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Biological Systems: Nonlinear Dynamics Approach

Springer

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Preface

This book brings together recent achievements in the field of biological systems from a nonlinear dynamics perspective. During the compilation of this book, we have received contributions of recent results obtained by the group of international scientists who attended the 2nd BCAM Workshop on Nonlinear Dynamics in Biological Systems, held at the Basque Center for Applied Mathematics, Bilbao in September 2016. These contributions embrace diverse disciplines and use multidisciplinary approaches-including theoretical concepts, simulations and experiments-that emphasize the nonlinear nature of biological systems in order to be able to reproduce their complex behavior. The results included in this book represent recent progress and not necessarily what was presented at the conference.

The topics included in the book relate to medical applications as well as more fundamental questions in biochemistry. One such question is the ability to control chemically driven reaction–diffusion systems that lead to periodic patterns, which are often observed in biological problems. Here, the authors present a study of this question as a mathematical control problem, taking into account time-delay feedback for both standing waves and travelling waves.

Closer to medical applications, we include a study about the prevention and treatment of heart diseases such as tachycardia, ventricular fibrillation and arteriosclerosis. In particular, this problem is discussed from the perspective of a simple dynamical model that describes electrical wave propagation through the heart tissue. This approach uses a reaction–diffusion model to simulate the contraction of the electrical pulse as it propagates through cardiac tissue, a phenomenon that can lead to tachycardia and fibrillation.

Another important topic with medical applications is neural network growth. The work presented here involved the performance of a longitudinal graph theory-based study of in vitro neuronal networks, comparing results from both simulations and experiments. This is an example of self-organization through an optimization process that leads to a random small-world network with positive degree–degree correlations. The phenomenon can be qualitatively described by a spatial network growth model based on random growth and neuronal migration.

This book also includes recent results in fundamental biochemical questions such as chiral symmetry breaking in polymers, including a brief description of the mechanical forces at play and a feasible dynamical model for enantioselective polymerization in closed systems. The presented model accounts for spontaneous mirror symmetry breaking as a consequence of competing recycling processes, also in the absence of chiral or mutual inhibition.

Lastly, we present the application of mechanochemical pattern formation in the cytoplasm. This problem is studied using viscoelastic models for solid and fluid cases and in the particular case of cardiac cells.

The editors and the authors wish to express their gratitude to the Basque Government (Eusko Jaurlaritza) for their financial support in the organization of the 2nd BCAM Workshop on Nonlinear Dynamics in Biological Systems. We would like to thank the Basque Center of Applied Mathematics (BCAM) for their valuable assistance in logistics, administrative duties and creation of a good atmosphere for knowledge exchange. We are also thankful to the Berlin Center for Studies of Complex Chemical Systems (BCSCCS) for providing further economic support.

Oviedo, Spain — Jorge Carballido-Landeira
Bilbao, Spain — Bruno Escribano
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Jorge Carballido-Landeira received his Ph.D. degree in Physics from the University of Santiago de Compostela (Spain) in 2011, where he worked on nonlinear physical dynamics emerging in active confined chemical systems. He is currently an Assistant Professor at the Department of Applied Physics at the University of Oviedo, Spain. His research focuses on a multidisciplinary field that includes nonlinear dynamics, self-organization processes, colloidal and polymer science, environmental constraints and fluid mechanics in order to gain an understanding of complex biological systems.

Bruno Escribano has been a researcher at the Basque Center for Applied Mathematics since 2014. He holds a Ph.D. in Physics and Mathematics from the University of Granada, Spain (2010). His highly multidisciplinary research focuses on such diverse topics as astrophysics, quasi-crystals, biomineralization and pattern formation in geophysics. His current research interests are related to the modeling and simulation of biological systems using nonlinear dynamical methods.