10.521: Design Principles in Mammalian Systems & Synthetic Biology

Fall 2024

Instructor:	Katie Galloway	**Time:**	TR 12:30 – 14:00
Email:	katiegal@mit.edu	**Place:**	66-156.

Course Description: This course focuses on the layers of design, from molecular parts to large transcriptional networks in mammalian biology. The course formally introduces concepts in the emerging fields of mammalian systems and synthetic biology, including engineering principles in the design of dynamic systems, molecular design of genetic parts, and integration into the genome. The goal is to expose students from quantitative backgrounds to problem-solving opportunities at the interface of molecular biology and engineering and to train them in methods of approaching, analyzing, and designing these biological systems.

Objectives: This course is primarily designed for graduate students and advanced undergraduates looking to dive into topics in mammalian synthetic and systems biology.

Prerequisites: An undergraduate-level understanding of molecular cell biology, kinetics, thermodynamics, and ordinary differential equations is assumed.

Course Page: Canvas

Office Hours: After class, or by appointment

Class Policy: Regular attendance is essential and expected.

Main References:

- Uri Alon, *An Introduction to Systems Biology - Second Edition*, CRC Press, 2019.
- Reading list and journal club papers

Lecture Outline:

Lecture 1: Intro Policies + Synthetic Biology: Tools, Parts, & Systems

Lecture 2: Introduction to Principles in Molecular Systems Biology
Lecture 3: Network Motifs + Negative feedback
Lecture 4: Feedforward motifs + Promoter Engineering
Lecture 5: Positive feedback and bistability

Lecture 6: Engineering Cell Fate: Stem Cells and Reprogramming
Lecture 7: Challenges in Transgenesis and Engineering Mammalian Cells
Lecture 8: Engineering Chromatin and Nuclear Architecture

Lecture 9: Systems-level Principles of Cell-fate Transitions-1
Lecture 10: Systems-level Principles of Cell-fate Transitions-2
Lecture 11: MAPK Pathways in Cell-fate Decision-Making

Grading Policy:

Journal club presentations	20%
Integrator presentations	10%
Written topic summary	20%
Modeling project	30%
Science + Society project	20%

Important Dates:

Lecture	Tuesdays
Journal club presentations	Thursdays
Topic summary	October 11, 2024
Modeling equations	October 11, 2024
Modeling code + plot	October 18, 2024
Modeling project presentation	November 7, 2024
Modeling project report	November 22, 2024
Final project presentation	December 5, 2024
Final project written documents	December 6, 2024

Speed Journal Club: There will be 6 journal clubs. For each topic, relevant papers will be posted. You will sign-up for one to provide the class with a quick summary. Each paper should be summarized in a single slide and no more than 5 minutes. The number of times that you present will varying depending on class enrollment Over the course of the semester you. These speed journal clubs are designed to give you a quick intro to the topic and potentially can provide a basis for your topic summary paper.

Integrator: Following the journal speed journal club presentations, the presenters for that week will have 5-10 minutes to discuss the commonalities and interesting intersections between the papers. Grading will be based on participation and the highlights you extract from the discussion across the papers. Submitted Highlights. **Additionally**, please submit 4-6 highlights (bullet points ¡100 characters) from the discussion here. **Please note** You don't have to read every paper for your week, but it might help. Otherwise, you are relying on what others present at the speed JC to inform your discussion.

Topic Summary: To integrate the material into an understanding, you will complete a topic summaries which represents a summary of the content and synthesis of the ideas. These topics can follow on of the weekly topics or be on a topic of your choosing. Please verify approval of your topic 2 weeks before the deadline. A questionnaire will be provided to guide the narrative response. One useful way of thinking about a topic summary is to structure it as a question rather than just a summary of an ideas and papers. For more detail, see Guidelines for Topic Summaries.

Modeling Project: Each student will select a model , compose and explore that model. Each student will summarize how changes in parameters affected the desired properties of the system and what mitigating strategies could be employed to restore or enhance functionality. For details, see modeling guidelines. The report and presentation are worth 30% of your total grade.

Science + Society Project: Art powerfully engages society in science, inspiring young scientists and illuminating ideas. In this project the goal is to to develop ideas, stories, pictures that illuminate the power and potential of synthetic biology, systems biology, and/or stem cell biology and spark awe and wonder in the audience. For details, see 10.521 Science + Society Project. The report and presentation are worth 20% of your total grade.