

USC Dornsife
College of Letters,
Arts, and Sciences

The Physics of Life
GESM140 (GE Seminar in the Life Sciences)
Spring 2020: Tuesday/Thursday 9:30 am -10:50 am
Location: WPH B36

Instructor: James Boedicker

Office: SSC 223

Office Hours: TBD, likely Wednesday 3-4 pm SSC 223

Contact Info: boedicke@usc.edu, 213-740-1104

Course Description

Have you wondered how life works? How do cells decide what to do? How do organisms communicate with each other and coordinate behavior? How does DNA serve as a blueprint for living systems? This course focuses on applying principles of the physical sciences to quantify and probe biological systems. During the course we will analyze biological systems through the lens of physics and mathematics, with topics including how the genome stores information and evolves, pattern formation in cellular networks, statistical methods in biology, finding correlations in “omics” data, the energetics of living systems, and cellular decision making. As part of this exploration, during the lecture we will work together to write simple computer programs in Matlab to develop a deeper understanding of the rules that govern the behavior of living systems. No background is necessary with programming or physics, the course is mean for beginners (although students with previous experience are welcome).

Learning Objectives

1. Applying the concepts of mathematics and physics to develop a quantitative understanding of how living systems function.
2. To explore the relationship between theoretical predictions made using abstract mathematical models and experimental data. We will discuss how such comparisons enable us to formulate and test hypotheses regarding the fundamental laws of biology.
3. Introduce students to statistical methods needed to interpret and draw conclusions from biological data.
4. Develop the ability to understand scientific reports and clearly communicate scientific findings to others.

Prerequisite(s): none

Co-Requisite/Concurrent Enrollment: none

Recommended Preparation: MATH 125

Course Notes

Your grade will be determined according to the following key:

- 45% Homework
- 5% Lecture minute
- 20% Midterm project
- 20% Final project
- 10% Class participation

Homework

Homework is assigned periodically throughout the course. In general, homework will consist of 1) a few short problems on the concepts of biophysics and quantitative analysis and 2) using the codes developed in class to explore the behavior of biological systems. At the end of the term, homework assignments will not be assigned in order to allow students time to work on their final project.

Midterm Project

A short Midterm Project will allow students to learn more about a topic in biophysics and the analysis and biological systems. In class students will present a 5 minute talk on a research topic based on independent reading of the scientific literature.

Final Project

As part of the course, students will complete a final project on the analysis of simulation of a biological process. Near the midpoint of the semester, students will meet with the professor to begin planning for their final projects. The project will involve taking a more in depth look at a biological problem using the quantitative reasoning and programming skills learned throughout the term. Students will write a short report detailing their findings.

Lecture Minute

Starting around lecture 5, one student will be assigned to give the "Lecture Minute" at the beginning of class. On your day, prepare and present a single slide detailing a fascinating fact or topic in biophysics.

Lectures

Lectures will be held twice a week for 1.5 hours. During each lecture, the first half will involve the discussion of the principles of biophysics and the application of quantitative models and analytical methods to biological data. The second half of the lecture will

involve hands on experience with Matlab. As a class we will learn how to code in Matlab and develop code to apply quantitative approaches to biological problems.

Technological Proficiency and Hardware/Software Required

The course will rely heavily on Matlab for writing simulations, analyzing data, and making predictions using mathematical models. All students will need computers running Matlab for every lecture. Matlab is available as a free download for USC students from the ITS web site.

Required Readings and Supplementary Materials

Recent journal articles on biophysics and quantitative analysis of biological data will be assigned throughout the term (approximately 1-2 per week). Reading assignments can be found on blackboard.

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 me (or to TA) 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. Website and contact information for DSP:

http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX) ability@usc.edu.

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, (www.usc.edu/scampus or <http://scampus.usc.edu>) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.

Course Schedule

Estimation and scales		
1	1/14/2020	Numbers and estimation in biology
2	1/16/2020	Length and timescales
3	1/21/2020	Time scales of biological processes
4	1/23/2020	Chemotaxis and diffusion
Dynamics		
5	1/28/2020	Enzymes
6	1/30/2020	Blood clotting dynamics
7	2/4/2020	Cytoskeleton
8	2/6/2020	Oscillations
Energy		
9	2/11/2020	Photosynthesis
10	2/13/2020	Energetics of growth
The five senses		
11	2/18/2020	Touch, hearing, taste and smell
12	2/20/2020	Vision
Data		
13	2/25/2020	Data analysis
14	2/27/2020	Machine learning
Randomness		
	3/3/2020	No Class
15	3/5/2020	Probability and the spread of disease
16	3/10/2020	Cellular noise
Midterm		
17	3/12/2020	Midterm Presentations
Vacation		
	3/17/2020	Spring break
	3/19/2020	Spring break
Emergence		
18	3/24/2020	Group behavior
19	3/26/2020	Percolation and criticality
20	3/31/2020	Sand piles and fractals
21	4/2/2020	Group project
Patterning Life		
22	4/7/2020	Evolutionary patterns
23	4/9/2020	Embryo development
Networks and States		
24	4/14/2020	Cellular states
25	4/16/2020	Information storage in the genome
26	4/21/2020	Neural networks
	4/23/2020	No Class
Building Life		
27	4/28/2020	Synthetic biology
28	4/30/2020	Genome editing and cellular memory