BioE 104: Biological Transport Phenomena
Department of Bioengineering, UC Berkeley
Spring 2021

"Essentially, all models are wrong, but some are useful." - *George Box*

Instructor: Prof. Aaron Streets
GSIs: Erfan Ghazimirsaeed and Qiutong Jin
Course designed by Terry Johnson

Texts:

- Course reader, lecture slides and COMSOL lab protocols (required, bcourses)
- Truskey, Yuan and Katz, *Transport Phenomena in Biological Systems*, 2nd edition (good reference, not required)
- Milo and Phillips, *Cell Biology by the Numbers* (supplemental text, online reference)
- Paul's Online Math Notes - Differential Equations (online reference)

Office hours (via Zoom):

- Monday 4-6PM (Streets)
- W 4-6PM (Jin)
- Th 5-7PM (Ghazimirsaeed)
- Flex hour by appointment (Ghazimirsaeed/ Jin)

Lab sections - Remote labs will be completed on your own the following labs will be synchronously supported by GSIs:

- W 1-4PM (Ghazimirsaeed)
- Th 1-4PM (Jin)
- Flex hour by appointment (Ghazimirsaeed/ Jin)

Important dates:

- Midterm exam: Friday 3/05, take home exam
- Final exam: Monday 4/19, take home exam
- Final Project (in PDF format) due: Wednesday 5/11 at 12PM

Course Details

Remote instruction:

- Lectures will be given live through Zoom synchronously, and recorded.
- Attendance will not be graded.
- Lecture recordings and lecture slides/notes will be provided on bCourses.
- Updates, deadlines and important details will be communicated with bCourses announcements.

Assignments and exams will be posted in bCourses and Gradescope and will be turned in through Gradescope.

<u>A note on synchronous instruction:</u> While attendance is not mandatory, I highly recommend attending lectures synchronously. In addition to being able to ask questions in real time, we will periodically be engaging in active learning exercises that will be beneficial to your learning. I invite you to turn your cameras on, if you feel that helps you to engage, but you will not be required to do so. If you do turn your cameras on, remember that you are in class and are being recorded. Please dress appropriately and make sure your background is suitable for class.

Course Description

The transport of mass, momentum, and energy are critical to the function of living systems and the design of medical devices. Biological transport phenomena are present at a wide range of length scales: molecular, cellular, organ (whole and by functional unit), and organism. This course develops and applies scaling laws and the methods of continuum mechanics to biological transport phenomena over a range of length and time scales. The course is intended for undergraduate students who have taken a course in differential equations and an introductory course in physics. Students should be familiar with basic biology; an understanding of physiology is useful, but not assumed. While this syllabus is meant to be an accurate description of the course and its content, it may be modified at the instructor's discretion.

Objectives
Students will understand the fundamentals of mass transfer and will be able to apply that knowledge to biological systems and to engineering design.

Grading Policy
25% Homework
25% Midterm exam
25% Final Exam
25% Final project

If you would like to contest a homework or exam grade, you should make a regrade request by email (to both Juan Hurtado and Jenna Wen) with the subject line "BioE 104 regrade homework X" that includes a note briefly describing the issue. **Regrades must be submitted no longer than one week after the grade has been posted.** This is to ensure that the grading is fresh in our minds, and we can judge your request fairly.

Your homework set should stand alone. If a homework is disorganized or ambiguous, and requires an extensive explanation to the grader, you will likely still lose points. The homework sets are not only evaluating your understanding of the material - they are also meant to evaluate your ability to communicate that understanding clearly and concisely. 1/2 credit will be deducted for late homework sets turned in *before* solutions are posted, no credit for homework sets that are turned in *after* solutions are posted.

When deliverables are missed due to unavoidable circumstances, alternate arrangements can be made at the instructor's discretion. **Don't be shy! Dealing with unavoidable circumstances is part of my job. The sooner you contact me regarding issues such as these, the better.** If something is preventing you from a satisfactory engagement with this course, let me know so I can take the appropriate steps to accommodate you.

Academic Integrity
You are a member of an academic community at one of the world's leading research universities. Universities like Berkeley create knowledge that has a lasting impact in the world of ideas and on the lives of others; such knowledge can come from an undergraduate paper as well as the lab of an internationally known professor. One of the most important values of an academic community is the balance between the free flow of ideas and the respect for the intellectual property of others. Researchers don't use one another's research without permission; scholars and students always use proper citations in papers; professors may not circulate or publish student papers without the writer's permission; and students may not circulate or post materials (handouts, exams, syllabi--any class materials) from their classes without the written permission of the instructor.

Any test, paper or report submitted by you and that bears your name is presumed to be your own original work that has not previously been submitted for credit in another course unless you obtain prior written approval to do so from your instructor. In all of your assignments, including your homework or drafts of papers, you may use words or ideas written by other individuals in publications, web sites, or other sources, but only with proper attribution. If you are not clear about the expectations for completing an assignment or taking a test or examination, be sure to seek clarification from your instructor or GSI beforehand. Finally, you should keep in mind that as a member of the campus community, you are expected to demonstrate integrity in all of your academic endeavors and will be evaluated on your own merits. Also, be aware of UC Berkeley's Code of Student Conduct. If you are unsure of how to properly cite sources, please ask!

Lastly, w**e do expect you to work with others in this class**. While outright copying is not allowed, collaboration on assignments is very much encouraged. Find a study group and make them a regular part of your week!

Final project
Each group of four students will be jointly responsible for the final product as a whole, and though you may split the work up amongst yourselves, all of you will be expected to comprehend and be able to explain any part of the final product.

If any member of the group is unable to do their share of the work due to unforeseen and extraordinary circumstances, it is that student's responsibility to inform the instructor *as soon as possible* so that alternate arrangements can be made. The instructor reserves the right to assign different grades to various members of the group if the workload is not distributed and carried out evenly.

The final project consists of a six page *maximum* (including Works Cited; not including Appendix I, II, and the project contract) paper. This paper should be in a 2-column format consistent the IEEE submissions (Times New Roman, font size 10 for main text, 14 for the title, 12 for subheadings). Please note that larger charts, diagrams, tables, etc. *should* break from the 2-column format and take the entire width of the page. All tables and figures should be numbered and have a descriptive legend. Citations should be in NLM format.

Course Content

The chapter indications below refer to Truskey, 2nd edition. The course notes are already arranged in this order.

- Diffusion of mass (Chapters 1, 6.8.1 – 6.8.2; skip Diffusion from a point source, 6.8.3, and 6.9)
    - Random Walk
    - Fick's Laws
    - Stokes-Einstein and Wilkie-Chang
    - Steady-state 1D diffusion in Cartesian, cylindrical, and spherical coordinates
    - Unsteady 1D diffusion in a semi-infinite medium
    - Unsteady 1D diffusion in a finite medium
    - Quasi-steady diffusion
- Diffusion and conservation of momentum (Chapters 2, 3, 4.4-4.6; skip 2.8, 3.5)
    - Newtonian and non-Newtonian shear in fluids
    - The Navier-Stokes equation
    - Dimensional analysis
    - Stokes' flow
    - Bernoulli's principle
- Diffusion and Convection (Chapters 3.5-3.6, 4.4-4.6, 7.1-7.3, 7.6, 7.8-7.9)
    - 1D diffusion and convection
    - Short contact time solution
    - Mass transfer coefficients
    - Co- and countercurrent mass transfer
- Diffusion and Reaction (Chapters 6.9, 10)
    - Diffusion- and reaction-limited adsorption
    - Reaction on and convection to a surface
    - Reaction and diffusion in a volume