USC Dornsife College of Letters, Arts, and Sciences

The Physics of Life
GESM140 (GE Seminar in the Life Sciences)
Spring 2022: Tuesday/Thursday 12:30 pm -2:00 pm
Location: WPH B36

Instructor: James Boedicker
Office: SSC 223
Office Hours: TBD, in SSC 223 or online
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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:

50% Homework
5% Lecture minute
20% Midterm project
20% Final project
5% 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

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. Every few class periods will be focused on writing Matlab programs to better understand the biological systems we discuss in class. 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 (https://software.usc.edu/). Matlab is also available at USC Computing Centers around campus and through a virtual desktop (Cloudapps.usc.edu)

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. Working together in groups to complete homework assignments is permissible, however working together should not often result in identical solutions given for the same problem.

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			HW Due Dates
1	1/11/2022	Numbers and estimation in biology	
2	1/13/2022	Length and timescales	
3	1/18/2022	Scales part 2 and Coding: Intro	
4	1/20/2022	Chemotaxis and diffusion	HW #1 (1/20)
5	1/25/2022	Coding: Random Walks	
Energy			
6	1/27/2022	Energy use in everyday life	
7	2/1/2022	Photosynthesis and growth	
8	2/3/2022	Coding: Caroboxysome partitioning	HW #2 (2/12)
Dynamics			
9	2/8/2022	Enzymes and Blood clotting	
10	2/10/2022	Coding: Blood clotting and Hill function	HW #3 (2/10)
11	2/15/2022	Cytoskeleton	
12	2/17/2022	Coding: Cytoskeleton	HW #4 (2/17)
Communicating science			
13	2/22/2022	Communicating science	
14	2/24/2022	Coding: Making plots	HW #5 (2/24)
Randomness			
15	3/1/2022	Probability and cellular noise	
16	3/3/2022	Coding: The flu	
17	3/8/2022	Midterm Presentations	
Data			
18	3/10/2022	Data analysis and machine learning	
	3/15/2022	SPRING BREAK	
	3/17/2022	SPRING BREAK	
19	3/22/2022	Machine Learning	
20	3/24/2022	Coding: Neural network	HW #6 (3/24)
Emergence			
21	3/29/2022	Percolation and critical behavior	
22	3/31/2022	Coding: Forest fire	
23	4/5/2022	Sand piles and fractals	
24	4/7/2022	Touch, hearing, taste, vision and smell	HW #7 (4/7)
Patterning Life			
25	4/12/2022	Evolutionary patterns and embryos	
26	4/14/2022	Evolutionary patterns and embryos Part 2	HW #8 (4/14)
27	4/19/2022	Coding: Synthetic pattern formation	
Building Life			
28	4/21/2022	Cellular states and Neural networks	
29	4/26/2022	Information storage in the genome	
30	4/28/2022	Synthetic biology and genome editing	