18.S995–Mathematical Concepts in Biology and Biological Physics

Jörn Dunkel | Fall 2017
Office 2-381 | MW 11-12.30
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Office hours: after class or per request | 12 units

Outline The course aims to provide an overview of theoretical concepts that are essential for the description of biological and biophysical systems. General ideas and mathematical approaches will be illustrated by means of specific examples. Topics covered will include:

- random motions, Brownian motors, stochastic resonance
- statistical description of polymers and membranes
- PDE models of structure and pattern formation
- self-propulsion at low Reynolds number
- models of collective motion
- biological networks

The course is intended for graduate students with a solid understanding of statistical mechanics and an interest in applications of mathematics to biologically relevant questions. A web page with continuously evolving lecture notes, slides and other materials can be found at

`http://math.mit.edu/∼dunkel/teaching.html`

Grading scheme Course work will be graded based on

- problem set 1 to be handed in on October 16, 11am (25%)
- problem set 2 to be handed in on November 13, 11pm (25%)
- one presentation related to a research article (50%); see paper suggestions selections below but feel free to pick others that are not on the list

See `http://web.mit.edu/catalog/overv.chap5.html` for grade definitions

Cooperation policy for problem sets Cooperation on problems is encouraged, but all solutions must be written up independently and you must list your collaborators on the problem set. You should try each problem alone for at least 30 minutes.

If you have any questions please contact Jörn Dunkel (`dunkel@mit.edu`).

Paper suggestions (random order)

1. B. H. Good, I. M. Rouzine, D. J. Balick, O. Hallatschek, M. M. Desai
Distribution of fixed beneficial mutations and the rate of adaptation in asexual populations
PNAS 109: 4950-4955, 2012

2. L. Dai, K. S. Korolev, J. Gore
Slower recovery in space before collapse of connected populations
Nature 496, 355 - 358, 2013

3. R. Daniel, J. R. Rubens, R. Sarpeshkar, T. K. Lu
Synthetic analog computation in living cells
Nature 497: 619623, 2013

4. A. Gamba, M. Nicodemi, J. Soriano, A. Ott
Critical behavior and axis defining symmetry breaking in hydra embryonic development
PRL 108: 158103, 2012

5. A. Shapere, F. Wilczek
Self-propulsion at low Reynolds number
PRL 58: 2051-2054, 1987

6. A. Shapere, F. Wilczek
Geometry of self-propulsion at low Reynolds number
Journal of Fluid Mechanics, 198: 557-585, 1989

7. A. Tero et al.
Rules for Biologically Inspired Adaptive Network Design
Science 327: 439-442, 2010

8. D. J. Watts, S. H. Strogatz
Collective dynamics of 'small-world' network
Nature 393: 440-442, 1998

9. V. Kantsler, R. E. Goldstein
Fluctuations, Dynamics, and the Stretch-Coil Transition of Single Actin Filaments in Extensional Flows
PRL 108: 038103, 2012

10. I. Lestas, G.Vinnicombe, J. Paulsson
Fundamental limits on the suppression of molecular fluctuations
Nature 467: 163-164, 2010

11. J. Paulsson
Summing up the noise in gene networks
Nature 427: 415-418, 2004