Math 21 366 2025
Topics in Applied Mathematics: Mathematical Biology
Probable time and place: MWF 1-1:50; WEH 7218
Instructor: David Kinderlehrer, davidk@andrew.cmu.edu
Text: Gerda de Vries, et al., A Course in Mathematical Biology, SIAM, 2006, ISBN 978-0898716-12-2 (pbk), [3].
SIAM = Society for Industrial and Applied Mathematics, pbk = paperback
The text is available as a download via the CMU library website.

Brief outline

Welcome to a an enchanting, and collaborative, exploration of mathematics in the life sciences. The life sciences, and biology in particular, at all length and time scales, are a vast diverse field of study. Thus, the range of possible mathematical applications is both vast and diverse. In this course we propose encounters: we shall touch on becoming familiar with the ideas and methods that pertain to both historically important and potentially new adventures. It is an extremely exciting field of research.

Biological systems are comprised of many interacting units participating at many physical and time scales. Their precise details are generally unknown. Our task is to describe the parts and functions over which we wish to have predictive capability. In our modeling we begin with what we think to be appropriate mathematics. For this we need to establish both the scope and the limitations of the mathematical description. Unlike most pure mathematics courses, this subject is not hierarchical; our tie together here will be like a tour.

When discussing a particular topic, you might consult several of the reference books and you are encouraged to do research on your own. We shall discuss some classical successes that include these highlights

- basic genetics: what is the connection between the Mendelian genetics and evolution, that we learned in secondary school?
- cooperative and competing systems, an introduction to dynamical systems. At CMU we do not offer a separate course in this subject.
- the Hodgkin-Huxley equations: nerves
- the remarkable Turing instability, with recent surprises
- the fundamental Luria Delbrück Experiment.

Math biology books at a similar level are [2], [4], [9], [6], [10], and have overlapping material. The books [7], [1], [6],[5],[8] cover material at a more advanced level and are very interesting as well. You will understand parts of them. Note that many of the books are in paperback; they are generally available through the library as downloads. For starting out I have posted the 'main text' and Britton on Canvas. Springer publications are easy to download and Springer will sell a softcover hardcopy for a low price. SIAM books may be downloaded chapter by chapter. I was able to download all of the references cited below.

The resources module in Canvas will also contain articles I think of interest and sometimes topical. 'Mistakes' are interesting to ponder, amusing as well. When found, they are uploaded to the resources module.

Prerequisites

There are no specific prerequisites. A course in real analysis, eg. 21 355, is a good background as well as some knowledge of linear algebra and probability. We can move on from there.

Assessment

The grade will be based primarily on homework. Registered students are expected to come to class.

References

[1] Arianna Bianchi, Thomas Hillen, Mark A. Lewis, and Yingfei Yi, editors. *The dynamics of biological systems*, volume 4 of *Mathematics of Planet Earth*. Springer, Cham, 2019. Papers from the summer school held as part of the Séminaire de Mathématiques Supérieures at the University of Alberta, Edmonton, AB, 2016.

[2] Nicholas F. Britton. *Essential mathematical biology*. Springer Undergraduate Mathematics Series. Springer-Verlag London Ltd., London, 2003.

[3] Gerda de Vries, Thomas Hillen, Mark Lewis, Johannes Müller, and Birgitt Schönfisch. *A course in mathematical biology*, volume 12 of *Mathematical Modeling and Computation*. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 2006. Quantitative modeling with mathematical and computational methods.

[4] Leah Edelstein-Keshet. *Mathematical models in biology*, volume 46 of *Classics in Applied Mathematics*. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 2005. Reprint of the 1988 original.

[5] G. Bard Ermentrout and David H. Terman. *Mathematical foundations of neuroscience*, volume 35 of *Interdisciplinary Applied Mathematics*. Springer, New York, 2010.

[6] Richard Haberman. *Mathematical models*, volume 21 of *Classics in Applied Mathematics*. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 1998. Mechanical vibrations, population dynamics, and traffic flow, An introduction to applied mathematics, Reprint of the 1977 original.

[7] Frank Charles Hoppensteadt. *Mathematical methods of population biology*, volume 4. Cambridge University Press, 1982.

[8] Jürgen Jost. *Mathematical methods in biology and neurobiology*. Universitext. Springer, London, 2014.

[9] J. D. Murray. *Mathematical biology*, volume 19 of *Biomathematics*. Springer-Verlag, Berlin, second edition, 1993.

[10] Lee A. Segel and Leah Edelstein-Keshet. *A primer on mathematical models in biology*. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 2013.

1. Student Well Being

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress. All of us benefit from support during times of struggle. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for

support sooner rather than later is almost always helpful. If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night: CaPS: 412-268-2922 Re:solve Crisis Network: 888-796-8226 If the situation is life threatening, call the police On campus: CMU Police: 412-268-2323 Off campus: 911 If you have questions about this or your coursework, please let me know.

2. Diversity Statement

We must treat every individual with respect. We are diverse in many ways, and this diversity is fundamental to building and maintaining an equitable and inclusive campus community. Diversity can refer to multiple ways that we identify ourselves, including but not limited to race, color, national origin, language, sex, disability, age, sexual orientation, gender identity, religion, creed, ancestry, belief, veteran status, or genetic information. Each of these diverse identities, along with many others not mentioned here, shape the perspectives our students, faculty, and staff bring to our campus. We, at CMU, will work to promote diversity, equity and inclusion not only because diversity fuels excellence and innovation, but because we want to pursue justice. We acknowledge our imperfections while we also fully commit to the work, inside and outside of our classrooms, of building and sustaining a campus community that increasingly embraces these core values. Each of us is responsible for creating a safer, more inclusive environment. Unfortunately, incidents of bias or discrimination do occur, whether intentional or unintentional. They contribute to creating an unwelcoming environment for individuals and groups at the university. Therefore, the university encourages anyone who experiences or observes unfair or hostile treatment on the basis of identity to speak out for justice and support, within the moment of the incident or after the incident has passed. Anyone can share these experiences using the following resources:

- Center for Student Diversity and Inclusion: csdi@andrew.cmu.edu, (412) 268-2150
- Report-It online anonymous reporting platform: reportit.net username: tartans password: plaid All reports will be documented and deliberated to determine if there should be any following actions. Regardless of incident type, the university will use all shared experiences to transform our campus climate to be more equitable and just.