AMATH 422/522
Problem set 1

Working together is absolutely encouraged. Please do not refer to previous years' solutions.

For each problem: together with any analysis or explanations, turn in both all code and all relevant plots, labeled and with all line styles, marker sizes etc. adjusted for readability.

Please note: E+G stands for our book, by Ellner and Guckenheimer.

I **Project warmup:** (This is Ellner and Guckenheimer Exercise 1.1:). **Turn this writeup in as a markdown cell within an ipython notebook! See the markdown cheatsheet linked from our python tutorial for guidance, and remember that equations can be formatted using dollar signs (LaTex).** Find a scientific research paper published that uses a dynamic model in a biology area of interest to you, read the paper, and turn in a short writeup with one-paragraph answers to the following questions.

- (a) Give the complete citation for the paper: authors, date, journal, pages.
- (b) What was the purpose of the model – that is, what was accomplished by building and using the model?
- (c) What are the parameters (fixed constants that the modeler chooses) of the model? What are the variables that change over time and/or change as a result of these parameters (sometimes called state variables)?
- (d) Identify one of the models simplifying assumptions – some known aspect of the real world that the model omits or simplifies.

Note: whatever paper you choose does NOT commit you to anything, project-wise. This is just to get us started in thinking about dynamical modeling in biology problems that we personally care about!

Some suggestions as example papers, but you are very encouraged to follow your own :

- Li and Anderson 2009, The Vitality model: a way to understand population survival and demographic heterogeneity, Theoretical Population Biology.
- Ma, Trusina, El-Samad, Lim, Tang. Defining Network Topologies that can achieve biochemical adaptation. Cell 2009 138(4) 760-73.
- Pedraza and Paulsson, Effects of molecular memory and bursting on fluctuations in gene expression, Science 319, 339-343.
- Wakamiya, Sarah, Roy, Charlotte 2009. Use of monitoring data and population vitality analysis to inform reintroduction decisions: perigrine falcons in the midwestern US. Biological conservation 142: 1767-1776.
- Prado, Kerr, 2008. Evolution of restraint in bacterial biofilm under nontransitive competition. Evolution 62-3, 538-548.
- J. C. Panetta. A Logistic Model of Periodic Chemotherapy. App. Math. Letters, Vol 8, 1995.
- Althaus, C. Estimating the Reproduction Number of Ebola Virus during the 2014 Outbreak in West Africa, PLOS Outbreaks, 2014.
- Prinz AA, Bucher D, Marder E. (2004) Similar network activity from disparate circuit parameters. Nat Neurosci. 7:1345-52.
- Moving forward: insights and application of moving-habitat models for climate change ecology, Harsh Not et al, J Ecology 2017.

- Ozeki, Finn, Schaefer, Miller, Ferster. Inhibitory Stabilization of the Cortical Network Underlies Visual Surround Suppression. Neuron, 2009.
- Tsodyks, Scaggs, Sejnowski, McNaughton B.L., Paradoxical effects of external modulation of inhibitory interneurons. J. Neurosci. 1997; 17: 4382-4388
- Digital logic circuits in yeast with CRISPR-dCas9 NOR gates, Gander et al Nature Comm 2017
- Bistability analysis of a caspase activation model for receptor induced apoptosis, Eissing et al, J Bio Chemistry 2004
- Cool-looking topic but probably dangerous for a project – may want to keep looking if interested in this topic: Evolutionary reinforcement learning of artificial neural networks. Nils T. Siebel, Gerald SommerPublished in Int. J. Hybrid Intell. Syst. 2007
- KD Harris, PS Dodds, CM Danforth. Dynamical influence processes on networks: General theory and applications to social contagion. Phys Rev E 88, 022816. 2013.
- A. Litwin-Kumar B. Doiron (2014). Formation and maintenance of neuronal assemblies through synaptic plasticity. Nature Communications 5(5319).
- A. Bertozzi et al. The challenges of modeling and forecasting the spread of COVID-19. PNAS, 117 (29) 16732-16738, 2020.
- S. He, Y. Peng, and K. Sun. SEIR modeling of the COVID-19 and its dynamics. Nonlinear Dynamics volume 101, 16671680 (2020).
- J. Hopfield. Neural networks and physical systems with emergent collective computational abilities. PNAS 79 (8) 2554-2558, 1982.
- D. Sussillo and O. Barak. Opening the black box: low-dimensional dynamics in high-dimensional recurrent neural networks. Neural Comput. Mar; 25(3):626-49 (2013).
- J. Kim, W. Leahy, E. Shlizerman. Neural Interactome: Interactive Simulation of a Neuronal System. Frontiers in Computational Neuroscience, 2019.
- M. Goldman. Memory without feedback in a neural network. Neuron 61 (4), 621-634, 2009.
- Your choice! The book, pubmed (or science citation index), or google scholar, and your fellow students will have more great options.

II **Turn this in as markdown and/or code cell(s) within the same ipython notebook!**. Write down at least two additional brief python or notebook tips / tricks, or GOTCHAs – beyond what is in the tutorial – to share with the class.