BIOINF 540 - MATH 540: Mathematics of Biological Networks

Fall 2019 (3 credit hrs.): **Open to upper-level undergraduates and graduate students**
Instructor: Prof. Indika Rajapakse (E-mail: indikar@umich.edu, Phone: 734-615-3134; Office: 2017A Palmer Commons Building, and 3367 NCRC building 520)
Class Time: Tues. & Thurs., 8:30 – 10:00 AM Location: **3096 East Hall**

Description: Data-guided modeling, analysis, and visualization of networks is critical for understanding biological processes. With appropriate methods, we can explore answers to many questions including:

- How do cells respond to internal and external stimuli, and how can we **reprogram them**?
- How do cellular proteins interact with one another?
- How do cellular metabolic processes interconnect to produce energy and make new substances?
- How do **cell** and **tissue functions emerge** from dynamical forces within (**genome**) and between cells?

This course explores methods and principles for constructing and studying the structure and function of biological networks using examples from real datasets. We will begin with a discussion of some general properties of networks. I will introduce some basics in linear algebra, which provides a natural language for describing and analyzing networks.

Some topics that I anticipate covering in this course:

- Review of linear algebra and MATLAB
- Overview of genomics technologies and associated data
- Spectral graph theory: Eigenvalues and eigenvectors of matrices associated with graphs, applications
- Many examples of graphs and their Laplacians; Fiedler number and Fiedler vector
- Network inference, dynamics and Controllability of networks
- Dynamic Mode Decomposition (DMD), Tensor Factorizations
- Mathematics of emergence

I will never forget the excitement I felt when I learned that combinatorial properties of graphs could be revealed through examination of the eigenvalues and eigenvectors of their associated matrices. I hope to convey this excitement while making the methods in this line of study feel like common sense. **I encourage anyone interested in these topics to enroll and try the course for the first day**.

Prerequisites: Students who have studied basic calculus, linear algebra, and biology will surely enjoy this class, but it is not a requirement to know these topics well. Experience with computer programming will be a great help in understanding parts of the course, but is not required. **I will provide everything you need to know in addition to class notes. Though this course is listed at the graduate level, undergraduate students are also welcome (feel free to contact me to discuss the course before enrolling).**

Workload: There will be a computing assignment every two weeks (approximately), and associated with every lecture there will be a "Problem of the Day (POD)" which should be worked out. These will not be submitted for grading, but will serve as the basis for discussion, so you should take them seriously. The PODs are a valuable way to keep up with the course. There will be two take home exams.

Resources: A comprehensive website containing all reading materials and class notes will be maintained throughout the term.

Books on topics related to networks	Linear algebra
● Mesbahi M, Egerstedt M. Graph Theoretic Methods in Multiagent Networks (2010) ● Strogatz S. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology,…., Engineering (2014) ● Chung F. Spectral Graph Theory (1997)	● Gil Strang's MIT Linear Algebra course videos and text are excellent. ● Gilbert Strang and Cleve Moler: Differential Equations and Linear Algebra Video Series

These books are **not** required reading, but you may find them useful if you want a second opinion or more detail on a topic. I will make them available through the library.