Math 21 366 2024
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, are a vast diverse field of study. Thus, the range of possible mathematical applications is both vast and diverse. We shall touch on becoming familiar with the ideas and methods that pertain to them. It is also a burgeoning, and 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.

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

- basic genetics: what is the connection between Mendelian genetics and evolution, that we learned in secondary school?
- mRNA: the basis of the covid vaccine
- 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. 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 hardcopy for 25. 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.

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.