Physics 176/276 Quantitative Molecular Biology

Winter 2021

Instructor: Terry Hwa (url: http://matisse.ucsd.edu/; email: hwa@ucsd.edu)

Format:

- Two weekly lectures Wed/Fri 9:30 – 10:50am; January 6 – March 12, 2021
- Location: synchronous on zoom [930-1588-0512]; requires login from ucsd domain
- lecture notes and recordings will be posted on course webpage (url: https://matisse.ucsd.edu/courses/w21-quantitative-molecular-biology/)
- Class size: no enrollment limit
- Targeted students: graduate and advanced undergraduate students from biophysics, biochemistry, bioengineering, bioinformatics & quantitative, systems biology
- core QBIO course; satisfies elective course requirements for PHYS, BENG, BISB, MBTG

Background: This is an annual course that presents molecular biology as *information processing systems* in the context of cellular physiology. The purpose of this course is two folds: One is to introduce to students of quantitative background a very important area of molecular biology which is ripe for quantitative studies. The other is to introduce to students of biology background the power and limitation of theory and modeling, demonstrating what it would take and what it may be like to make biology quantitative.

Scope and content: The focus of the course is on gene regulation in bacteria. Starting from the molecular components and the physics/chemistry of their interactions, I will build up a comprehensive and quantitative approach to bacterial gene regulation including transcriptional and post-transcriptional control of individual genes, as well as feedback and stochastic effects in genetic circuits. They will be integrated into the control of bacterial growth and metabolism. Whenever possible, I will use natural examples (mostly taken from *E. coli*) to illustrate the principles, and to convey the immense complexity of experimental biology often under-appreciated by people of quantitative background.

A rough outline of the topics to be discussed is as follows:

- Introduction and overview: central dogma, gene regulation, genetic circuits
- Molecular interaction: kinetics, equilibrium, cooperativity; protein-DNA interaction
- Transcriptional control by activators, repressors, and combination
- Post-transcriptional control: attenuation, termination, and degradation
- Simple genetic circuits with feedback: bistability and oscillation
- Stochastic gene expression
- Control of bacterial growth and metabolism

Preparation: The targeted audiences are the advanced undergraduate and beginning graduate students who are interested in taking on research in quantitative/systems biology. Both theoretical and experimental students from either the quantitative or life sciences are welcome. I will assume working knowledge of ordinary differential equation, thermodynamics and statistical mechanics (at the level of an upper division physics course such as PHY140A or physical chemistry), as well as a basic command of introductory molecular biology. However, knowledge of molecular biology is not essential for those with strong interest to learn.