Department of Mathematics, UAB
Mathematical Modeling
MA361/519-OW Summer 2025

Instructor: Dr Ian Knowles, Room 4024, University Hall.
Email: iknowles@uab.edu
Class Meeting Times: TuTh: 12:40 – 2:40pm, HHB 221.
Office Hours. See me after class; you may also email to arrange for additional office or Zoom meetings.
Textbook. None: we use my lecture notes; download these from Canvas.
Prerequisite Course. Calculus I (MA125), or permission of instructor.
Term Dates. First day of classes: Monday June 02, 2025. UAB Holiday: Thursday June 19, 2025. Last day of classes: Friday August 08, 2025.

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 10.6 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/programming language 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, while you will develop the necessary programming skills during the course, no prior computer skills are assumed at the beginning of the course.

Grading. There will be approximately one written Homework assignment and one computer Lab assignment per week; these collectively will constitute 100% of the course grade. There are no other written examinations in this course. Your final grade is determined from your course grade according to the following 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 Homework assignment you should submit a **single *.pdf file** in Canvas on or before the due time. The easiest way to produce the requisite pdf file is to write directly on the downloaded homework pdf file (obtained from the Canvas directory `Files/Assignments`) using a tablet computer (such as an iPad). Alternately, hand-written paper homework sheets can be scanned to a single pdf file using a mobile scanning app such as Adobe Scan. Please make sure that your scanned sheets are readable (in particular, not too dark) and that you have included the whole viewing area in your scan.

For each Lab you should download the appropriate *.ipynb lab file from the `Files/Computer Labs` directory, work on it inside SageMath, and then submit the completed *.ipynb file in Canvas on or before the due time.

Class Schedule.

Week	**Tuesday**	**Thursday**
06/02 – 06/06	First Class	
06/09 – 06/13	Lab 1	HW 1
06/16 – 06/20		UAB Holiday
06/23 – 06/27	Lab 2/Lab 1 due	HW 2/HW 1 due
06/30 – 07/04	Lab 3/Lab 2 due	HW 3/HW 2 due
07/07 – 07/11	Lab 4/Lab 3 due	HW 4/HW 3 due
07/14 – 07/18	Lab 5/Lab 4 due	HW 5/HW 4 due
07/21 – 07/25	Lab 6/Lab 5 due	HW 6/HW 5 due
07/28 – 08/01	Lab 7/Lab 6 due	HW 7/HW 6 due
08/04 – 08/08	Lab 7 due	Last Class/HW 7 due
08/11 – 08/15	UAB Summer Final Exam Week	

Syllabus. In this course we approach mathematical modeling as a tool for understanding how biological and physical systems evolve over time. We consider the biology and physics of a variety of problems that arise in nature, science and medicine, and first review then build upon the calculus ideas already developed in the prerequisite course, adding additional mathematical tools as needed to facilitate the solution of these problems.

The new mathematics includes an introduction to the dynamics of linear and nonlinear systems of differential equations, mathematical chaos in biological systems, introductory linear algebra (matrices, eigenvalues, eigenvectors) and its use in determining the stability of equilibrium states, thereby providing a mathematical underpinning for homeostasis, and introductory multivariable calculus (Taylor series, partial differentiation, Jacobians and linear approximation). Biological topics include single species and interacting population dynamics, regulation of cell function, and biological oscillators. There will also be discussions of current topics of interest such as loss of chaos and its connection to cardiac arrhythmias, and how dynamically stable limit cycles relate to neuron action potentials.

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 those involving steady-states, oscillations, and mathematical chaos, and their relationship to homeostasis, the central organizing principle of physiology, and understand the causes of these behaviors, 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 SageMath;
- relate mathematical chaos and cardiac arrhythmias;
- use eigenvalues and eigenvectors to investigate the long term behavior of linear models in black bear populations;
- use Jacobians to analyze the stability of equilibrium states in nonlinear models such as the model for the neuron action potential and the related model for the pacemaker neuron.

Reference Material. As mentioned above, there is no prescribed textbook for this course. The book *Modeling Life* by Alan Garfinkel, Jane Shevetsov, and Yina Guo, Springer International Publishing (2017) is useful as a supplementary reference if you seek more than is in my notes. Likewise, there is no text for the Lab component of the course, which we will do as an in-class/homework activity. Regular class attendance is highly recommended for this reason. For SageMath and Python, the online documentation is quite good and of course you should never hesitate to ask me if your code is not behaving properly.