Department of Mathematics, UAB
Mathematics of Biological Systems I
MA 168-DV Fall 2024

Instructor: Dr Ian Knowles, Room 4024, University Hall.
Email: iknowles@uab.edu
Teaching Assistant: Michael Pogwizd, Room 4013, University Hall.
Email: mpogwizd@uab.edu
Class Meetings: MTuWTh: 1:25 – 2:15pm, HHB221.
Office Hours. After class in my office; you may also email to arrange for additional office or Zoom meetings.
Texts. *Modeling Life* by Alan Garfinkel, Jane Shevetsov, and Yina Guo, Springer International Publishing AG 2017. My lecture notes; download these from Canvas.
Prerequisite Course. MA106 or MA107, or equivalent.
Term Dates. First day of classes: Mon Aug 26, 2024. Labor Day: Mon Sep 02, 2024. Fall Break: Nov 25–Dec 01. Last day of classes: Friday December 06, 2024.

SageMath Software. Access to the SageMath software package is needed for this course. This package may be freely downloaded from the SageMath website `https://www.sagemath.org/` (this is a "live" URL), with available binaries for Mac and Linux, and installation via WSL for Windows, that may be obtained by clicking the download button Download 10.4 on this website. Aside from the machines located in our classroom HHB221, additional Mac computers with SageMath installed are available in the Math Learning Lab in HHB202. Free access to SageMath is also available online via the CoCalc website located at `https://cocalc.com` (also a "live" URL).

SageMath is a computer algebra system with features covering many aspects of mathematics, including calculus, statistics, numerical analysis, and algebra. Together with the web-browser-based Jupyter Notebook this software contains much of the functionality of the commercially available packages Mathematica, Maple, and Matlab and uses a similar command set to the popular programming language Python whose syntax you will naturally acquire as you use SageMath. Please note that you will develop the necessary programming skills during the course, and in particular no prior computer skills are assumed at the beginning of the course.

Syllabus. MA168 may be taken by biology students instead of the regular Calculus I course (MA 125) and is designed specifically to satisfy the mathematical needs at this level of life science students in general.

In this course we teach mathematical modeling as a tool for understanding how biological and physical systems evolve over time. We begin with models of dynamical processes occurring in ecology, biology, physiology, neurology, physics, chemistry, and other applications in which quantities change with time. In the lab session parts of each class, we will often run prepackaged computer programs for problem-solving, visualization, plotting and simulation. Basic programming concepts like program flow control and data structures will be introduced as needed, and no background in computer programming is required for this course.

As we proceed you will notice that the process of modeling involves rewriting real-world problems in mathematical terms so as to facilitate their solution. Inevitably, in pursuing these ends one must bump into the fundamentally powerful ideas, techniques and notations of Calculus, but for us this will not happen right away. Rather, we use the model problems themselves to uncover the need to use Calculus, and thereby obtain a deeper understanding of both.

The overall focus of the course is to use the math to help us understand the science.

Aims of the Course. Upon successful completion of the course a student can

- describe the dynamics in practical systems and the different types of behaviors of complex systems including steady-states and oscillations, and their causes including the effects of delay, and positive and negative feedback;
- explain how the variables in each term in the differential equations arise from practical observations and assumptions;
- translate a verbal description of interacting variables into a differential equation model of a dynamical system, using the concepts of state space and tangent space;
- simulate differential equation models using Euler's method by hand, and on a computer via PYTHON or SAGEMATH;
- understand the meaning of the terms point attractor, periodic attractor, and chaotic attractor for a dynamical system insofar as they relate to homeostasis and dynamical stability in biological systems;
- derive models of biological systems that exhibit switch-like behavior using the concept of positive feedback; use negative feedback to model the neuron as an excitable oscillatory dynamical system;
- use chaos and dynamical system trajectories formed from electrocardiograph (ECG) data to investigate heart arrhythmias.

Grading. At the beginning of the term you will each be assigned to a study group containing four or so of your fellow students. The intention here is that you will work with your study group on homework assignments and labs, both inside and outside of class, prior to submitting each individually on Canvas.

There will be approximately one computer lab and one homework assignment per week; collectively, the homework assignments and the labs will each constitute 20% of the course grade. The midterm and final exams will each count 30%. Each exam will consist of a group part, and an individual part, each counting 15%. For the group part you will work with your study group on a set of review problems that I will provide, and submit (**one** pdf file, on Canvas) the solutions as a group for grading during the week before each individual exam. The individual part will be an in-class written exam based upon the review problems for that exam.

Your final grade is determined from your course grade according to the table

Course Grade:	88-100	75-87	62-74	50-61	below 50
Final Grade:	A	B	C	D	F

Lab/Homework File Submission. For each Lab assignment you need to submit the completed *.ipynb file in Canvas on or before the due time.

For each homework assignment you are required to submit a **single** *.pdf file in Canvas on or before the due time. It is recommended (but certainly not mandatory) that you use a tablet to write directly onto the homework pdf that you downloaded from Canvas. Alternately, separate paper homework sheets can be scanned to a single pdf file using a mobile scanning app such as Adobe Scan, for example.

Class Schedule.

Week	**Monday**	**Wednesday**	**Thursday**
08/26 – 08/30	First Class/Lab 1		HW1
09/02 – 09/06	Lab 2/Lab1 due		HW2/HW1 due
09/09 – 09/13	Labor Day		HW3/HW2 due
09/16 – 09/20	Lab 3/Lab2 due		HW4/HW3 due
09/23 – 09/27	Lab 4/Lab3 due		HW4 due
09/30 – 10/04	Lab4 due	Midterm Review	
10/07 – 10/11		Midterm Review due	
10/14 – 10/18		Midterm Exam	HW5
10/21 – 10/25	Lab 5		HW6/HW5 due
10/28 – 11/01	Lab 6/Lab 5 due		HW7/HW6 due
11/04 – 11/07	Lab 7/Lab 6 due		HW8/HW7 due
11/11 – 11/15	Lab 8/Lab 7 due		HW8 due
11/18 – 11/22	Lab 8 due	Final Review	
11/25 – 11/29	Thanksgiving Break		
12/02 – 12/06		Final Review due	Last Class
12/09 – 12/13		Final 1:30-4 Room TBD	

Reference Material. The prescribed text, *Modeling Life* by Alan Garfinkel, Jane Shevetsov, and Yina Guo, Springer International Publishing (2017) is useful inter alia as a supplementary reference if you seek more than is in my lecture notes. There is no formal text for the Lab component of the course, which we will do as an in-class/homework activity. Regular class attendance, while not mandatory, is highly recommended for this reason.

For SageMath and Python, the online documentation is quite good for free software, but of course you should never hesitate to ask either me or Mrigank if your code is not behaving properly. We are always ready to sit down and have extended code discussions with you or your group, both in and outside of class.