# Advanced Mathematical Methods for the Biological Sciences
## MATH 563/BIOINF 563, Winter 2019

This course will focus on mathematical modeling of how biological objects, such as molecules, cells or whole organisms, move and interact in time and in space. Depending on the biological process, time scales for interaction can vary widely, from milliseconds to days, and spatial scales can vary from microns to miles, however we can use similar mathematical techniques to capture behavior of these diverse systems. These techniques stem from the theory of random walks and involve partial differential equations (PDEs). The course will cover analytical and numerical techniques for solving random walk systems and associated PDE equations in the context of modeling diverse biological processes. Agent-based modeling will also be introduced to model highly complex and variable interactions among biological objects.

**Meeting times**: T, Th 2:30-4pm 4153 USB

**Instructor**: Victoria Booth
Math Dept Office: East Hall Rm 3858, 763-4730
Email: vbooth@umich.edu

**Office Hours**: T 4-5pm, W 5:30-6:30pm, Th 11am-12pm and by appointment

**CANVAS Website**: MATH 563 001 WN 2019

**Textbook**: No required textbook. Readings will be posted on course webpage. Readings and homework problems will be selected from a number of different texts including:

1. Biology in Time and Space by James Keener (pre-print 2018)
2. Mathematical Models in Biology by Leah Edelstein-Keshet (SIAM 2005). Available electronically through UM library
3. Random walk models in biology by EA Codling, MJ Plank and S Benhamou. J. R. Soc. Interface 5:813-834, 2008

**Homework**: Weekly/bi-weekly homework assignments will include analytical and numerical-based problems. Late homework will be grudgingly accepted. Additionally, short, class work assignments will be given for some lectures. Electronic submissions should be in pdf format and uploaded to the course CANVAS site.

**Course project**: A modeling project will occupy a substantial portion of your time and effort in the course. Students should work in teams of two or three. For the project, you will give a 20-minute in-class presentation and submit a research paper. Be prepared to submit project topics in mid-February and project outlines in March. Presentations will be given in class on April 16, 18 & 23. The research paper is due May 1.

Start early thinking about and doing internet searches on a biological system, process or pathology that you are interested in learning about and modeling. For the project, you can provide extensions or new applications for an existing mathematical model or develop a novel model related to your topic. It will not be sufficient to study an existing model and recreate already reported results; there must be a novel component to your project. The project can be related to research you are currently participating in as long as it implements analysis of spatial and temporal interactions. More details will be given later.

**Grading**: Homework 50%, modeling project 40%, class work and participation 10%

**Numerics**: Numerical implementation and analysis of models using multiple techniques will be an integral part of the course. You may use a programming language or numerical package of your choice. I can offer support and demonstration code for Matlab.

**Approximate dates and approximate topics covered (will be subject to change):**
Jan 10: Introduction, review of multivariate calculus
Jan 15, 17: Conservation Law, Derivations of diffusion equations
Jan 22, 24: Numerical realizations of diffusion processes: random walk and agent-based models
Jan 29, 31: Analytical and numerical solutions of the diffusion equation
Feb 5, 7: Diverse random walk models
Feb 12, 14: Reaction-Diffusion models
Feb 19, 21: Agent-based models for systems biology
Feb 26, 28: Agent-based modeling continued
Mar 5, 7: Spring Break
Mar 12, 14: Bistable models, traveling wave solutions
Mar 19, 21: Bistable models, traveling wave solutions continued
Mar 26, 28: Advection and Reaction models
Apr 2, 4: Chemotaxis
Apr 9, 11: Spatial patterns, Turing mechanism
Apr 16, 18, 23: Presentations of projects