

Course outline for Biological Dynamics & Networks CHE / 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, Jack Peterson

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	8/28/2012 8/30/2012
Statistical thermodynamics II 1. Waiting times. 2. Brownian ratchets. 3. Chemical kinetics. 4. Transition states.	Dill	9/4/2012 9/6/2012
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 Wang	9/11/2012 9/13/2012
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	9/18/2012 9/20/2012
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	9/25/2012 9/27/2012
Large-scale structure of networks	Maslov	10/2/2012 10/4/2012

<ul style="list-style-type: none"> 1. The small-world effect 2. Power laws and scale-free networks 3. Clustering coefficients <p>Reference: Newman chapter 8</p>		
<p>Network evolution models</p> <ul style="list-style-type: none"> 1. Properties of random graphs 2. Preferential attachment models <p>Reference: Newman chapters 12,14</p>	Peterson	10/9/2012 10/11/2012
<p>Metabolic networks I</p> <ul style="list-style-type: none"> 1. Background on metabolism 2. Modeling large systems using stoichiometric networks 3. Case study: glycolysis <p>Reference: Palsson, Chapters 7 and 10</p>	MacCarthy	10/16/2012 10/18/2012
<p>Metabolic networks II</p> <ul style="list-style-type: none"> 4. Metabolomics 5. Metabolic network reconstruction 6. Flux analysis <p>Reference: Voit, Chapters 3 and 8</p>	MacCarthy	10/23/2012 10/25/2012
<p>Gene regulatory networks I</p> <ul style="list-style-type: none"> 1. Background on gene regulation and transcription networks 2. Network motifs 3. Biological oscillators and autoregulation. <p>Reference: Alon, Chapters 2-4</p>	MacCarthy Wang	10/30/2012 11/1/2012
<p>Signal transduction systems</p> <ul style="list-style-type: none"> 1. Background on signal transduction 2. Two-component signaling systems. Bistability and hysteresis. <p>Reference: Voit, Chapter 9</p>	MacCarthy	11/6/2012 11/8/2012
<p>Robustness</p> <ul style="list-style-type: none"> 1. Overview of biological robustness 2. Robustness in signalling networks: bacterial chemotaxis 3. Robust patterning in development <p>Reference: Alon, Chapters 7,8</p>	MacCarthy	11/13/2012 11/15/2012 11/20/2012
<p>Thanksgiving break</p>		11/22/2012
<p>Algorithms for network analysis</p> <ul style="list-style-type: none"> 1. Modularity in biology 2. Community detection <p>Newman, Chapter 11</p>	MacCarthy	11/27/2012 11/29/2012
<p>Modeling noise</p> <ul style="list-style-type: none"> 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, <i>Science</i>,297, 1183–1186. 3. Gillespie algorithm 	Wang	12/4/2012 12/6/2012