

Transformative Concepts in Systems Biology

BIOL GU4036

Fall 2023. Wednesdays 2:40-4:30

Systems biology approaches are rapidly transforming the technological and conceptual foundations of research across diverse areas of biomedicine. In this course we will discuss the fundamental developments in systems biology with a focus on two important dimensions: (1) the unique conceptual frameworks that have emerged to study systems-level phenomena and (2) how these approaches are revealing fundamentally new principles that govern the organization and behavior of cellular systems. Although there will be much discussion of technologies and computational approaches, the course will emphasize the conceptual contributions of the field and the big questions that lie ahead. Lectures and discussions of primary literature will enable students to scrutinize research in the field and to internalize systems biology thinking in their own research. To make this a concrete endeavor, the students will develop mini-NIH-style grant proposals that aims to study a fundamental problem/question using systems biology approaches. The students will then convene an in-class NIH-style review panel that will assess the strengths and weaknesses of these proposals. In addition, the students will have the opportunity to defend their proposals in a live presentation to the class. The course is open to graduate students in Biological Sciences. Advanced undergraduates in biological sciences, and other graduate students with background in biology from other disciplines, including physics, chemistry, E3B, computer science, and engineering may also attend after consulting with the instructor.

Instructor: Saeed Tavazoie, Ph.D. Professor (Biological Sciences & Systems Biology)

Grading rubric: Grades are determined on the basis of written work (45%), a formal class presentation (30%), and class participation (25%). Written work will consist of a 3-page systems biology related grant pre-proposal due on October 11th (15%), and a 5-page NIH style grant proposal due on November 1st (30%). The formal presentation will consist of students defending the rationale for, and potential impact of their proposed research.

Course policies: All students are expected to pledge to the [Columbia College Honor Code](#) and to adhere to the [Faculty Statement on Academic Integrity](#).

Accommodations for students with disability: In order to receive disability-related academic accommodations for this course, students must first be registered with their school Disability Services (DS) office. Detailed information is available online for both the [Columbia](#) and [Barnard](#) registration processes. Refer to the appropriate website for information regarding deadlines and disability documentation requirements.

Syllabus:

Sep 6. Introduction

Conceptual and technological foundations of systems biology I

Sep 13. Intro. continued & Grant proposal Preparation

Conceptual and technological foundations of systems biology II
Introduction to grant proposal preparation

Sep 20. Cellular behavior I

Phenomenological characterization of cell state dynamics; cellular adaptation
Statistical inference of mechanistically constrained models

Sep 27. **Grant proposal workshop**

Oct 4. **Cellular behavior II**

Regulatory networks; DNA/RNA motif discovery; predicting gene expression from sequence

Oct 11. **Neural networks and deep learning in systems biology**

Foundations of neural network learning

Application of neural networks to data-rich problems in systems biology

Journal club: Developmental robustness

Due: 3-page grant proposal

Oct 18. **Cellular behavior III**

Single-cell analysis of biological phenomena; single-cell RNA-seq technologies and analyses

Single-cell phenomena in microbes; single-cell analysis in multicellular systems

Oct 25. **Molecular networks**

Technologies for mapping bi-molecular interactions

In vitro and in vivo technologies; DNA sequencing-based readouts of molecular interactions

Journal club: In vivo mRNA display

Nov 1. **Genetic architecture**

Systems-level characterization of genetic architecture, fitness, and phenotypes

Functional genomics; CRISPR-based screens; genetic interaction networks; synthetic lethality

Due: 5-page grant proposal

Nov 8. **Towards predictive models of cellular behavior**

Whole-cell computational models

Inference and synthetic biology of minimal genomes

Nov 15. **Panel review of grant proposals**

Nov 22. **Holiday**

Nov 29. **Student presentations I**

Dec 6. **Student presentations II**