BINF 8204/6204
Mathematical Systems Biology
01-10-12
Weekly or bi-weekly homework assignments (paper work) 30% for Ph.D. students, 40% for MS students;

Two midterm exams, 50%:
   3/1 and 05/03

Paper presentation, Ph.D. students only, 10%;
A research paper will be assigned to each student from the current literature, and he/she will present and lead the discussion of the algorithms, methods and models involved at appropriate points in the class;

Classroom participation 10%.  

Students evaluation
1. An Introduction to Systems Biology: Design Principles of Biological Circuits.

   Uri Alon:
   CRC Press, 2007
   ISBN 1584886420

   Physics Today, p63-64, June, 2007

2. Additional materials from the current literature will be also presented.
What is life?

- Life usually possesses the following the features:

  1. Complexity: the components that form even a simplest type of life and the interactions among these components are much more complex than any non-life matter/object/device;

  2. Robustness: a life is very tolerant to environmental disturbances, it can function normally in a certain region of environmental changes;

  3. Reproductivity: a life can autonomously reproduce a similar copy of itself;

  4. Evolvability: a life can autonomously adapt itself to the long term changes in the environments through changing itself or evolution.

- So, can we fully understand life, including ourselves by scientific research?
What is life?

- From a reductionist’s point of view [e.g. Erwin Schrödinger (1887–1961)], all the phenomena of life are the manifestation of the interactions of molecules that constitute the organism.

- In order to understand life, we must understand not only the functions of each molecules in the organism, but also understand the emerging properties that are resulted from the interactions among these molecules.
What is systems biology?

Traditionally, molecular biologists study the functions of a single molecule in the cell in isolation from its interacting partners.
What is systems biology?

- This analytical approach has been extraordinarily successful in understanding the functions of individual genes, proteins, RNAs and other molecules.

- However, it seems less likely that this approach will yield an understanding of complex biological behaviors.

- This obvious limitation of traditional molecular biology is now overcome by the revival of an existing discipline --- systems biology.
What is systems biology?

- However, currently, there is no consensus definition for systems biology yet. Different authors come up with different definitions with different emphases.

- But, in general, systems biology is an old biological field with a recent resurrection, it studies the interactions among multiple entities of life in a quantitatively manner.

- The entities here can be physiological systems, organs, cells or molecules. However, in this class, we mainly consider genes, protein, RNAs and small metabolites in a cell. Thus, we will focus on molecular systems biology.

- “Yet systems biology is not as new as many of its practitioners like to claim. It is a mutated soup of artificial life, computational biology and computational chemistry, with a bit of mathematics, physics and computer science thrown in”---Eric Werner at Department of Physiology, University of Oxford
The driving forces for systems biology

What is rejuvenating systems biology a hot discipline are:

1. The new development of high throughput technologies and the enormous amount of various data generated by such technologies, which makes it possible to study the functions of multiple molecules at the same time;
   - Sequencing technologies:
     Sanger sequencing methods;
     Massively parallel or next-gen sequencing methods
   - Microarray technologies:
   - Proteomics and metabolomics technologies:

2. Increasing computational power in software and hardware;

3. The better understanding of the functions of individual cellular components that have been accumulated through decades of intensive individual research, demanding a synthetic and quatatitive view of interacting molecules in the cells.
The methodologies of systems biology

- Systems biology attempts to describe the molecular interactions in a quantitative, and dynamic manner, thus, mathematics is an indispensable tool for systems biology.

- Inference and analysis of the emerging properties of molecular systems require extensive computation, thus computer science is another indispensable tool for systems biology.

- A systems biology study usually involves abstraction, model building and simulations based on experimental data, thus, methods from physical sciences are often borrowed.

- A systems biology study also often takes an engineering approach for data acquisition, synthesis and interpretation.

- Therefore, systems biology is an interdisciplinary science for studying biological phenomena using a combination of methods from biology, mathematics, computer science, physics and engineering.
Objectives of the course

Having successfully completed this course, students will be able to:

1. Understand the design principles of the biological networks under different contexts.

2. Understand the complexity and robustness of biological systems;

3. Understand the hierarchal and modular structure of molecular interaction networks;

4. Understand the constrained evolutionary optimization process of biological circuits;

5. Design and implement efficient methods to model and analyze special biological systems quantitatively.