



Systems biology: Modeling the dynamics of life

Units: 4.0

Spring 2023

11:00am - 12:20pm Tuesdays & Thursdays

Discussion 1:00pm - 1:50pm Fridays

Location: RRI 421

Instructor: Prof. Adam MacLean

Office: RRI 403H

Office Hours: contact Prof to schedule

Contact Info: 213-740-7055, macleana@usc.edu

Instructor: Prof. Geoffrey Fudenberg

Office: RRI 413E

Office Hours: contact Prof to schedule

Contact Info: 213-740-0778, fudenber@usc.edu

Course Description

As our ability to study the full complexity of biological systems has increased, quantitative and computational tools have become increasingly essential for understanding these systems. From numerical simulations of molecular networks to ecosystem dynamics to processing huge datasets, quantitative biological tools have truly become a fundamental aspect of biological sciences. This course will provide a foundation for quantitative biology and cover an overview of key topics including: random walks, diffusion, deterministic and stochastic dynamics, equilibria and stability, bifurcation analysis, agent-based models, ecological models, population models, and single-cell dynamics. The course will provide students with the fundamental skills of developing and coding models of dynamic biological systems.

Learning Objectives

Students will become proficient in using quantitative modeling and numerical simulations methods for biology. The course will include hands-on exercises to teach students how to build their own models of dynamic biological systems and will culminate in a final project. Specifically, during the first half of the class, a portion of each class will be devoted to basic programming concepts which will provide the students with the necessary skills to complete an independent research project during the second half of the class.

Required Readings: No single text is required. Readings will be provided from:

Modeling Life, 2017. Garfinkel, Shevtsov & Guo. Springer, 1st Ed. Available for free download online. (GSG)

Random Walks in Biology, 2018, Berg. Princeton University Press, Rev. Ed. Available from USC libraries online.

In addition, journal articles will be assigned and provided on Blackboard.

Technological Proficiency and Hardware/Software Required

This course will use Julia and Python as a platform to provide examples for topics discussed during the lectures and for problem sets.

Description and Assessment of Assignments

Assignments will be in the form of problem sets which will require the students to create and run scripts related to the topics discussed during the week's lecture. Students will complete a final project for the class worth 25% of their grade. This project will expand upon one of the topics in the class. Each student will meet with one of the instructors to discuss potential project ideas in week 10 and will turn in a brief description of the project topic. The project will be graded based on the proposal, the code generated, a 2 page description of the research and results, and a 15 minute presentation to the class.

Grading Breakdown

Assignment	% of Grade
Problem sets	25
Midterm & Final	50
Project	20
Participation	5
TOTAL	100

Assignment Submission Policy

You should hand in your homework and projects by the due date specified by the instructors. Points will be subtracted for homework and projects submitted after the due date without prior approval.

Course Schedule: A Weekly Breakdown

Prof Fudenberg will teach weeks 1-8

Prof MacLean will teach weeks 9-15

[List of potential projects](#)

2023/01/10, Week 1

Topics: random walks, diffusion

Reading: Berg Ch.1-2

2023/01/17, Week 2

Topics: biased random walkers, drift

Reading: Berg Ch. 4

2023/01/24, Week 3

Topics: diffusion to capture, diffusion limited aggregation

Reading: Berg Ch. 3, Philips, Ch. 13

2023/01/31, Week 4

Topics: reaction-diffusion systems, pattern formation

Readings: Philips Ch. 20

2023/02/07, Week 5

Topics: molecular dynamics

Reading: Vollmayr-Lee (2020) "Introduction to molecular dynamics simulations", AJP.

(Project plan due by end of week)

2023/02/14, Week 6

Topics: Cell movements

Reading: Berg Ch7, Philips Ch 19

2023/02/21, Week 7

Topics: Review & midterm

2023/02/28, Week 8

Project week

2023/03/07, Week 9

Topics: Dynamical models of biological systems, biological rates of change

Reading: Kitano (2002), "Systems Biology: A Brief Overview" *Science*, 295 (will be on Blackboard)

2023/03/14 Spring break, no class

2023/03/21, Week 10

Topics: Ordinary differential equation (ODE) models in biology, developing models from building blocks, solving models and fixed points

Readings: GSG Ch. 1.1-1.4; 2.

2023/03/28, Week 11

Topics: Stable states and attractors, analysis of ODE models at steady state: linear stability analysis, multistability, bifurcations

Reading: GSG Ch. 1.5-7; 3.

2023/04/04 Week 12

Topics: Modeling biological noise, stochastic gene expression, stochastic differential equations, linear noise approximation

Reading: Elowitz et al. (2002) "Stochastic gene expression in a single cell" *Science*, 297 (will be on Blackboard)

2023/04/11, Week 13

Topics: Fitting models to data / Parameter estimation and model selection / maximum likelihood estimation / Bayes rule and Bayesian inference for systems biology / Model identifiability

Reading: Kirk et al. (2013) "Model selection in systems and synthetic biology" *Curr Opin Biotech*, 24(4) (will be on Blackboard)

2023/04/18, **Week 14**

Project week

2023/04/25, **Week 15**

Review & wrap-up

2023/05/09, Final exam: 11am-1pm

Please note that some reading assignments and homework due dates will be announced at a later time.

Statement for Observance of Religious Holidays:

The university's policy grants students excused absences from class to observe religious holidays (<http://orl.usc.edu/religiouslife/holydays/absences.html>). In this case, please contact your instructor in advance to agree on alternative course requirements.

Statement for Students with Disabilities:

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to your instructor as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity:

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. SCampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: <http://www.usc.edu/dept/publications/SCAMPUS/gov/>. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: <http://www.usc.edu/student-affairs/SJACS/>.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Student Health Counseling Services - (213) 740-7711 – 24/7 on call
engemannshc.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call

engemannshc.usc.edu/rsvp

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) | Title IX - (213) 740-5086

equity.usc.edu, titleix.usc.edu

Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

Bias Assessment Response and Support - (213) 740-2421

studentaffairs.usc.edu/bias-assessment-response-support

Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.

The Office of Disability Services and Programs - (213) 740-0776

dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710

studentaffairs.usc.edu/ssa

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101

diversity.usc.edu

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

dps.usc.edu, emergency.usc.edu

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call

Dps.usc.edu. Non-emergency assistance or information