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In this Issue

This issue of THE BIOLOGICAL PHYSICIST brings you a feature interview with Olga Sosnovtseva and Erik Mosekilde about the BioSim Network of Excellence project, a major European biological physics initiative. We also bring you PRE and PRL Highlights and a special conference announcement.

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FEATURE

Olga Sosnovtseva and Erik Mosekilde Discuss the BioSim Network of Excellence

Olga Sosnovtseva and Erik Mosekilde have collaborated for more than a decade in the areas of biological physics and modeling of complex dynamical phenomena in living systems. During the spring of 2004 they formulated the application to the European Biotechnology for Health Programme that led to the establishment of BioSim, an unusually successful Network of Excellence in "Biosimulation – A New Tool in Drug Development", described in detail at http://biosim.fysik.dtu.dk:8080/biosim/index.jsp.

Erik Mosekilde is a professor of physics at The Technical University of Denmark (DTU), where he teaches courses in complex systems theory and modeling of biological systems. In 1977, he defended his second doctor's degree in theoretical and experimental physics, but at that time he had already become interested in modeling the dynamics of economic and biological systems. The challenge was to try to establish mechanism-based models of systems that had not previously been submitted to this approach. His education in electrical engineering and physics provided a powerful background for understanding the dynamics of biological feedback networks, and his early research on acoustoelectric phenomena in piezoelectric semiconductors had given him experience with instabilities and nonlinear dynamic phenomena under far-from-equilibrium conditions. His initial work on respiratory control during exercise led to studies of the absorption of insulin from the skin, the mechanisms behind the pulsatile release of insulin, nephron pressure and flow regulation, bone remodeling, and cellular communication.

Olga Sosnovtseva is a lecturer with the Department of Physics at DTU and holds a prestigious Skou Stipend, named after the Danish physiologist Jens Christian Skou, who was recently awarded the Nobel Prize for his discovery of the Na/K pump. Olga Sosnovtseva graduated from Saratov State University in the field of Nonlinear Dynamics. Her interests in biological physics developed through collaboration with experimental groups in Copenhagen, Marburg and Moscow. She has worked on dynamical properties of kidney pressure and flow autoregulation, on multiscale cellular interactions including neuron-glia networks and smooth muscle cells, and on application of the novel experimental technique of interference microscopy, combined with double-wavelet analysis, to study intra- and inter-cellular processes.

Sosnovtseva and Mosekilde talked with THE BIOLOGICAL PHYSICIST *about the origins and goals of the BioSim project.*

Why did you feel there was a need for a new approach to drug development?

The pharmaceutical industry is generally considered as one of the best performing industries in Europe. However, during the last decade it has become clear that the industry faces a number of serious problems, and that a new approach to the drug development process must be found. While R&D investments have continued to rise at a significant rate, the number of major new drugs has stagnated, or even declined. Due to the enormous costs and the long lead times in conjunction with the relatively high probability that a drug will fail in the final trial, the economic risks have risen to an unacceptable level.

Was it difficult to find funding?

Through discussions with the European Federation for Pharmaceutical Scientists (EUFEPS), the European Medicines Agency (EMEA), and other organizations, the European Commission was fully aware of the above problems, and BioSim was established on December 1, 2004 in response to a direct call from the Commission. The total budget is 10.7 million Euro over a period of 5 years. This budget primarily covers training of young scientists, exchange of students and staff, development of collaborative projects, common conferences and workshops, spreading of excellence, and communication with the public. Most of the research performed by the BioSim groups must be funded by other agencies. However, many of the groups also have significant funding from national research councils.

What is the purpose of BioSim?

The primary purpose of the Network is to establish a strong and lasting collaboration among some of Europe's leading research groups in systems biology. More specifically, the aim is to demonstrate that application of mechanism-based modeling represents an effective way to interpret the data obtained in the industry's clinical and pre-clinical trials. As the models are gradually developed and improved, this will allow the industry to reduce the number of trials and obtain an earlier warning of possible failure. By mechanism-based modeling we understand a modeling approach where the actual physical, chemical and biological processes of relevance to a given phenomenon are represented in as much detail as necessary. This approach underlies most research in physics. The challenge is, of course, to show that it can also be brought to work with the extreme complication that we find in biological systems.

How many scientists are involved in BioSim?

The BioSim Network involves 26 academic, 10 industrial, and 4 regulatory partners, or a total of nearly 200 scientists and PhD-students from 10 different countries.

The regulatory partners play an important role, because they define the criteria for acceptance of a new drug. If models have to be used as part of the documentation for efficacy and lack of adverse side effects, then the regulatory agencies must be able to evaluate these models. 9 of the industrial partners are small and medium-sized enterprises, and Novo Nordisk is the only large industrial partner. However, most of the academic and SME partners maintain close collaborations with one or more large pharmaceutical companies. The academic partners cover a wide range of different biological and pharmaceutical specialties as well as physics, mathematics and complex systems theory.

Olga Sosnovtseva

What are the main scientific results produced from the BioSim Network so far?

BioSim's research is organized in six activity areas: diabetes, cardiovascular diseases, cancer, mental disorders, methodological developments, and communication with public. Within each of the first four areas, research is performed at many different biological levels, from the genetic and molecular level over biochemistry, cell biology and cell-to-cell communication to the function of organs, hormonal control and disease modeling. Some BioSim partners are also involved in

experimental treatments of patients with cancer, Parkinson's disease, or depression.

BioSim partners publish 50-60 papers a year in major international journals. Besides a recent special issue of *Journal of Biological Physics,* BioSim has also edited a book on "*Biosimulation in Drug Development*" (Wiley-VCH, Berlin, 2007).

Among the most significant results obtained so far are major improvements in the chronotherapy of certain forms of cancer and in deep-brain stimulation of patients with Parkinsonian and other forms of tremor. By analysing the synchronization phenomena in models of many globally coupled phase oscillators, the group in Jülich has been able to define a stimulation signal that can be used in a demand-controlled mode and at the same time is 10 times lower in amplitude than the standard signal. Preliminary results seem to indicate that, rather than gradually destroying brain tissue near the stimulation site, the improved approach may to some extent allow the brain cells to recover.

In collaboration with biophysicists from Moscow University, the BioSim group at the Department of Physics at DTU has studied interactions and mutual modulation between different intracellular processes by means of the newly developed phase modulated laser interference microscope. This equipment allows noninvasive studies of simultaneous intracellular processes over the frequency range from 0.2 to 20 Hz. In a fully developed version the equipment will make it possible to study automatically intracellular reactions to different drugs.

Would it be helpful for such a network to be established in the US as well?

The challenges that a mechanism-based description of the development and function of living organisms represents to science are the same in the US as in Europe, and so are the problems faced by the pharmaceutical industry. In a recent report, the Food and Drug Administration (FDA) concluded that a major change in the current drug development process is required, particularly an improvement in the way information is obtained and exploited. At the same time, the American side may be inspired by the significant resources that the EU Commission has set aside for the Innovative Medicines Initiative in the 7th Framework Programme.

BioSim already collaborates with the Canadian network for Applied Mathematics (MITACS) and, within the rules defined by the EU Commission, we are obviously interested in collaboration with networks in biological physics or systems biology in the US as well.

Erik Mosekilde

What do you think is the future for interdisciplinary science?

Interdisciplinary scientific activities have probably always experienced difficult times. The reason for this is, of course, that practitioners of such activities are considered as amateurs in their second field and sometimes even as traitors to their original discipline. It may also be difficult to establish strict criteria of quality in such areas, because publications always have to include a certain pedagogical element. However, interdisciplinary areas are often the areas where

new science is born and where the major challenges are found. In our view, biological physics and systems biology are already so well established that they will soon become major disciplines in their own right. Hence, we do not foresee difficulties for the funding in these areas.

The main difficulty for the two disciplines is the fact that the educational system in many cases is unprepared. Hence, much too few courses in physics and mathematics are offered to students of biology and medicine, and too few courses in biological disciplines are required by students of mathematics and physics.

What advice can you give to young scientists in interdisciplinary research?

It is very important that the group you join, either as a PhD-student or a postdoc, functions well and operates at a high international level. In view of the problems we have sketched above it is also clear that you need to maintain a quality in your research that exceeds, or at least matches, the quality reached in other areas. If you can manage this, you are likely to have more fun in your work than most of your peers in the established disciplines. Please remember, though, that the established fields also develop, and if they control most of the funding they may suddenly swallow the concepts and ideas of a smaller field.

PRL HIGHLIGHTS

Soft Matter, Biological, &
Inter-disciplinary Physics Articles from
Physical Review Letters

1 June 2007
Vol 98, Number 22, Articles (22xxxx)
Articles published 26 May - 1 Jun 2007
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Evidence for Viscoelastic Effects in Surface Capillary Waves of Molten Polymer Films
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227801

Cation Transport in Polymer Electrolytes: A Microscopic Approach
A. Maitra and A. Heuer
Published 30 May 2007
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Precision of Genetic Oscillators and Clocks
Luis G. Morelli and Frank Jülicher
Published 31 May 2007
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Stochastic Resonant Signaling in Enzyme Cascades
Yueheng Lan and Garegin A. Papoian
Published 1 June 2007
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Scaling and Continuum Percolation Model for Enzyme-Catalyzed Gel Degradation
D. Lairez, J.-P. Carton, G. Zalczer, and J. Pelta
Published 1 June 2007
228302

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Articles published 2 Jun - 8 Jun 2007
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Dipole-Quadrupole Force Ratios Determine the Ability of Potential Models to Describe the Phase Diagram of Water
José L. F. Abascal and Carlos Vega
Published 5 June 2007
237801

Charged Particles on Surfaces: Coexistence of Dilute Phases and Periodic Structures at Interfaces
Sharon M. Loverde, Francisco J. Solis, and Monica Olvera de la Cruz
Published 6 June 2007
237802

Velocity Correlations in Dense Granular Flows Observed with Internal Imaging
Ashish V. Orpe and Arshad Kudrolli
Published 4 June 2007
238001

Determination of Interbilayer and Transbilayer Lipid Transfers by Time-Resolved Small-Angle Neutron Scattering
Minoru Nakano, Masakazu Fukuda, Takayuki Kudo, Hitoshi Endo, and Tetsurou Handa
Published 7 June 2007
238101

Neural Field Dynamics with Heterogeneous Connection Topology
Murad R. Qubbaj and Viktor K. Jirsa
Published 7 June 2007
238102

"Bending to Stretching" Transition in Disordered Networks
Gavin A. Buxton and Nigel Clarke
Published 7 June 2007
238103

Effect of Salt Concentration on the Electrophoretic Speed of a Polyelectrolyte through a Nanopore
Sandip Ghosal
Published 7 June 2007
238104

Randomly Hyperbranched Polymers
Dominik Konkolewicz, Robert G. Gilbert, and Angus Gray-Weale
Published 4 June 2007
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Nonequilibrium-Driven Motion in Actin Networks: Comet Tails and Moving Beads
N. J. Burroughs and D. Marenduzzo
Published 5 June 2007
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Strain-Rate Frequency Superposition: A Rheological Probe of Structural Relaxation in Soft Materials
Hans M. Wyss, Kunimasa Miyazaki, Johan Mattsson, Zhibing Hu, David R. Reichman, and David A. Weitz
Published 7 June 2007
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Colloid Particles in the Interaction Field of a Disclination Line in a Nematic Phase
David Pires, Jean-Baptiste Fleury, and Yves Galerne
Published 13 June 2007
247801

Modulated Structures in Bent-Core Liquid Crystals: Two Faces of One Phase
Nataša Vaupotič, Martin Čopič, Ewa Gorecka, and Damian Pociecha
Published 14 June 2007
247802

Measuring the Coordination Number and Entropy of a 3D Jammed Emulsion Packing by Confocal Microscopy
Jasna Brujić, Chaoming Song, Ping Wang, Christopher Briscoe, Guillaume Marty, and Hernán A. Makse
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248001

Ultrafast Changes of Molecular Crystal Structure Induced by Dipole Solvation
M. Braun, C. v. Korff Schmising, M. Kiel, N. Zhavoronkov, J. Dreyer, M. Bargheer, T. Elsaesser, C. Root, T. E. Schrader, P. Gilch, W. Zinth, and M. Woerner
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Dong-Hee Kim and Adilson E. Motter
Published 15 June 2007
248701

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Articles published 16 Jun - 22 Jun 2007
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Species Clustering in Competitive Lotka-Volterra Models
Simone Pigolotti, Cristóbal López, and Emilio Hernández-García
Published 18 June 2007
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Kinesin's Network of Chemomechanical Motor Cycles
Steffen Liepelt and Reinhard Lipowsky
Published 20 June 2007
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Molecular Origin of Model Membrane Bending Rigidity
Erol Kurtisovski, Nicolas Taulier, Raymond Ober, Marcel Waks, and Wladimir Urbach

Published 21 June 2007
258103

Finite-Size Scaling in Complex Networks
Hyunsuk Hong, Meesoon Ha, and Hyunggyu Park
Published 20 June 2007
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J. P. de Silva, M. Geoghegan, A. M. Higgins, G. Krausch, M.-O. David, and G. Reiter
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Force-Extension Relationship of Cell-Cell Contacts
Julien Brevier, Marcel Vallade, and Daniel Riveline
Published 28 June 2007
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Architecture of Columnar Nacre, and Implications for Its Formation Mechanism
Rebecca A. Metzler, Mike Abrecht, Ronke M. Olabisi, Daniel Ariosa, Christopher J. Johnson, Bradley H. Frazer, Susan N. Coppersmith, and P. U. P. A. Gilbert
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Titus S. van Erp
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Formation of sp^3 Hybridized Bonds and Stability of $CaCO_3$ at Very High Pressure
Sergiu Arapan, Jailton Souza de Almeida, and Rajeev Ahuja
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Gabriel Caballero, Raymond Bergmann, Devaraj van der Meer, Andrea Prosperetti, and Detlef Lohse
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Mechanical Properties of Axons
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Changhong Ke, Michael Humeniuk, Hanna S-Gracz, and Piotr E. Marszalek
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Sunil K. Sainis, Vincent Germain, and Eric R. Dufresne
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Experimental Evidence for Molecular Chaos in Granular Gases
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Capturing the Interaction Potential of Amyloidogenic Proteins
Nadeem Javid, Karsten Vogtt, Christina Krywka, Metin Tolan, and Roland Winter
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Three-Dimensional Imaging of Colloidal Glasses under Steady Shear
R. Besseling, Eric R. Weeks, A. B. Schofield, and W. C. K. Poon
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Dynamics of Domain Walls in Pattern Formation with Traveling-Wave Forcing
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Gravitational Stability of Suspensions of Attractive Colloidal Particles
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Published 11 July 2007
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Gas-Mediated Impact Dynamics in Fine-Grained Granular Materials
John R. Royer, Eric I. Corwin, Peter J. Eng, and Heinrich M. Jaeger
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Effective Medium Theory of Semiflexible Filamentous Networks
Moumita Das, F. C. MacKintosh, and Alex J. Levine
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Controlling Vibrational Excitation with Shaped Mid-IR Pulses
David B. Strasfeld, Sang-Hee Shim, and Martin T. Zanni
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Rate Determining Factors in Protein Model Structures
Pierpaolo Bruscolini, Alessandro Pelizzola, and Marco Zamparo
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Inter-DNA Attraction Mediated by Divalent Counterions
Xiangyun Qiu, Kurt Andresen, Lisa W. Kwok, Jessica S. Lamb, Hye Yoon Park, and Lois Pollack
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Reversible Photomechanical Switching of Individual Engineered Molecules at a Metallic Surface
Matthew J. Comstock, Niv Levy, Armen Kirakosian, Jongweon Cho, Frank Lauterwasser, Jessica H. Harvey, David A. Strubbe, Jean M. J. Fréchet, Dirk Trauner, Steven G. Louie, and Michael F. Crommie
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Switching and Nonswitching Phases of Photomechanical Molecules in Dissipative Environments
Chang-Qin Wu, Jian-Xin Li, and Dung-Hai Lee
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Localized and Delocalized Motion of Colloidal Particles on a Magnetic Bubble Lattice
Pietro Tierno, Tom H. Johansen, and Thomas M. Fischer
Published 20 July 2007
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Spectral Coarse Graining of Complex Networks
David Gfeller and Paolo De Los Rios
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V. Ranjan, L. Yu, Marco Buongiorno Nardelli, and J. Bernholc
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Granular Rayleigh-Taylor Instability: Experiments and Simulations
Jan Ludvig Vinningland, Øistein Johnsen, Eirik G. Flekkøy, Renaud Toussaint, and Knut Jørgen Måløy
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Statistical Mechanics of Semiflexible Bundles of Wormlike Polymer Chains
Claus Heussinger, Mark Bathe, and Erwin Frey
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Self-Motile Colloidal Particles: From Directed Propulsion to Random Walk
Jonathan R. Howse, Richard A. L. Jones, Anthony J. Ryan, Tim Gough, Reza Vafabakhsh, and Ramin Golestanian
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048102

Molecular Synchronization Waves in Arrays of Allosterically Regulated Enzymes
Vanessa Casagrande, Yuichi Togashi, and Alexander S. Mikhailov
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Stress Distributions in Diblock Copolymers
P. Maniadis, T. Lookman, E. M. Kober, and K. Ø. Rasmussen
Published 27 July 2007
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PRE HIGHLIGHTS

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RAPID COMMUNICATIONS

Quantification of spatial intensity correlations and photodetector intensity fluctuations of coherent light reflected from turbid particle suspensions
Vinayakrishnan Rajan, Babu Varghese, Ton G van Leeuwen, and Wiendelt Steenbergen
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Oscillations in intracellular signaling cascades
K.-H. Chiam and Gunaretnam Rajagopal
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061901

Growth of tactoidal droplets during the first-order isotropic to nematic phase transition of F-actin
Patrick W. Oakes, Jorge Viamontes, and Jay X. Tang
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Effects of coupling strength and space on the dynamics of coupled toggle switches in stochastic gene networks with multiple-delayed reactions
Andre S. Ribeiro
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061903

Reduction of higher-order photobleaching in two-photon excitation microscopy
Partha Pratim Mondal and Alberto Diaspro
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061904

Quantifying noise levels of intercellular signals
Kai Wang, Wouter-Jan Rappel, Rex Kerr, and Herbert Levine
Published 5 June 2007 (*5 pages*)
061905

Self-consistent analyses for potential conduction block in nerves by an ultrashort high-intensity electric pulse
R. P. Joshi, A. Mishra, Q. Hu, K. H. Schoenbach, and A. Pakhomov
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061906

RNA folding in the presence of counterions
Yevgeni Sh. Mamasakhlisov, Shura Hayryan, V. F. Morozov, and Chin-Kun Hu
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061907

Pattern formation, outbreaks, and synchronization in food chains with two and three species
Sabrina B. L. Araújo and M. A. M. de Aguiar
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Evolution equation of phenotype distribution: General formulation and application to error catastrophe
Katsuhiko Sato and Kunihiko Kaneko
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061909

Two-site realization of the Davydov model in a finite size lattice: A time-

convolutionless master equation approach
Vincent Pouthier
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Brain, music, and non-Poisson renewal processes
Simone Bianco, Massimiliano Ignaccolo, Mark S. Rider, Mary J. Ross, Phil Winsor, and Paolo Grigolini
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061911

Polymer translocation through a nanopore under a pulling force
Ilkka Huopaniemi, Kaifu Luo, Tapio Ala-Nissila, and See-Chen Ying
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061912

Multiscale mode dynamics of a tethered membrane
R. B. Pandey, Kelly L. Anderson, and B. L. Farmer
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061913

1/*f* fluctuations of DNA temperature at thermal denaturation
Marc Joyeux, Sahin Buyukdagli, and Michaël Sanrey
Published 28 June 2007 (*9 pages*)
061914

Long-range correlation and charge transfer efficiency in substitutional sequences of DNA molecules
Ai-Min Guo
Published 29 June 2007 (*8 pages*)
061915

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RAPID COMMUNICATIONS

Solution of an infection model near threshold
David A. Kessler and Nadav M. Shnerb
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Generalized theory of site-specific DNA-protein interactions
R. Murugan
Published 2 July 2007 (*9 pages*)
011901

Speed of reaction diffusion in embryogenesis
Karen M. Page, Nicholas A. M. Monk, and Philip K. Maini
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011902

Bending rigidity of mixed phospholipid bilayers and the equilibrium radius of corresponding vesicles
M. M. A. E. Claessens, B. F. van Oort, F. A. M. Leermakers, F. A. Hoekstra, and M. A. Cohen Stuart
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Intermittent dynamics underlying the intrinsic fluctuations of the collective synchronization patterns in electrocortical activity
Pulin Gong, Andrey R. Nikolaev, and Cees van Leeuwen
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Spiking synchronization of ion channel clusters on an axon
Shangyou Zeng, Yi Tang, and Peter Jung
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Raman intensity and spectra predictions for cylindrical viruses
Eric C. Dykeman, Otto F. Sankey, and Kong-Thon Tsen
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Dynamics of the Davydov-Scott monomer in a thermal bath: Comparison of the full quantum and

semiclassical approaches
J. Cuevas, P. A. S. Silva, F. R. Romero, and L. Cruzeiro
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Complex population dynamics as a competition between multiple-time-scale phenomena
Ioana Bena, Michel Droz, Janusz Szwabiński, and Andrzej Pękalski
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Opening rates of DNA hairpins: Experiment and model
Jeungphill Hanne, Giovanni Zocchi, Nikolaos K. Voulgarakis, Alan R. Bishop, and Kim Ø. Rasmussen
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Frustration, drift, and antiphase coupling in a neural array
Oliver Weihberger and Sonya Bahar
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Analysis of structures causing instabilities
Thomas Wilhelm
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Coupled composition-deformation phase-field method for multicomponent lipid membranes
Chloe M. Funkhouser, Francisco J. Solis, and K. Thornton
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Structure optimization and folding mechanisms of off-lattice protein models using statistical temperature molecular dynamics simulation: Statistical temperature annealing
Jaegil Kim, John E. Straub, and Thomas Keyes
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Dynamic and static light scattering analysis of DNA ejection from the phage λ
David Löf, Karin Schillén, Bengt Jönsson, and Alex Evilevitch
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Theoretical study of kinetics of zipping phenomena in biomimetic polymers
Arthi Jayaraman, Erik E. Santiso, Carol K. Hall, and Jan Genzer
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Gap junctions mediate large-scale Turing structures in a mean-field cortex driven by subcortical noise
Moira L. Steyn-Ross, D. A. Steyn-Ross, M. T. Wilson, and J. W. Sleigh
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011916

Representing perturbed dynamics in biological network models
Gautier Stoll, Jacques Rougemont, and Felix Naef
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Stress fluctuations and motion of cytoskeletal-bound markers
Carina Raupach, Daniel Paranhos Zitterbart, Claudia T. Mierke, Claus Metzner, Frank A. Müller, and Ben Fabry
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Evolution of microorganism locomotion induced by starvation
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Effects of dielectric discontinuities on two charged plates
Y. S. Jho, G. Park, C. S. Chang, P. A. Pincus, and M. W. Kim
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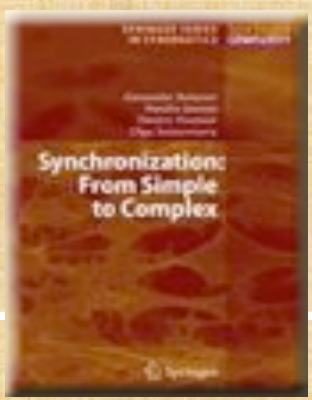
BRIEF REPORTS

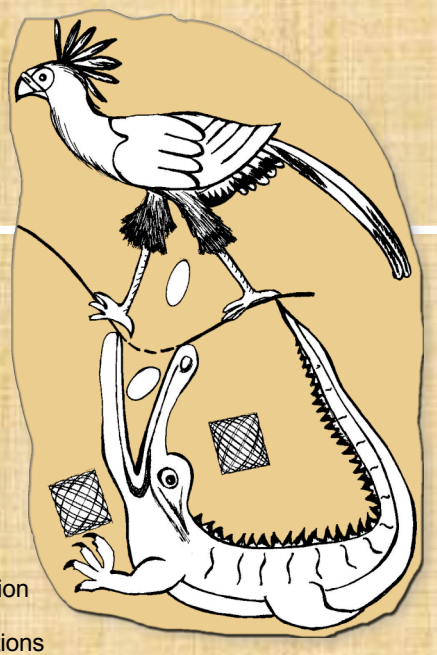
COMMENTS

New book by Springer coming



Synchronization: From Simple to Complex

for students and scientists



Authors about the Book

Alexander Balanov, Nottingham University, United Kingdom:

``Interaction of systems with irregular (chaotic and stochastic) dynamics is a problem that arises in a number of branches of modern science. It has been known for quite a while now, that in spite of their complexity, such oscillations can be synchronized. However, it is really amazing that the physical mechanisms of synchronization of unpredictable chaotic and even stochastic oscillations are identical to the ones inherent in the quite predictable periodic motion. The universality of synchronization is an important concept in understanding of the functioning of complex systems that contain coupled oscillators".

Natalia Janson, Loughborough University, United Kingdom:

``Synchronization plays the central role in modern science of oscillations and waves. However, classical results that form the basis of synchronization concept are not easily accessible, in particular for young scientists and students: they are distributed over a huge number of publications in different languages, and often described in a style which non-mathematicians consistently find difficult to follow. Also, synchronization is a real-life phenomenon that manifests itself in adjustment of measurable physical quantities like timescales and amplitudes. This books establishes the link between its mathematical and physical descriptions, while presenting the material at a level suitable for interested people with only basic mathematical background."

Dmitry Postnov, Saratov State University, Russia

``Turning over the pages of our scientific papers I realized that they are anyhow related to different aspects of synchronization in various systems. I like the idea of combining in one book the classical approach and up-to-date understanding of synchronization of complex systems".

Olga Sosnovtseva, Technical University of Denmark:

``I believe that the concept of synchronization can be applied to improve our understanding of complex systems of interacting biological oscillators. Although many cells in the body display intrinsic spontaneous rhythmic activity, physiological function derives from the interactions of these cells with each other and with external environment in order to generate rhythms that are essential for life. Synchronization refers to the way in which the networked elements communicate and exhibit collective behaviour. "

Book page: http://www-staff.lboro.ac.uk/~manbj/www_book_syn/index.html
Order from
http://www.springer.com/west/home/physics?SGWID=4-10100-22-173735810-0

Table of Contents

Book Features

- Key classical results are derived in every detail and explained from different angles; no steps of calculations are omitted, no “it is easy to show” or “it is obvious” remarks.
- Most synchronization mechanisms are illustrated with full-scale electronic or biological experiments.