18.S995–Mathematical Concepts in Biology and Biological Physics

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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 17, 5pm (25%)

- problem set 2 to be handed in on November 14, 5pm (25%)

- one presentation related to a research article (50%); see paper suggestions selections below but feel free to pick others that ar 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