BIOE 498TL/598TL Introduction to Synthetic Biology

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Lectures:
Time: Tuesdays and Thursdays, 4:00pm – 5:20pm **Location**: Room 1265 DCL

Office Hours:
Time: Thursdays, 5:30-6:30pm, or other times by appointment **Location**: Room 3121 DCL

Course description

Synthetic biology is an emerging field that spans the boundary of biology, engineering, and physical sciences with its goal of engineering biomolecular systems and cellular capabilities for a variety of applications. This course aims to offer an introduction to this rapidly evolving field and equip students with foundational skills and critical mindsets that are required for synthetic biology research. It will cover three foundational parts, including biological background of gene regulation, experimental methods for circuit construction, and mathematical basis of circuit modeling. This foundational knowledge will be subsequently applied and illustrated through the examination of representative functional circuits at different scales and in different organisms. Successful examples in biofuels, biomedicine, and other areas will be further discussed to show tremendous application potentials. This course will be appropriate for upper-level undergraduate and graduate students, and also helpful for students interested in participating International Genetically Engineered Machine (iGEM) jamboree.

Grading:

Homework	30%
Final exam	30%
Paper presentation	20%
Final report	20%

Course prerequisite

MCB 150 and MATH 285 or equivalent

Course outline

1. Overview of synthetic biology: history, current, and future
2. Biological background of gene regulation
2. Experimental foundation for gene circuit construction
3. Mathematical modeling and simulation
4. Engineered functional circuits: from modules and systems
5. Circuit design principles and tools
6. Applications of synthetic biology

Course schedule

Lecture	Topics

1	Overview and introduction: History, status, challenges, ethics, and future
2	Key biological numbers
3	Central dogma: transcription, reverse transcription, translation, post-translational modification
4	Transcriptional regulation: Biology & engineering systems
5	Post-transcriptional regulation: Biology & engineering systems
6	Experimental foundation: Genetic engineering and genome engineering
7	Experimental foundation: DNA assembly and synthesis
8	Experimental foundation: Directed and continuous evolution
9	Modeling foundation: Chemical kinetics (M-M equation and Hill function)
10	Modeling foundation: Deterministic models
11	Modeling foundation: Stochastic models
12	Modeling foundation: Spatiotemporal models
13	Noise in gene expression: Origin, propagation, consequences, and control
14	Robustness and evolvability of genetic networks
15	Bacterial circuits: Toggle switch and repressilator
	Instructor out of town
16	Bacterial circuits: Feedback, feed-forward, signal propagators, and band filter
17	Bacterial communication circuits: Population control and patterning systems
18	Bacterial communication circuits: Synchronized oscillators
19	Functional synthetic systems: From modules to systems
20	Gene circuit design and engineering: Biobricks/BioFAB and designing softwares
21	Synthetic circuits beyond bacteria: Phage, virus, and eukarypotic
22	In vitro/cell-free systems
23	Applications: Biomedicine and biomaterials
24	Applications: Biofuels and bioremediation
	Thanksgiving Break
	Thanksgiving Break
25	Student paper presentation
26	Student paper presentation
27	Challenges and outlook
28	Take-home final exam

Textbooks

1. Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, Chapman & Hall/CRC (2006).
2. Eric Davidson, The Regulatory Genome: Gene Regulatory Networks In Development And Evolution, Academic Press (2006).
3. Hamid Bolouri, Computational Modeling Of Gene Regulatory Networks - A Primer, Imperial College Press (1st edition) (2008).

Advanced references

1. Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts and Peter Walter, Molecular Biology of the Cell, Garland Science (4th edition) (2002).
2. Robert Brooks Phillips, Jane Kondev and Julie Theriot, Physical Biology of the Cell, Garland Science (1st edition) (2008).
3. Mark Ptashne and Alexander Gann, Genes and Signals, Cold Spring Harbor Laboratory Press (1st edition) (2001).
4. Selected papers.