

Calculating Biological Quantities

CSCI 2897

Prof. Daniel Larremore
2021, Lecture 1

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Lecture 1 Plan

1. Course mechanics & setup

1. Website
2. Syllabus
3. Canvas

2. Schedule & Syllabus Review

3. Textbooks

4. A tour of mathematical models and linear algebra

5. About me

Course Mechanics

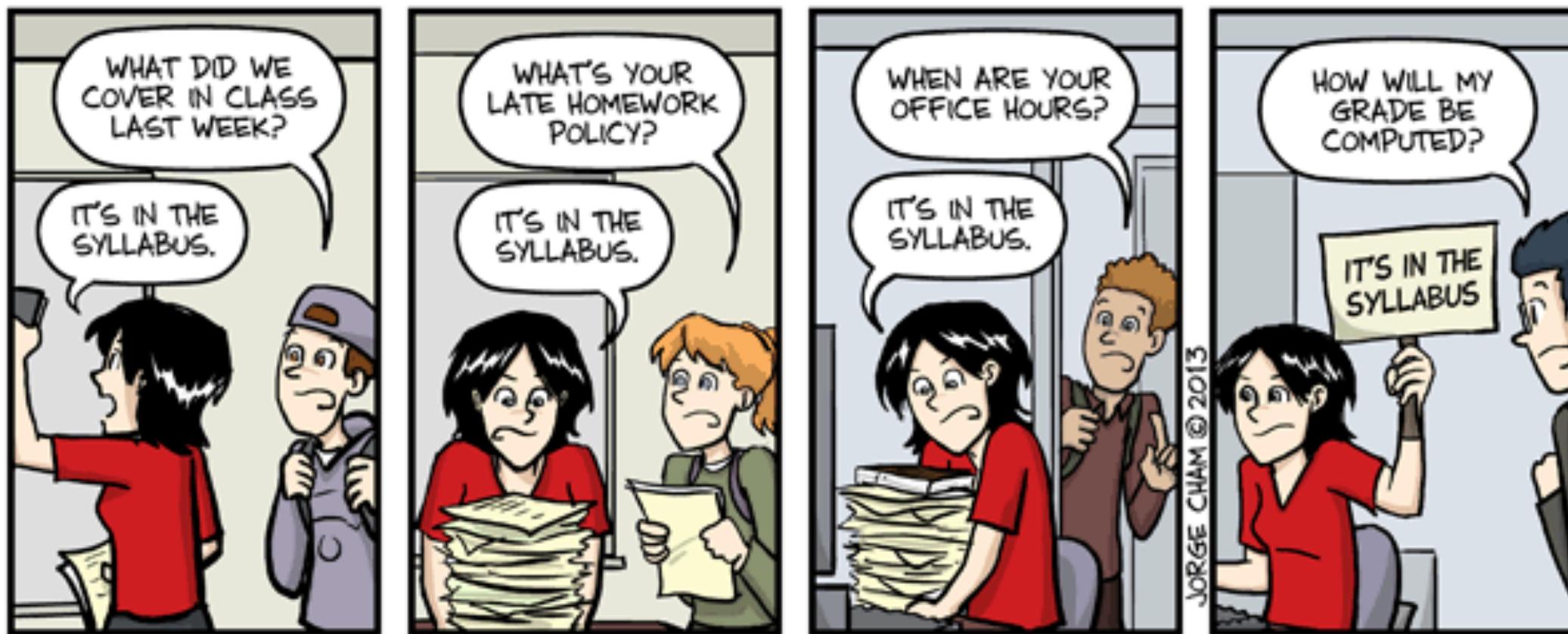
- Website: <https://github.com/dblarremore/CSCI2897>
 - Homework & reading posted
 - Code examples
 - Class notes
- Syllabus: <https://github.com/dblarremore/CSCI2897#syllabus>
- Canvas:
 - Turn in homeworks ✓
 - Lecture links ✓
 - Check grades ✓
- Slack:
 - Q&A
 - Swap files

Schedule & Syllabus Review

- <https://github.com/dblarremore/CSCI2897>

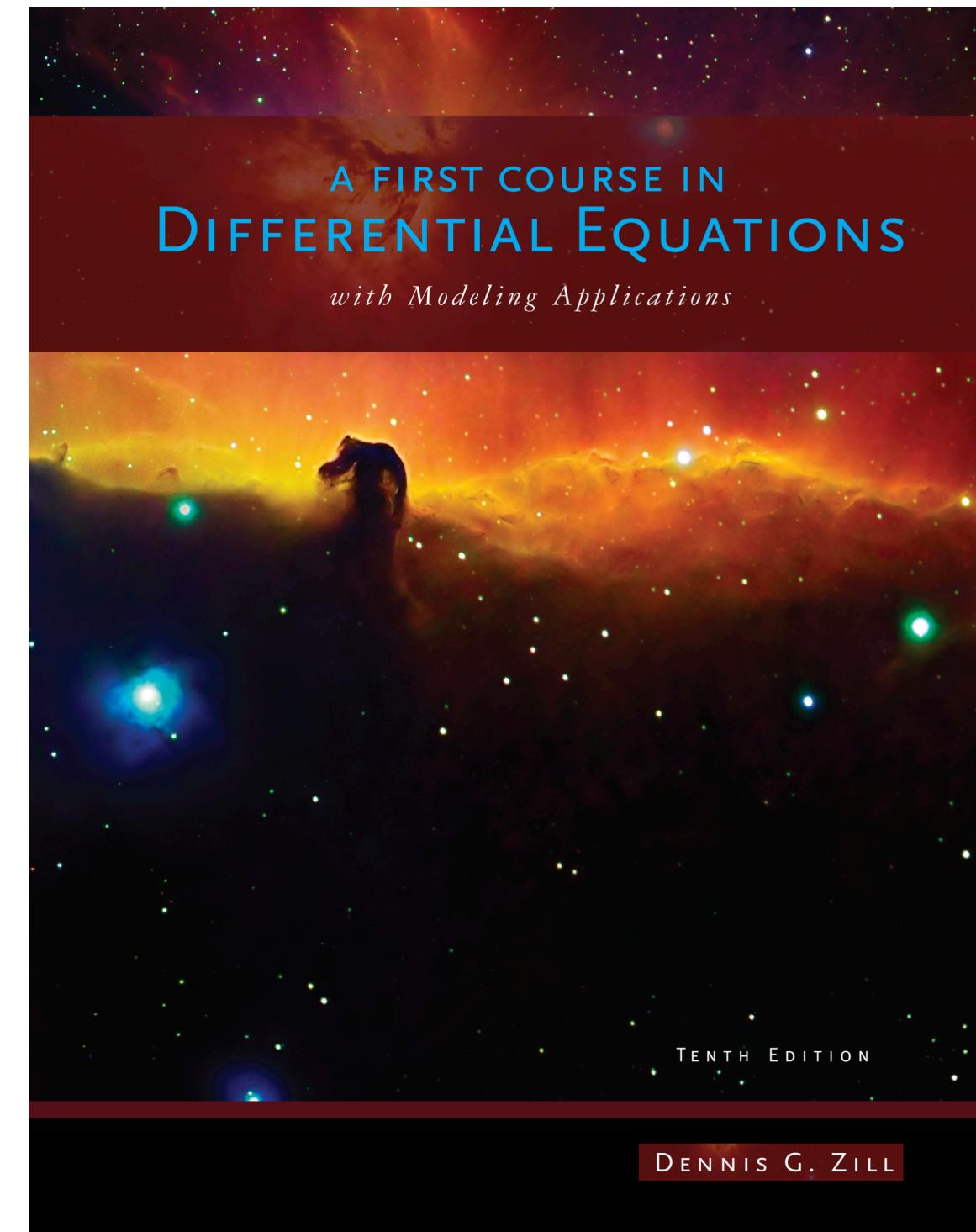
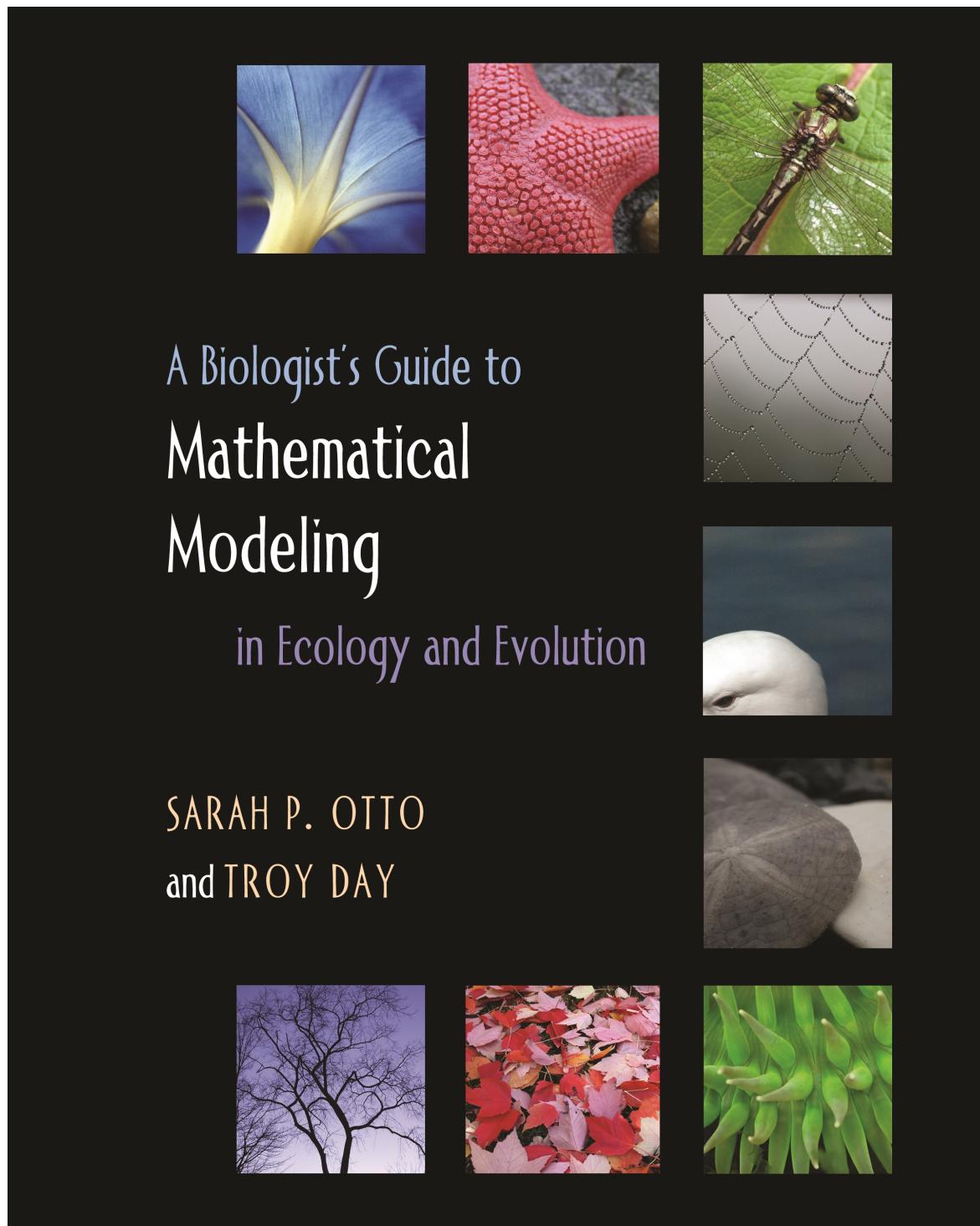
Piled Higher and Deeper by Jorge Cham

www.phdcomics.com



IT'S IN THE SYLLABUS

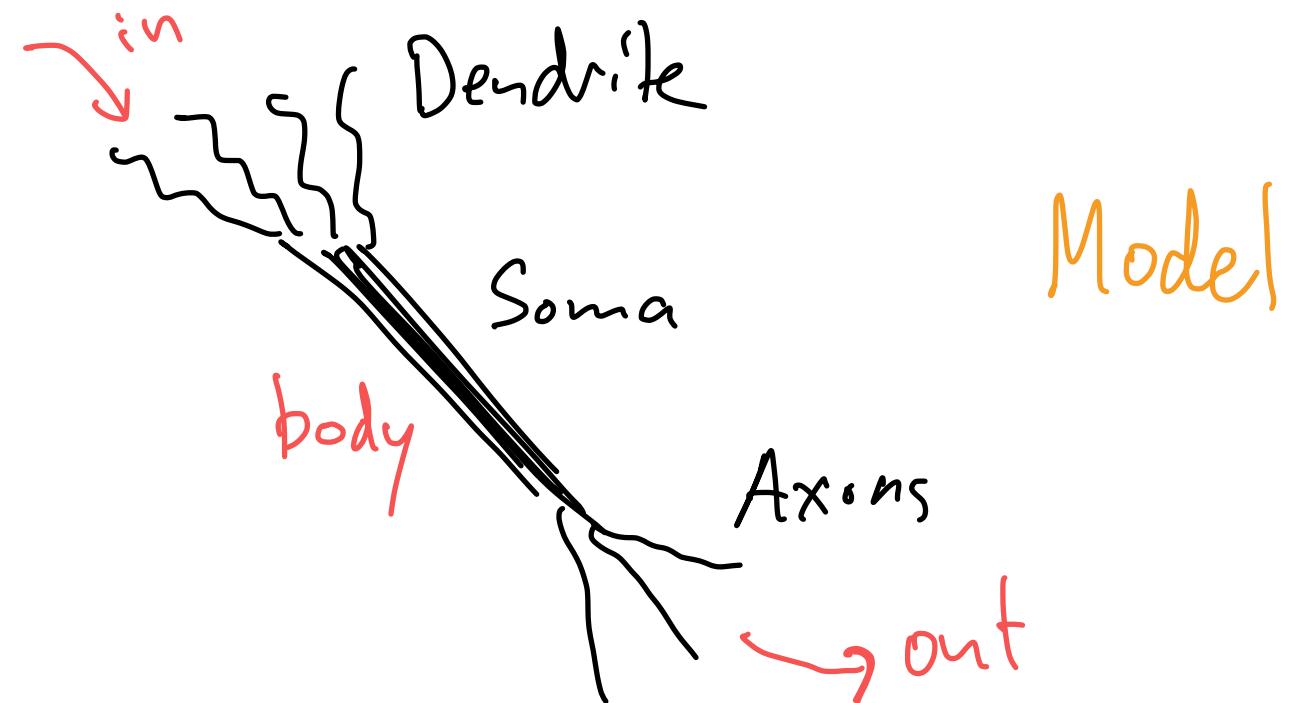
Textbooks



Mathematical models & linear algebra

Point 1: Our understanding of biology *is* a model—an abstraction or simplification.

- Neuron



- Structure of RNA

- guess/model structure
of pairing combinations

- Structure of Proteins

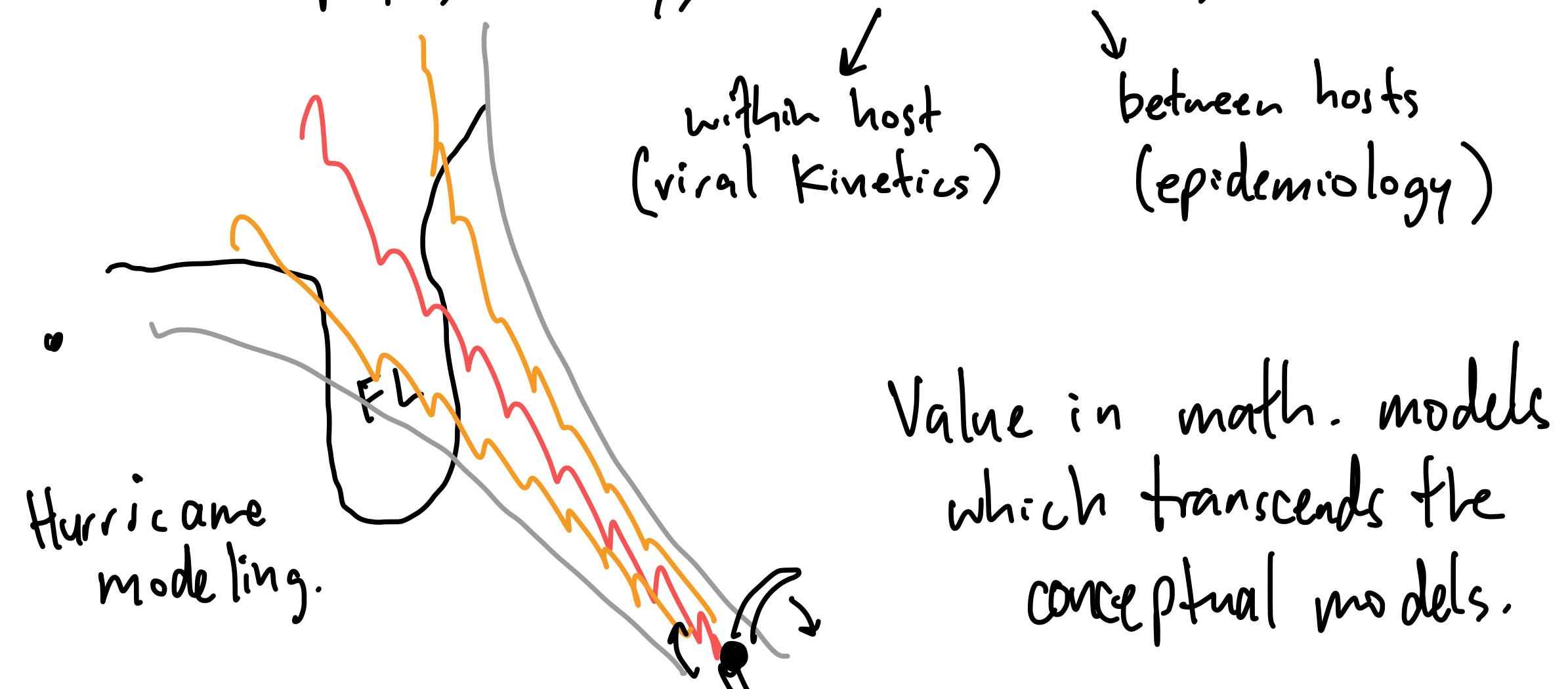
- Abstractions of abstractions

Subpoint: not all models are mathematical.

Mathematical models & linear algebra

Point 2: Mathematical models are better. We get *quantitative predictions* and *mechanism*.

- Population Models
 - birth, death, emigration (out), immigration (in).
(people, fishery, infectious disease)



Key modeling vocabulary

Variable: a quantity that changes (e.g. over time)

What we want to track.

Dynamics: the patterns of changes that occur over time.

in the variables

Parameter: a quantity in a model that remains constant over time.

Climate — Air pressure

Temperature

COVID-19 — Hospitalizations

Testing per day

Hurricane — Wind Speed

(lat, lon)

Some of the classics:

Discrete time

Population growth:

$$n(t+1) = R n(t)$$

of animals at time $t+1$
of animals at time t

Variables

Parameters

change this only to alter growth/non-growth rate.

Logistic growth:

$$n(t+1) = n(t) + rn(t) \left(1 - \frac{n(t)}{K} \right)$$

carrying capacity

Disease dynamics:

$$\frac{dS}{dt} = \dot{S} = -\beta SI$$

growth rate
infectiousness

Continuous Time

$$\frac{dI}{dt} = \dot{I} = \beta SI - \gamma I$$

recovery rate

$$\frac{dR}{dt} = \dot{R} = \gamma I$$

R_0 "basic reproduction #"

$$R_0 = \frac{\beta}{\gamma}$$

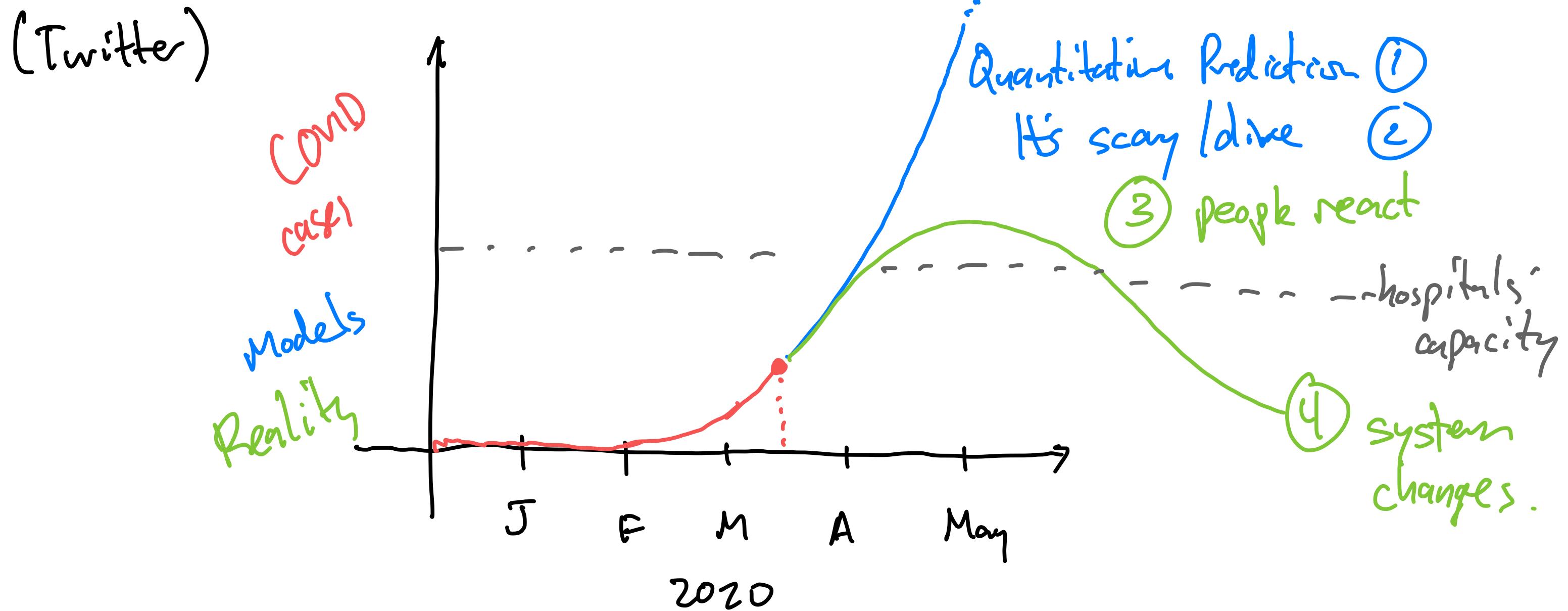
FitzHugh Nagumo Neuron:

$$\begin{aligned} \dot{v} &= v - \frac{v^3}{3} - w + RI_{ext} \\ \tau \dot{w} &= v + a - bw \end{aligned}$$

voltage
non-physical

Mathematical models & linear algebra

Point 3: Mathematical models are stories we tell about how the future comes about.



Subpoint: sometimes being wrong is the point!

Models. Great. So...why linear algebra too?



Linear algebra is... algebra.

But simplified (or lazy? or elegant?)

$$\begin{aligned} 3x + 5y &= 8 \\ x + 2y &= 11 \end{aligned}$$

$5y = 8 - 3x$
 $y = \frac{8}{5} - \frac{3}{5}x$

solve for x .

$$\begin{aligned} \frac{1}{6}6x &= 12 \cdot \frac{1}{6} \\ x &= \frac{12}{6} = 2 \end{aligned}$$

matrix vector vector

$$\begin{bmatrix} 3 & 5 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 8 \\ 11 \end{bmatrix}$$

$$M^{-1} M v = M^{-1} w$$

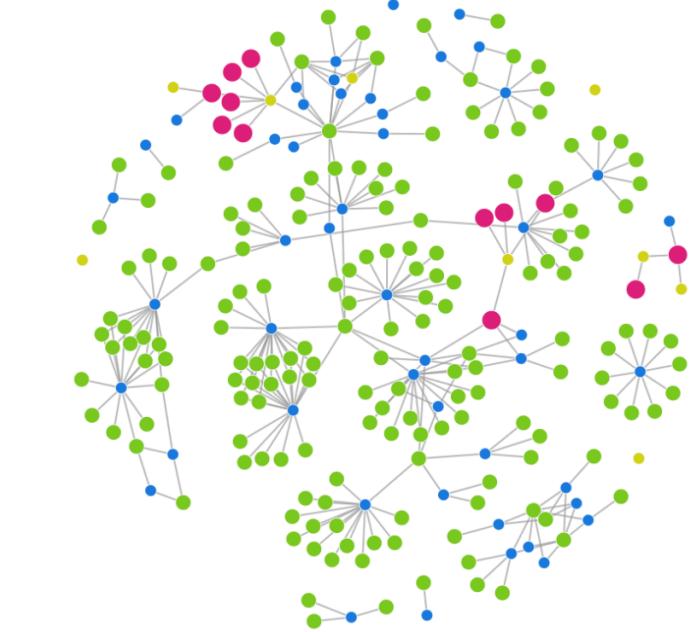
$$x_n = x_{n-1} + x_{n-2}$$

$$v = M^{-1}w$$

Fibonacci

→ Matrix → Analyze → Golden Ratio

Linear algebra comes up everywhere



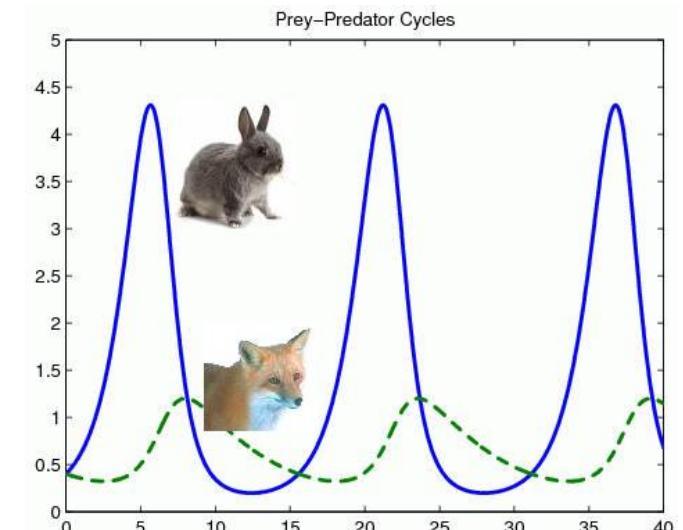
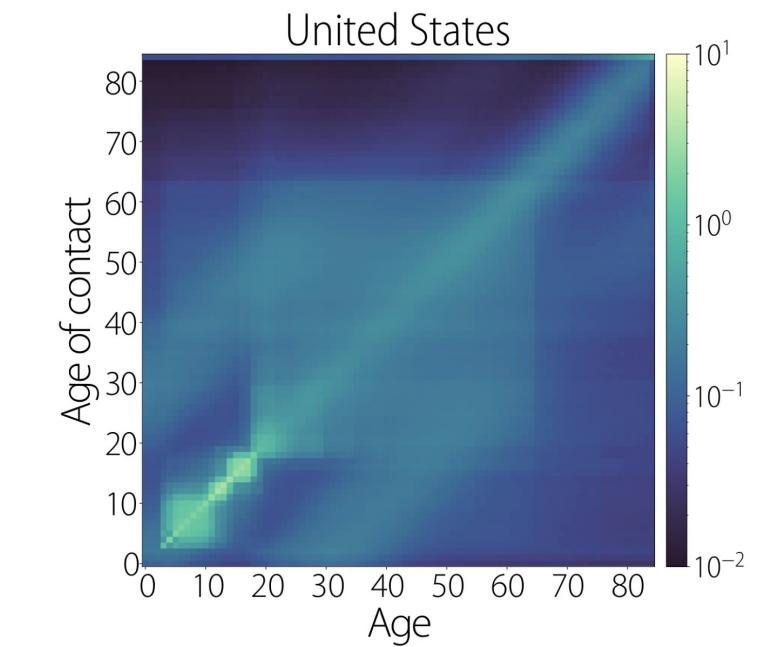
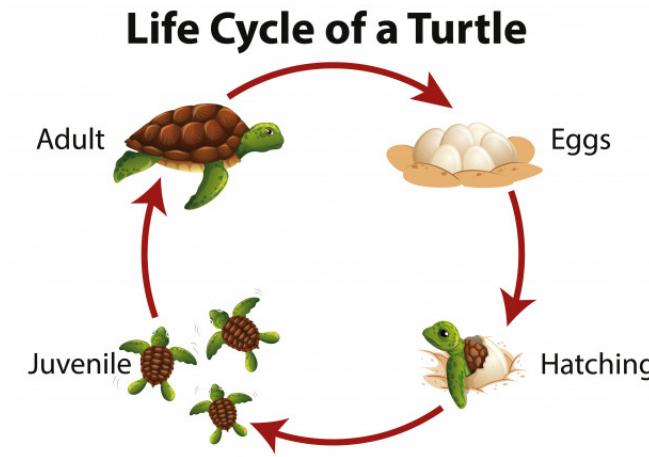
Computer Graphics

AI & Machine Learning

PCA & Clustering

Networks

Google
Technology company



Web Search

Population Structure

Age-structured models

Predator-prey dynamics

In this course...

Dynamic Models in Biology

Mathematical Approaches
to Analysis

Demystifying Jargon
and Vocabulary

Coding to Explore
and Understand

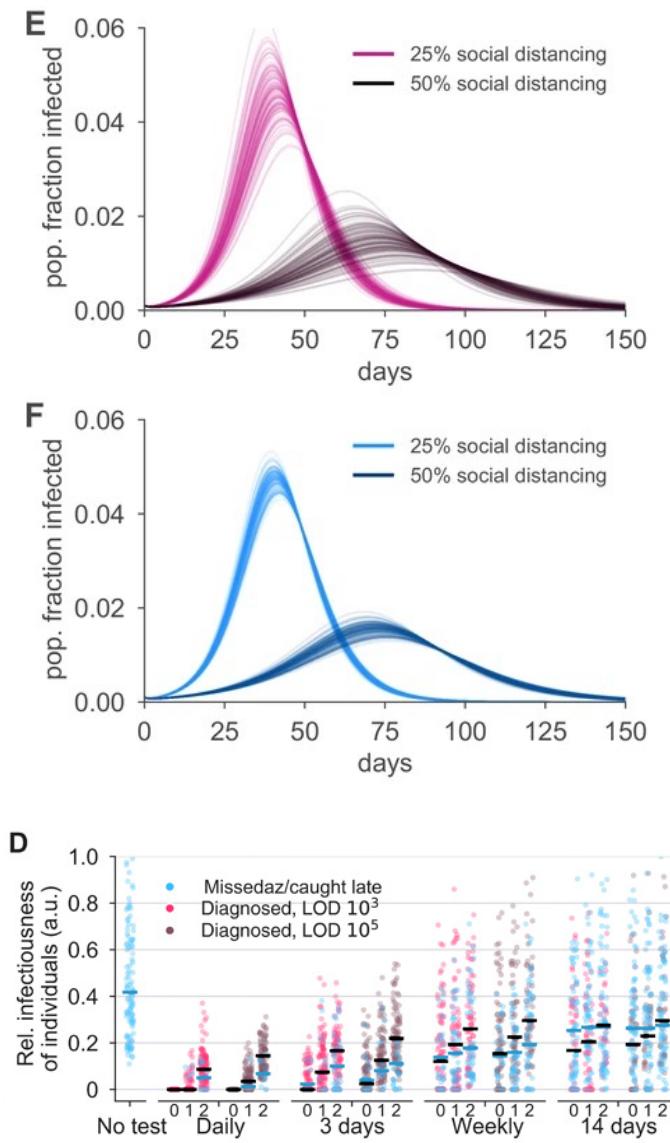
Concept, Application, Practice

Questions & Answers

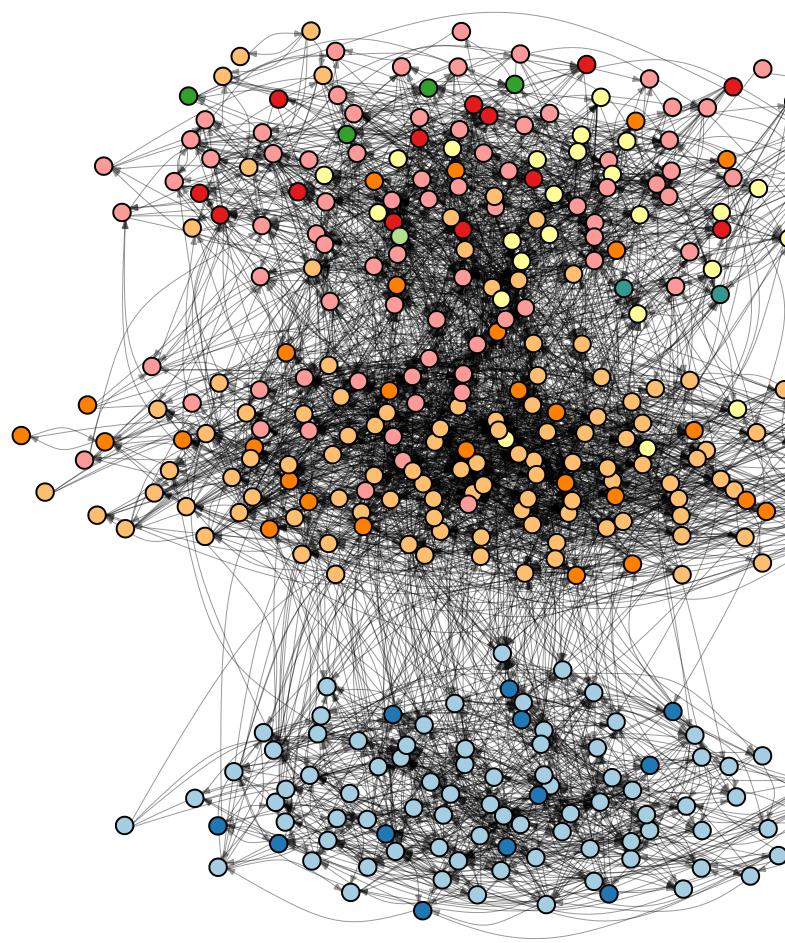
About me

Assistant Professor, BioFrontiers Institute & Department of Computer Science
External Faculty: Harvard School of Public Health – Center for Communicable Disease Dynamics

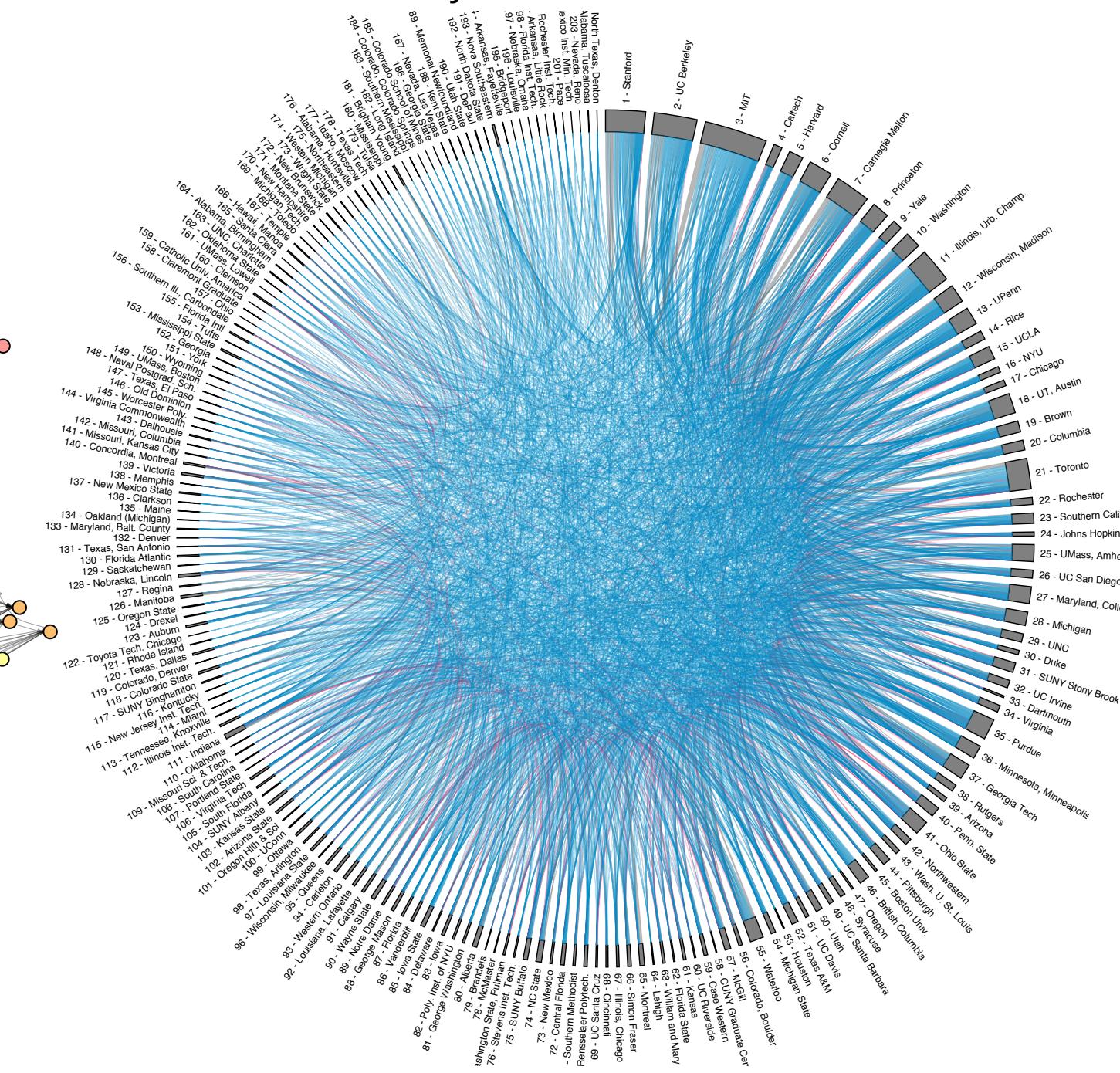
infectious disease
epidemiology



mathematical methods for
statistical inference/analysis



the scientific ecosystem & the science of science



Research should be fun

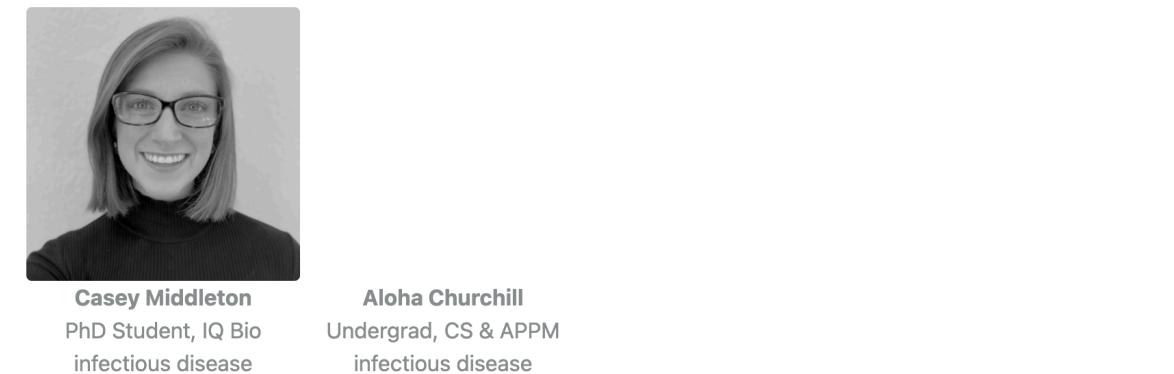
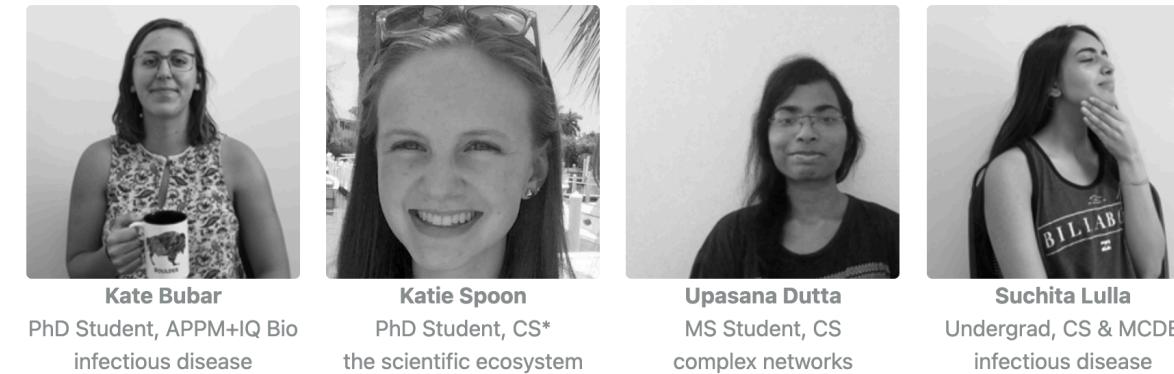
malaria parasite evolution
and epidemiology



optimal vaccine prioritization for
SARS-CoV-2 vaccine rollout



prestige & gender inequality in
academic faculty hiring



structured hierarchy in
online dating markets

provably optimal play in
generalized *misere* Connect 4

the dominance hierarchy
in the network of hockey fighters

Homework

Before next class:

1. Join the CBQ Slack.
2. Go to the github and bookmark it. github.com/dblarremore/CSCI2897
3. Get the textbooks.
4. Take the survey (Canvas).
5. Do the reading (literally just a 10-tweet thread)