Course outline for Biological Dynamics & Networks   AMS 537 / CHE 559 / PHY 559

This course will provide a solid foundation in key theoretical concepts for the study of dynamics in biological systems and networks at different scales ranging from the molecular level to metabolic and gene regulatory networks.

Course instructor: Tom MacCarthy   Guest lecturers: Ken Dill, Sergei Maslov, Jin Wang
Room: Laufer Center Seminar Room 101
Day/Time: Tuesday/Thursday 2:30-3:50pm

Reference Books

Ken Dill, *Molecular Driving Forces: Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience*
Bernhard Palsson, *Systems Biology: simulation of dynamic network states*
Eberhard Voit, *A first course in Systems Biology*
Uri Alon, *An introduction to Systems Biology*
M.E.J. Newman, *Networks: an introduction*

Topics	**Instructor**	**Dates**	
Introduction to networks and statistical thermodynamics 1. Brief introduction to networks in biology and beyond 2. Physical kinetics. 3. Diffusion/Smoluchowski. 4. Random flights.	MacCarthy Dill	1/27/2015	1/29/2015
Statistical thermodynamics II 1. Waiting times. 2. Brownian ratchets. 3. Chemical kinetics. 4. Transition states.	Dill	2/3/2015	2/5/2015
Biochemical networks 1. Rate laws and basic properties of reactions 2. Reversible linear and bilinear reactions 3. Connected reversible linear and bilinear reactions 4. Autocatalysis and dynamical stability Reference: Palsson, Chapters 2 and 4	MacCarthy	2/10/2015	2/12/2015
Enzyme kinetics 1. Background on enzyme catalysis 2. Michaelis-Menten kinetics 3. Hill kinetics for enzyme regulation 4. Cooperative phenomena Reference: Palsson, Chapter 5	MacCarthy	2/17/2015	2/19/2015
Network measurements 1. Networks as graphs 2. Non-biological networks: technological, social and information networks 3. Degree distribution 4. Centrality measures Reference: Newman, Chapters 6,7	MacCarthy	2/24/2015	2/26/2015
Large-scale structure of networks	Maslov	3/3/2015	3/5/2015

1. The small-world effect 2. Power laws and scale-free networks 3. Clustering coefficients Reference: Newman chapter 8			
Network evolution models 1. Properties of random graphs 2. Preferential attachment models Reference: Newman chapters 12,14	MacCarthy	3/10/2015	3/12/2015
Spring recess			
Metabolic networks I 1. Background on metabolism 2. Modeling large systems using stoichiometric networks 3. Case study: glycolysis Reference: Palsson, Chapters 7 and 10	MacCarthy	3/24/2015	3/26/2015
Metabolic networks II 4. Metabolomics 5. Metabolic network reconstruction 6. Flux analysis Reference: Voit, Chapters 3 and 8	MacCarthy	3/31/2015	4/2/2015
Gene regulatory networks I 1. Background on gene regulation and transcription networks 2. Network motifs 3. Biological oscillators and autoregulation. Reference: Alon, Chapters 2-4	MacCarthy	4/7/2015	4/9/2015
Signal transduction systems 1. Background on signal transduction 2. Two-component signaling systems. Bistability and hysteresis. Reference: Voit, Chapter 9	MacCarthy	4/14/2015	4/16/2015
Robustness 1. Overview of biological robustness 2. Robustness in signalling networks: bacterial chemotaxis 3. Robust patterning in development Reference: Alon, Chapters 7,8	MacCarthy	4/21/2015	4/23/2015
Algorithms for network analysis 1. Modularity in biology 2. Community detection Newman, Chapter 11	MacCarthy	4/28/2015	4/30/2015
Modeling noise 1. Definitions of intrinsic and extrinsic noise. 2. Case study: M. B. Elowitz, A. J. Levine, E. D. Siggia & P. S. Swain, 2002, Stochastic gene expression in a single cell, *Science*,297, 1183–1186. 3. Gillespie algorithm	Wang	5/5/2015	5/7/2015