

Quantitative Understanding in Biology II

Q3 2025

Course Syllabus

Tuesday, October 21st – Tuesday, December 9th, 2025

Tuesdays & Thursdays, 5:30 PM – 7:30 PM

Location: In-person/Zoom hybrid

Course Director: Derek M. Shore, Ph.D. (des2037@med.cornell.edu)

This course will be fully graded: (*Honors, High Pass, Low Pass, Fail*)

This course, a continuation of Quantitative Understanding in Biology I, further prepares students to apply quantitative techniques to the analysis of experimental data and the modeling of dynamic biological systems. This course is organized into three modules: in Module 1, we first provide our students with the necessary background in linear algebra and ordinary differential equations, with applications to natural and synthetic biological systems. In Module II we expand our focus to more advanced concepts including model linearization, dimensionality reduction, and analysis of experimental kinetic data with Markov Chain and Hidden Markov Models. Finally, in Module III we conclude the course with an exploration of these methods being applied in contemporary research.

Course Modules

Module I: Linear algebra review; introduction to dynamical systems; eigenvalues and eigenvectors analysis; modeling biochemical systems with ODEs

Module II: Introduction to chemical kinetics. non-linear systems; dynamic system stability; dimensionality reduction; law of mass action; Michaelis-Menten kinetic scheme; Markov Chains & Markov processes; Hidden Markov Models

Module III. Exploration of dynamic system modeling in current research (student presentations)

Course Grading:

- Homework & Quizzes: 50%
- Student Presentation: 20%
- Class Participation: 30%

Schedule of Classes (*Dates of specific lectures are subject to change*).

Module I. Linear algebra and Python bootcamp

Tuesday, October 21st: Vector arithmetic, systems of linear equations; Gaussian elimination; matrix properties; matrix inverse; introduction to Python, conda, Jupyter notebooks, and NumPy. **HW #1 assigned.**

Thursday, October 23rd: Matrix diagonalization and matrix decomposition; Python applications. **HW #1 due.**

Tuesday, October 28th: Periodic systems, complex eigenvalues/eigenvectors. **HW #2 assigned.**

Thursday, October 30th: Modeling dynamic systems with ordinary differential equations (ODEs); model simulation; model stability; Python applications. **Quiz #1.**

Tuesday, November 4th: **NO CLASS (Election Day)**

Thursday, November 6th: Linearizing 1D systems; phase portraits; linearizing multivariate systems; the Jacobian; Python applications. **HW #2 due.**

Module II. Introduction to chemical kinetics Discrete systems and application of Markov Chains

Tuesday, November 11th: Law of mass action; elementary first order reactions; pseudo-first order reactions; complex reactions; linear algebra in chemical kinetics.

Thursday, November 13th: Dimensionality reduction: principal component analysis (PCA) **HW #3 assigned.**

Tuesday, November 18th: Markov Chains & Markov processes

Thursday, November 20th: Hidden Markov models. **HW #3 due.**

Module III. Applications of qBio2 methods 'in the wild'

Tuesday, November 25th: **NO CLASS** (Thanksgiving Holidays)

Thursday, November 27th: **NO CLASS** (Thanksgiving Holidays)

Tuesday, December 2nd: Student presentations

Thursday, December 4th: Student presentations

Tuesday, December 9th: Student presentations