Computational & Mathematical Modeling of Infectious Diseases

Syllabus, Spring 2025

Course: CSCI 4897 / 5897
Lectures: Tuesday & Thursday, 1:00pm - 2:15pm
Location: JSCBB B231
Lecturer: Prof. Daniel Larremore
Office Hours: Mon 10:00-11:00, Tues & Thurs 2:15pm-3:15pm, JSCBB A414
Email: daniel.larremore@colorado.edu
Webpage: https://canvas.colorado.edu/courses/127576

Description

Computational and Mathematical Modeling of Infectious Diseases explores the ways we model infectious diseases using math and computing, from the dynamic spread of infectious diseases between humans, to a pathogen's growth within the body. Our **learning goals** include:

1. Gain a mastery of the classic infectious disease models, mathematically, computationally, and intuitively.
2. Explore modern topics in the area of infectious disease modeling, including age-structured models, human mobility patterns, sophisticated models of vaccination, interventions like masks, testing, and treatment
3. Learn about a wide variety of human infectious diseases and their natural histories of infection
4. Dive deep into learning about a few particular infectious diseases of your choice
5. Engage meaningfully with the ethics of infectious disease modeling

Topics Covered

The following topics constitute a rough schedule for the course, though current events will *always* cause us to deviate toward timely understanding of our world.

- Modes of Transmission & Koch's Postulates
- SIR Models — the workhorse
- Ethics of Modeling
- Simulating from the SIR model
- SIS Model, Birth & Death, and Vaccination Models
- Population Structure and Contacts
- High Impact Applications
- Stochastic Models
- Superspreading & Overdispersion
- Estimating Parameters from Data
- Imperfect Diagnosis: Sensitivity & Specificity
- Within-host dynamics
- Frequentist & Bayesian Approaches to Modeling Uncertainty
- Symptoms, Testing, Quarantine, Isolation
- When Multiple Pathogens Interact

Prerequisites

- Data structures (CSCI 2270 or equivalents)
- Probability and statistics (CSCI 3022, APPM 3570, or equivalents)
- Calc I (APPM1350 or equivalents)

Additional Recommended Preparation:

- Calc 2
- Intermediate skill in Python.

This course has its roots in biology, math, and computer science, and while knowledge of all three is great, the whole point of the class is to develop strengths in the interdisciplinary space *between* these three fields. If you are enrolled in the course and feel that one area or another is a problem, let's talk about it.

Texts

- Lecture notes posted to Canvas. Additional readings may be assigned and will be provided.

Overview

- This will be a lecture and discussion style class. We will *almost always* meet in person, though there may be times when, due to travel, we will either meet on Zoom *or* I will provide pre-recorded lectures.
- Readings will be assigned before class.
- **Problem sets** will consist of math, to be hand-written *or* LaTeX'ed, as well as coding assignments. The code itself won't be graded, but instead we'll use outputs from the code. All problem sets must be submitted on Canvas in PDF format.
- A **Course Project** will allow you to engage with the course material over a longer period than problem sets.
- The **Adopt-a-Pathogen** program will also allow you to become an expert in three infectious diseases, including how they are modeled, throughout the semester.

Coursework & Grading

- **Grade breakdown**:
  - Adopt-a-pathogen: 25%
  - Course project: 25%
  - Problem sets: 25% — 3 late days available.[1]
  - Quizzes: 25% — Lowest 2 dropped.
- **Schedule**: There will be four problem sets, every 2-3 weeks, leaving approximately the last month to work on the course project. There will be a course project proposal due before spring break. The three Adopt-A-Pathogens will run from weeks 2-5, 6-9, and 10-14. Project

[1]The fine print: I don't need to or want to know why you're using one or more late days. Your privacy is your privacy. Anything turned in 1 minute to 24h late counts as one day. You can use all three days for a single assignment, one day each for three assignments, or no late days at all.

presentations will take place during the last week of class. The final project writeup will be due on the day of the scheduled "final".

- **Exams**: None. The quizzes are weekly, closed-book, and short, and are meant to incentivize your continued attendance, attention, and studying of the notes.
- **Submission**: Homework should be submitted via canvas.
- **Grad vs Undergrad Grading**: Graduate students are graded in a generally similar way to undergrads, except (i) there are higher expectations for the course project, detailed below; and, (ii) there are homework problems which are optional extra credit for undergraduates but required regular credit for graduates.
- **Collaboration Policy**: Don't Google, StackOverflow, ChatGPT, buy the teacher's edition of the books, or buy Chegg. Instead, work together. *Collaboration is encouraged* on the problem sets. However, you may not copy (in any way) from your collaborators and you must respect University academic policies at all times. To be clear: you may discuss the problems verbally, but you must write up your solutions separately. If you do discuss the problems with someone (and you are encouraged to!), **you must then list and describe the extent of your collaboration in your solutions** (a footnote is fine).
- Violations of the Collaboration policy will result in failing the course and a trip to the honor code.
- **Generative AI Opinion**: ChatGPT, Claude, and other LLMs are pretty wild. They could definitely get a borderline C- in this class by barfing out your AAPP writeups, your project, and your homework. They'll make mistakes or hallucinate here and there, and they can't do the quizzes or presentations. On the other hand, the whole point of taking college classes is that you get to learn from the world's experts, and put amazing things in your brain for the rest of your life. You'll get out what you put in, and it's nearly impossible to learn complex things without struggling and challenging yourself.
- **Generative AI Policy**: I will not police the use of these tools.
- If you're unsure about anything above, please ask ahead of time.

Adopt A Pathogen

- Three times this semester, you'll partner up with one other person, and will get to adopt a pathogen for 4 weeks.
  - Week 1: you'll learn about the pathogen, its morphology, taxonomic information, the disease it causes, how we diagnose it, its reservoir(s), its modes of transmission, and the natural history of disease.
  - Week 2: you'll learn about its history of discovery, history of burden, and the current global burden and distribution thereof.
  - Week 3: you'll learn about our countermeasures against it, including prevention, detection, and therapeutics, as well as how well the countermeasures work.
  - Week 4: you'll learn about how it is modeled, including reading an academic paper.
- In the process, you and your partner(s) will read at least one academic paper focused on modeling your pathogen, and will be strongly encouraged to write a note to the authors thanking them for their paper and asking a few questions. This is a nice thing to do, but it also is good practice writing questions and networking with colleagues!
- You can't pick a pathogen that another group has already adopted.
- Each week, a randomly chosen subset of teams will briefly present to the class a small aspect of your current pathogen. That way, we will all learn about each other's pathogens.

Presentations must be in slides and should include visuals for engagement.
- Pathogens will be adopted on Thursdays of weeks 1, 5, and 9.
- Disputes or colliding interests will be settled by `np.random.choice()`

Course Project

There are three components of the course project to be graded:

1. A project proposal.
2. A short presentation of the key ideas and results.
3. A 5-page (undergraduate) or 7-page (graduate) project report, due on the day of the "Final."

- The **goal** of the course project if for students to explore one of the topics from class more deeply, developing and following their own curiosity in a scholarly way.
- Any topic covered in class, from mathematics to biological applications, is in-bounds.
- Students are encouraged to work in groups of up to size 3.
- All groups should integrate 3 or more concepts from class into their project. Graduate students should integrate 4 or more.
- Graduate students must include *some* de novo simulations or calculations.

Project Proposal — Submitted via canvas as a typeset PDF *only*, project proposals should include (0) a title and proposer names, and three paragraphs covering (1) background on the topic, (2) research or scholarly questions, and (3) learning goals and anticipated findings. Finally, proposers should note in a bulleted list (4) the key ways that the proposed project connects with topics from class.

Project Presentation — A 10 minute presentation, delivered in class with slides, should summarize the background and goals of the project, alone with the important results found. Presenters should expect to field questions from an engaged audience! Presented in the final week of class.

Project Paper — A 5-page typeset paper (7 pages for graduate students), with additional pages for references as needed, submitted as a singled PDF via Canvas. The report should be formatted like a scientific paper (11pt font, 2-column, 1-inch margins), with Introduction, Methods, Results, Discussion, and Bibliography sections, with an optional Appendix or github reposition for code. The Bibliography should include appropriate references for your work (primary literature, course materials, websites, source data, methods, etc.).

Advice for how to write any of the sections, or typeset a report, is available at any time during office hours. Warning: Do not plagiarize any part of the report. Suspected plagiarism will receive a zero.

Schedule

Date	Topic	AAPP
08/21	Lecture 1 - Welcome	Build a list
08/26	Lecture 2 - SIR	Pick a Pathogen
08/28		1-1
09/02	Lecture 3 - SIR Simulation and Analysis	
09/04		1-2
09/09	Lecture 4 - Two SIR Variations	
09/11		1-3
09/16	Lecture 5 - Vaccination	
09/18		1-4
09/23	Lecture 6 - Population Structure	Pick a Pathogen
09/25		2-1
09/30	Lecture 7 - Applications of SIR models	
10/02		2-2
10/07	Lecture 8 - Toward Reality I - Stochasticity	
10/09	NO CLASS — READING DAY	
10/14	Lecture 9 - Toward Reality II - Superspreading	
10/16		2-3
10/21	Lecture 10 - Parameters from Data	
10/23		2-4
10/28	Lecture 11 - Sensitivity and Specificity	Pick a Pathogen
10/30		3-1
11/04	Lecture 12 - Symptoms Testing Quarantine Isolation	
11/06		3-2
11/11	Lecture 13 - Multiple Pathogens	
11/13		3-3
11/18	Lecture 14 - Within-host models	
11/20		3-4
11/25	NO CLASS — FALL BREAK	
11/27	NO CLASS — THANKSGIVING	
12/02	Project Presentations	
12/04	Project Presentations	

Suggestions

Suggestions for improvement are welcome at any time. Any concern about the course should be brought first to my attention. Further recourse is available through the office of the Department Chair or the Graduate Program Advisor, both accessible on the 7th floor of the Engineering Center Office Tower.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part of adhering to the Honor Code.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from Student Conduct & Conflict Resolution and will be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

If you have a temporary illness, injury or required medical isolation for which you require adjustment, just send me a note via email letting me know you'll be absent.

Accommodation for Religious Obligations

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments, or required attendance. Please communicate the need for a religious accommodation in a timely manner. In this class, just send me a note via email letting me know you'll be absent. See the campus policy regarding religious observances for full details.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information does not always align with how they identify. If you wish to have your preferred name (rather than your legal name) and/or your preferred pronouns appear on your instructors' class rosters and in Canvas, visit the Registrar's website for instructions on how to change your personal information in university systems.

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

Additional classroom behavior information

- Student Classroom and Course-Related Behavior Policy.
- Student Code of Conduct.
- Office of Institutional Equity and Compliance.
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Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email OIEC@colorado.edu. Information about university policies, reporting options, and OIEC support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors are required to inform OIEC when they are made aware of incidents related to these concerns regardless of when or where something occurred. This is to ensure the person impacted receives outreach from OIEC about resolution options and support resources. To learn more about reporting and support a variety of concerns, visit the Don't Ignore It page.