an index for easy location of particular topics as well as an extensive bibliography of the current literature The target audience of these notes are mainly graduates students and young researchers with a solid mathematical background calculus ordinary differential equations and probability theory at a minimum as well as with basic notions of biochemistry cell biology and molecular biology They are meant to serve as a readable and brief entry point into a field that is currently highly active and will allow the reader to grasp the current state of research and so prepare them for defining and tackling new research problems **Mathematical Models of Cancer and Different Therapies** Regina Padmanabhan,Nader Meskin,Ala-Eddin Al Moustafa,2020-10-31 This book provides a unified framework for various currently available mathematical models that are used to analyze progression and regression in cancer development and to predict its dynamics with respect to therapeutic interventions Accurate and reliable model representations of cancer dynamics are milestones in the field of cancer research Mathematical modeling approaches are becoming increasingly common in cancer research as these quantitative approaches can help to validate hypotheses concerning cancer dynamics and thus elucidate the complexly interlaced mechanisms involved Even though the related conceptual and technical information is growing at an exponential rate the application of said information and realization of useful healthcare devices are lagging behind In order to remedy this discrepancy more interdisciplinary research works and course curricula need to be introduced in academic industrial and clinical organizations alike To that end this book reformulates most of the existing mathematical models as special cases of a general model allowing readers to easily get an overall idea of cancer dynamics and its modeling Moreover the book will help bridge the gap between biologists and engineers as it brings together cancer dynamics the main steps involved in mathematical modeling and control strategies developed for cancer management This also allows readers in both medical and engineering fields to compare and contrast all the therapy based models developed to date using a single source and to identify unexplored research directions

Math Everywhere G. Aletti,Martin Burger,Alessandra Micheletti,Daniela Morale,2007-07-11 These proceedings report on the conference Math Everywhere celebrating the 60th birthday of the mathematician Vincenzo Capasso The conference promoted ideas Capasso has pursued and shared the open atmosphere he is known for Topic sections include Deterministic and Stochastic Systems Mathematical Problems in Biology Medicine and Ecology Mathematical Problems in Industry and Economics The broad spectrum of contributions to this volume demonstrates the truth of its title Math is Everywhere indeed

Mathematical Modeling of Biological Systems, Volume II Andreas Deutsch,Rafael Bravo de la Parra,Rob J. de Boer,Odo Diekmann,Peter Jagers,Eva Kisdi,Mirjam Kretzschmar,Petr Lansky,Hans Metz,2007-11-07 Volume II of this two volume interdisciplinary work is a unified presentation of a broad range of state of the art topics in the rapidly growing field of mathematical modeling in the biological sciences Highlighted throughout are mathematical and computational apporaches to examine central problems in the life sciences ranging from the organization principles of individual cells to the dynamics of large populations The chapters are thematically organized into the following main areas epidemiology evolution and ecology immunology neural systems and the brain and innovative mathematical methods and education The work will be an excellent reference text for a broad audience of researchers practitioners and advanced students in this rapidly growing field at the intersection of applied mathematics experimental biology and medicine computational biology biochemistry computer science and physics *Mathematical Models and Methods for Living Systems* Luigi Preziosi,Pasquale Ciarletta,Thomas Hillen,Hans Othmer,Dumitru Trucu,2016-11-09 The aim of these lecture notes is to give an introduction to several mathematical models and methods that can be used to describe the behaviour of living systems This emerging field of application intrinsically requires the handling of phenomena occurring at different spatial scales and hence the use of multiscale methods Modelling and simulating the mechanisms that cells use to move self organise and develop in tissues is not only fundamental to an understanding of embryonic development but is also relevant in tissue engineering and in other environmental and industrial processes involving the growth and homeostasis of biological systems Growth and organization processes are also important in many tissue degeneration and regeneration processes such as tumour growth tissue vascularization heart and muscle functionality and cardio vascular diseases *Analysis of biological processes* Alfonsas Juška,2015-12-04 The main concern of the book is analysis of biological processes the final stage of which is mathematical modeling i e quantitative presentation of the processes in rigorous mathematical terms It is designated for non mathematicians Mathematical models can be compared with experimental data thus verifying the validity of the models and finally of the initial assumptions and verbal descriptions of the processes The models usually in the form of mathematical equations are achieved painlessly via the schemes summarising verbal description of what is known concerning the processes To solve the equations computer software is used The step by step analysis leads to quite sophisticated models some of them being original The book helps the reader to develop more general approach to the problems It may be useful for experienced readers as well *Methods In Animal Physiology* Zdenek Deyl,2019-08-08 The aim of the present volume was to give an overview over different available methodological approaches The specialists may perhaps object that in their particular field the level of information is superficial However let them look at other chapters in which different approaches are discussed and which surely will appear less superficial from the more general point of view We hope at least that crucial references can be traced throughout the book that would enable the readers to go in more detail when desired It can be traced throughout the book that would enable the readers to go in more detail when desired It was really one of our ideas to draw the survey of possibilities available If this can stimulate the readers to use ideas to draw the survey of possibilities available If this can stimulate the readers to use other methods that those they are routinely using the goals will be met **Modeling and Control in the Biomedical Sciences** H.T. Banks,2013-03-12 These notes are based on i a series of lectures that I gave at the 14th Biennial Seminar of the Canadian Mathematical Congress held at the University of Western Ontario August 12 24 1973 and li some of my lectures in a modeling course that I have cotaught in the Division of Bio Medical Sciences at Brown during the past several years An earlier version of these notes appeared in the Center for Dynamical Systems Lectures Notes series CDS LN 73 1 November 1973 I have in this revised and extended version of those earlier notes incorporated a number of changes based both on classroom experience and on my research efforts with several colleagues during the intervening period The narrow viewpoint of the present notes use of optimization and control theory in biomedical problems reflects more the scope of the CMC lectures given in August 1973 than the scope of my own interests Indeed my real interests have included the modeling process itself as well as the contributions made by investiga tors who employ the techniques and ideas of control theory systems analysis dif ferential equations and stochastic processes Some of these contributions have quite naturally involved application of optimal control theory But in my opinion many of the interesting efforts being made in modeling in the biomedical sciences encompass much more than the use of control theory

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