PRELIMINARY SYLLABUS

BME 210: Biomedical Computer Simulation Methods
Spring 2021

1. Basic Information

Course:	Biomedical Computer Simulation Methods, BME 210, 4 units
Lecture:	Section 29200: D'Argenio, (online), M&W: 2:00 to 3:20 PM
	Section 29201: Kay, (online), M&W: 2:00 to 3:20 PM
Discussion:	Section 29211: (online), Tu: 12:30 to 1:50 PM (TA: Jonathan Pham)
	Section 29212: (online), Th: 9:30 to 10:50 AM (TA: Sean Hu)
Faculty:	David Z. D'Argenio, Ph.D., Professor, BME
	Brittany P. Kay, Ph.D., Lecturer, BME
Office:	Denney Research Center (DRB), DZD: room 154; BPK: room 163
Email:	dargenio@usc.edu; bkay@usc.edu **(put "BME 210" in subject line)**
Office Hours:	DZD: M&W, 3:30 to 4:30 PM (online)
	BPK: M&W, 3:30 to 4:30 PM (online)
TAs:	Jonathan Pham (duytanph@usc.edu)
	Sean Hu (shihaoh@usc.edu)
TA Office Hours:	Jonathan Pham: Tu, 10:30 AM to 12:30 PM (online)
	Sean Hu: Th, 3:00 to 5:00 PM (online)
Graders:	Ahmed Mohamed (awmohame@usc.edu)
	Kerry Jiang (kjiang@usc.edu)
Final Exam:	Monday, May 10, 2:00 to 4:00 PM
Co-requisite:	MATH 245
Class web page:	https://blackboard.usc.edu/ (follow links to BME 210)

2. Motivation for BME 210

While the computer has been an essential scientific and engineering problem-solving tool since the 1960's, much of its early use involved data reduction problems. With the dramatic advances in the computational power of more recent machines, however, the computer has also become a tool for simulation, exploration and discovery of underlying principles describing the natural world. It is, therefore, critically important that as undergraduate biomedical engineering students, you are exposed to computing as a central and essential tool for scientific exploration and engineering problem solving in biology and medicine.

There is a small number of basic concepts and principles that are the foundation for a large portion of modern-day science and engineering (e.g., principles of mass, momentum, energy, heat and information transfer). Extensive treatment of many of these concepts traditionally does not take place until upper division courses, after an adequate background is achieved in mathematics, physics, chemistry and biology. Some of these important cross-disciplinary concepts, however, can be introduced earlier in the undergraduate curriculum using computational based simulations. This course will illustrate how these fundamental concepts can be applied, via appropriate computational methods, to explore some basic biomedical phenomena and to address problems of disease diagnosis and treatment.

3. Course Goals, Learning Objectives, and Relation to Student Outcomes & other BME Courses

3.1. Goals: The BME 210 curriculum is problem-based and is organized to answer the following six questions:

1. Cardiac output, the volume of blood pumped by the heart over a given time period, can vary widely in health and disease. How can we measure cardiac output?
2. Addiction to nicotine is a complex process that involves social, behavioral and biological factors. What is the molecular basis for nicotine addiction?
3. X-ray computed tomography scans (CT scans, CAT scans) are a valuable diagnostic tool. How are CT images produced?
4. There is considerable variability across patients in their response to treatment with medicines. Can we improve the effectiveness of a given therapy using knowledge about factors that contribute to interpatient differences in treatment response (precision medicine)?
5. Understanding how an infectious disease spreads in a population is essential to developing rational approaches for controlling the disease. Can we predict the time course of how the influenza virus spreads at the population level?
6. Age-related macular degeneration can be treated by intravitreal injections of ranibizumab, an antibody that binds and inhibits vascular endothelial growth factor (VEGF). What is the spatial and temporal distribution of ranibizumab in the vitreous and at the macula following injection?

To address these questions, you will need to engage in some independent investigation to understand and apply the multidisciplinary principles that are needed to formulate solutions to these problems. To help guide you in answering these questions, you will be introduced to a number of important computational techniques, including: numerical quadrature; spline approximation; solution of ordinary differential equations; solution of systems of linear equations; function minimization; simulation of random processes; solution of partial differential equations. In addition, we will review the underlying biology, chemistry, physics and mathematics needed to address the questions posed; much of which you will have been introduced to in other courses.

3.2 Learning Objectives and relationship to Student Outcomes: After successfully completing this course, you should be able to:

- **Outcome 1:** describe the principle of indicator dilution and its application to measuring cardiac output;
- **Outcome 2:** explain the basic idea for receptor-ligand interaction and models describing this process;
- **Outcome 3:** explain the processes governing the transport of xenobiotics (e.g., drugs, biologics, vaccines, stem cells, etc.) in the body and the compartment modeling framework used to characterize the time course of their transport;
- **Outcome 4:** describe the principle of x-ray computed tomography for medical imaging and how to formulate the image reconstruction problem;
- **Outcome 5:** explain the steps involved in the spread of disease in a population, and how to model the process using random events;
- **Outcome 6:** describe methods for numerical quadrature, design software that applies different methods to indicator dilution data for calculating cardiac output;
- **Outcome 7:** describe methods for numerically solving differential equations, and to implement these methods in software to solve receptor-ligand and drug kinetic models;

- **Outcome 8:** explain methods for solving systems of linear equations that arise in medical image reconstruction; use MATLAB to solve image reconstruction problems;
- **Outcome 9:** use MATLAB to simulate and analyze a stochastic simulation of the spread of disease;
- **Outcome 10:** describe methods for numerically solving partial differential equations, and to implement these methods in software to solve an intraocular drug delivery model;
- **Outcome 11:** prepare written reports that document solutions to homework projects and present simulation results and analyses;
- **Outcome 12:** supplement through independent study of reference readings the biological and computational concepts presented in class.

The relation of these 12 Course Outcomes to the seven Student Outcomes of the BME curriculum at USC (listed below on the last page of this syllabus) are indicated in the following table:

Relationship of Course to Student Outcomes

Student Outcomes → **↓ Course Outcomes**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Outcome 1	x						
Outcome 2	x						
Outcome 3	x						
Outcome 4	x						
Outcome 5	x						
Outcome 6	x						
Outcome 7	x						
Outcome 8	x						
Outcome 9	x						
Outcome 10	x						
Outcome 11			x				
Outcome 12							x
All course outcomes	x		x				x

3.3 Relation of BME 210 to the other BME courses that you have taken: At this point in your studies, most of you have taken both BME 101 (Introduction to Biomedical Engineering) and BME 202 (Control and Communication in the Nervous System). An overview of the material you covered in these courses is provided below (Section 11 of this syllabus), which summarizes the concepts, physiological processes, and methods introduced in these courses. The corresponding summary is also shown for BME 210. This high-level synopsis is provided to guide you in understanding the overall connections between these courses.

From BME 101, we will apply the conservation of mass principle to address several of the problems posed in BME 210, including to Question #1 (How can we measure cardiac output?) and Question #4 (How can we improve drug treatment using interpatient differences?). From BME 202, we will build on your introduction to ion channels and kinetic models in exploring receptor-ligand interactions in general, as a basis for addressing Question # 2 (What is the molecular basis for nicotine addiction?). We will also apply and extend the methods for solving differential equations you were introduced to in BME 202. In addressing the six questions of BME 210, we will make extensive use of the MATLAB environment that you were introduced to in both BME 101 and BME 202.

4. Schedule of Lectures

Date	Day	Topic	Homework
Jan 18	**M**	**MLK Holiday**	
Jan 20	W	Introduction	
Jan 25	M	MATLAB Overview/ Measuring Cardiac Output	HW1 Assigned
Jan 27	W	Measuring Cardiac Output	
Feb 1	M	Measuring Cardiac Output	
Feb 3	W	Measuring Cardiac Output	
Feb 8	M	Receptor Kinetics	HW1 Due Noon/HW2 Assigned
Feb 10	W	Receptor Kinetics	
Feb 15	**M**	**President's Day Holiday**	
Feb 17	W	Receptor Kinetics	
Feb 22	M	Receptor Kinetics	
Feb 24	W	Review for Exam 1	HW2 Due Noon
Mar 1	M	**Exam 1**	
Mar 3	W	Medical Imaging	HW3 Assigned
Mar 8	M	Medical Imaging	
Mar 10	W	Medical Imaging	
Mar 15	M	New Medicine Development	HW3 Due Noon/HW4 Assigned
Mar 17	W	New Medicine Development	
Mar 22	M	New Medicine Development	
Mar 24	W	Review for Exam 2	HW4 Due Noon, March 26 (Friday)
Mar 29	M	**Exam 2**	
Mar 31	W	Spread of Disease	HW5 Assigned
Apr 5	M	Spread of Disease	
Apr 7	**W**	**Wellness Day**	
Apr 12	M	Spread of Disease	
Apr 14	W	Spread of Disease	
Apr 19	M	Ocular Drug Delivery	HW5 Due Noon/HW6 Assigned
Apr 21	W	Ocular Drug Delivery	
Apr 26	M	Ocular Drug Delivery	
Apr 28	W	Review for Final Exam	HW6 Due Noon, April 29 (Thurs.)
May 10	**M**	**Final Exam (2:00 to 4:00 PM)**	

5. Discussion Sessions

The overall goals of the discussion sessions are to 1) guide you in learning the essential elements of MATLAB and its application, and 2) answer your questions about lecture material, homework assignments, and MATLAB. You are expected to have completed the reading assignments prior to that week's meeting.

The Discussion Session will comprise the following types of activities:

1. Answer Questions: At the beginning of each week's meeting, you will have the opportunity to ask questions related to the material covered in the previous lectures and discussion sessions, as well as on the current homework assignment.
2. Homework Assignment Overview: The homework assignments will be presented (see Lecture Schedule above for assignment and due dates).
3. Guided Tour: Interactive walk-through of MATLAB commands and code.
4. Exercise: Each student will complete a task/problem. Solutions will be presented.
5. Discussion Logs: For most discussion sessions, you will be asked to submit a log of all of the work you have done during that session (i.e., a log of all of your inputs to MATLAB and all of the outputs from MATLAB, as well as any m-files you have made).

Discussion Schedule and Readings

Week	Lecture Topic(s)	Discussion Topics	Reading**
1	Intro/MATLAB Basics/ Measuring Cardiac Output	MATLAB Installation/Desktop	(N/A)
		Using MATLAB	H&V: Ch 1.1.1-1.1.5
		MATLAB Fundamentals	H&V: Ch 2.1-2.8
2	Measuring Cardiac Output	Built-In Functions	H&V: Ch 4.1
		Data Import/Export	H&V: Ch 4.2
		Matrices & Arrays	H&V: Ch 6.1-6.3
		Basic 2D Graphics	H&V: Ch 9.1
3	Measuring Cardiac Output	Homework 1 Overview	HW1 Assignment
		Program Design	H&V: Ch 3.1
		Programming MATLAB Functions	H&V: Ch 3.2
4	Receptor Kinetics	Loops	H&V: Ch 8
		More on Function M-Files	H&V: Ch 7.1-7.5
5	Receptor Kinetics	Homework 2 Overview	HW2 Assignment
		Debugging MATLAB Code	H&V: Ch 7.6
		Implementation of Algorithms	(N/A)
6	Receptor Kinetics	`ODE45()` and Examples	(N/A)

7	**Exam 1**	**No Discussion**	
8	Medical Imaging	Detailed Review of Exam 1 Solutions	
9	New Medicine Develop.	Homework 3 Overview	HW3 Assignment
		Imaging Functions	(N/A)
10	New Medicine Develop.	Homework 4 Overview	HW4 Assignment
		Zeroes of a Function	(N/A)
		Function Minimization	(N/A)
11	**Exam 2**	**No Discussion**	
12	Spread of Disease	Detailed Review of Exam 2 Solutions	
13	Spread of Disease	Homework 5 Overview	HW5 Assignment
		Random Numbers	H&V: Ch 13.1-13.4
		Frequencies, Bar Charts, Histograms	H&V: Ch 10.2
		Logical Vectors	H&V: Ch 5
14	Ocular Drug Delivery	Homework 6 Overview	HW6 Assignment
		3D Plotting	H&V: Ch 9.2.1-9.2.5
15	Ocular Drug Delivery	Review	

**H&V refers to reference #3 under Source Materials below

6. Source Materials

1. BME 210 Study Book. Available from BME 210 Blackboard website as separate chapters.
2. BME 210 Lecture Slides. Available from BME 210 Blackboard website.
3. Essential MATLAB for Engineers and Scientists. Seventh Edition. Hahn and Valentine, Elsevier 2019.
4. MATLAB. Math Works. A Campus wide license is available (PC and Mac). Download the software via http://www.usc.edu/its/matlab/. (A valid USC login is required.)

7. Work Load, Grading, Academic Integrity

Your grade will be based on your performance on class tests and homework assignments as follows:

	Percent of final grade
Exam 1	20
Exam 2	20
Final Exam	25
Homework assignments (6)	25
Discussion logs (~10)	10
	100

The homework will consist of both written assignments and computer work. The computer work will involve solving problems using the MATLAB software system. While you may consult with classmates regarding the homework assignments, you are expected to write your own computer code (code may not be shared) and to write your own homework reports. Plagiarism of another's work (including computer program code) is a serious offense and all suspected cases will be handled according to University regulations (see Section 9 below).

Homework assignments are due as indicated on the homework assignment. For every day (or portion of a day) an assignment is late, 25% will be subtracted from its maximum point total.

Discussion logs will be submitted via Blackboard at the end of the associated discussion session, as a PDF, Word document, or plain text file. There will be no extensions or late submissions. Grading will be on a credit/no-credit basis. The top 10 scores will be recorded.

For each exam, students will be allowed to bring a calculator and two double-sided, 8.5" by 11" note pages. These note pages may either be typed, hand-written, or a combination of both.

8. Web Page

This course uses Blackboard and can be accessed via https://blackboard.usc.edu. Be sure to CHANGE/FORWARD YOUR EMAIL to the one you use most frequently as we will send out email messages during the semester using your email address that is associated with Blackboard.

9. 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.

10. Support Systems

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.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 and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by 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. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, 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
uscsa.usc.edu
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.

11. How BME 210 relates to the other BME classes you have taken

The following overview of BME 101, BME 202, and BME 210 summarizes the concepts, physiological processes, and methods covered in these courses. This high-level synopsis is provided to guide you in understanding the overall connections between these courses.

BME 101: Introduction to Biomedical Engineering (4 units)
Concepts/Principles
- Conservation of mass
- Conservation of charge
- Electrical circuit theory

Physiological/Cellular/Molecular Processes
- Cellular reactions: cellular respiration, production of biomass
- Membrane potentials
- Renal filtration (also dialysis)

Methods/Tools
- Excel (basic)
- MATLAB
- Arduino (basic circuit wiring, some measurements)

BME 202: Control and Communication in the Nervous System (4 units)
Concepts/Principles
- Ion channel transport

Electrical circuit theory
Cable theory
Kinetic models
Poisson process
Oscillatory circuits

Physiological/Cellular/Molecular Processes

Action potential propagation
Synaptic transmission
Sensory systems (visual, auditory, somatosensory)
Motor system

Methods/Tools

Ordinary differential equations
Image filtering
Population decoding
MATLAB, Excel

BME 210: Biomedical Computer Simulation Methods (4 units)

Concepts/Principles

Mass action kinetics
Conservation of mass
Mass transport
Electromagnetic absorption/emission for imaging

Physiological/Cellular/Molecular Processes

Receptor-ligand interactions
Circulatory system (measuring cardiac output)
Material exchange in tissues (tracer, pharmaco- and toxico-kinetics)
Spread of disease

Methods/Tools

Ordinary differential equations
Partial differential equations
Large scale linear algebraic systems
Stochastic simulations
MATLAB

STUDENT OUTCOMES of BIOMEDICAL ENGINEERING PROGRAM

Students completing the program have

1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factor
3) an ability to communicate effectively with a range of audiences
4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies