Math 563:101

2013W Term 1, September - December

Course Outline

Instructor: <u>Eric Cytrynbaum</u>
Email: cytryn@math.ubc.ca

Phone: 604-822-3784
Office: MATX 1219
Office hours: By appointment

Contents

- <u>1 Course goals</u>
 - o 1.1 Basic physical and chemical principles
 - o 1.2 Application to cell-level modeling
 - o 1.3 Analytical and numerical methods
- 2 Workload
- 3 Assessment
- 4 Background

Course goals

This course will focus on mathematical and computational modeling in cell biology. Four broad goals for the course are for students

- 1. to become familiar with some of the basic physical and chemical principles that underly many cell-level models,
- 2. to learn how to build mathematical models of cell-level processes and study them both analytically and numerically,
- 3. to build critical-thinking skills by reviewing and evaluating recently published models and
- 4. to become proficient at presenting their own and others' research.

Basic physical and chemical principles

The following basic principles, which underly a large number of models in cell biology, will be discussed (or more likely a subset determined by student interest).

- Basic mechanics force and energy, force-balance equations
- Conservation laws, diffusion, diffusion-advection, multi-compartment conservation.
- Langevin/Brownian dynamics, Fokker-Planck equation, first-passage times.
- Biochemical reactions, rate theory, equilibrium and the Boltzmann Distribution, detailed balance.
- Polymerization dynamics, chemical potential, mechano-chemical force transduction, Brownian ratchet, molecular motors.
- Electrophysiology, ion transport, Nernst potential.
- Reaction-diffusion systems, traveling waves, Turing instability.
- Polymer mechanics, Euler-Lagrange equations, motor force-balance equations, multiple-motor mechanics.

Application to cell-level modeling

Application of these basic principles to (a subset of) the following problems will be discussed by studying published modeling papers:

- cell motility
- cell cycle
- cell division
- intra- and inter-cellular signaling
- intracellular transport
- cell polarization
- spatial organization of the cell
- action potentials, electrophysiological signaling, bursting

Students will be responsible for choosing (in consultation with the instructor) and presenting appropriate papers. Other topics may be added if students request appropriate ones.

Analytical and numerical methods

Analytical and numerical-simulation techniques will be emphasized throughout the course including dimensional analysis, time and space scale determination, steady state and stability calculation (ODE and PDE), bifurcation theory, asymptotics, finite difference schemes, Gillespie algorithm, Brownian dynamics. In most cases, the emphasis will be on the how these techniques arise in modeling work rather than an in-depth theoretical treatment.

Workload

- A small number of assignments (3-4).
- Reading a set of 2-3 papers (from a preset list or pre-approved) each week with a class discussion lead by one student (on a rotating basis).

• Research project with oral and written report - starting from one of the sets of papers on the course list, extend the work by addressing unanswered questions or recapitulate results using a different technique (e.g. theoretical instead of numerical, stochastic simulation instead of ODE/PDE, etc.)

Assessment

Assignments 30%; paper presentation(s) 20%; project presentation 25% and write-up 25%.

Background

Familiarity with differential equations (undergraduate ODE, PDE courses) is expected. Background in cell biology and biophysics will be useful but not required.