

Calculating Biological Quantities

CSCI 2897

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Lecture 1

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Calculating Biological Quantities

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

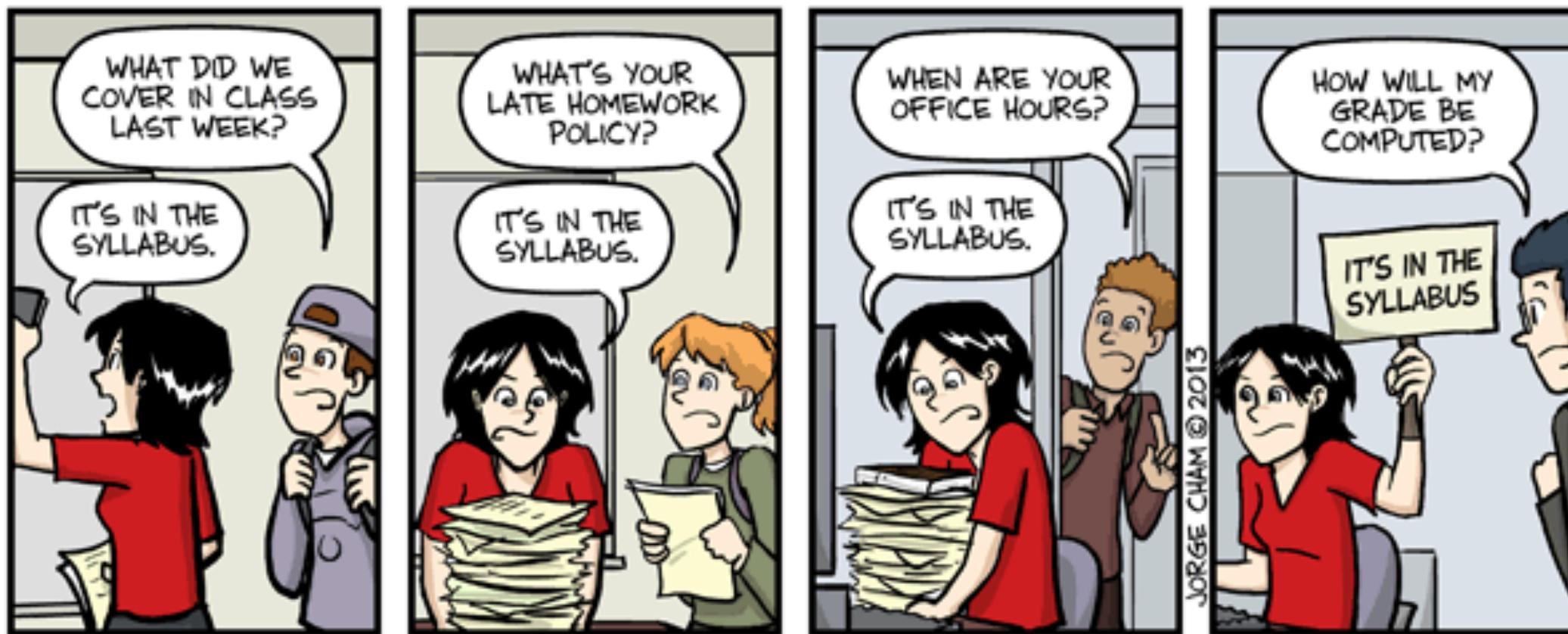
- Website: <https://github.com/dblarremore/CSCI2897>
 - ✓ • Homework & reading posted
 - ✓ • Code examples
 - ✓ • Class notes
- Syllabus: <https://github.com/dblarremore/CSCI2897#syllabus>
- Canvas:
 - ✓ • Turn in homeworks
 - ✓ • Lecture links
 - ✓ • Check grades
- Slack:
 - ✓ • Q&A
 - ✓ • Swap files

Schedule & Syllabus Review

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

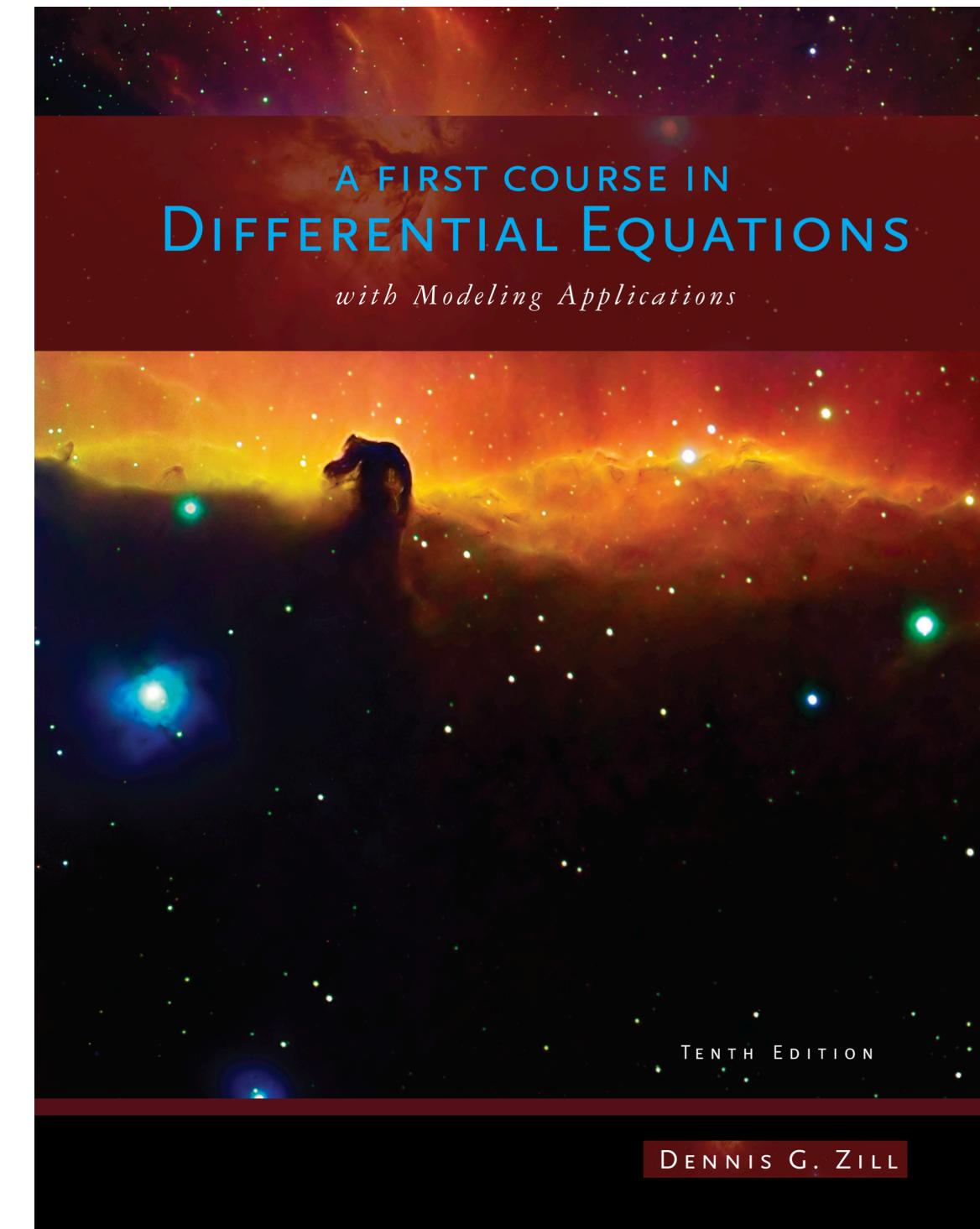
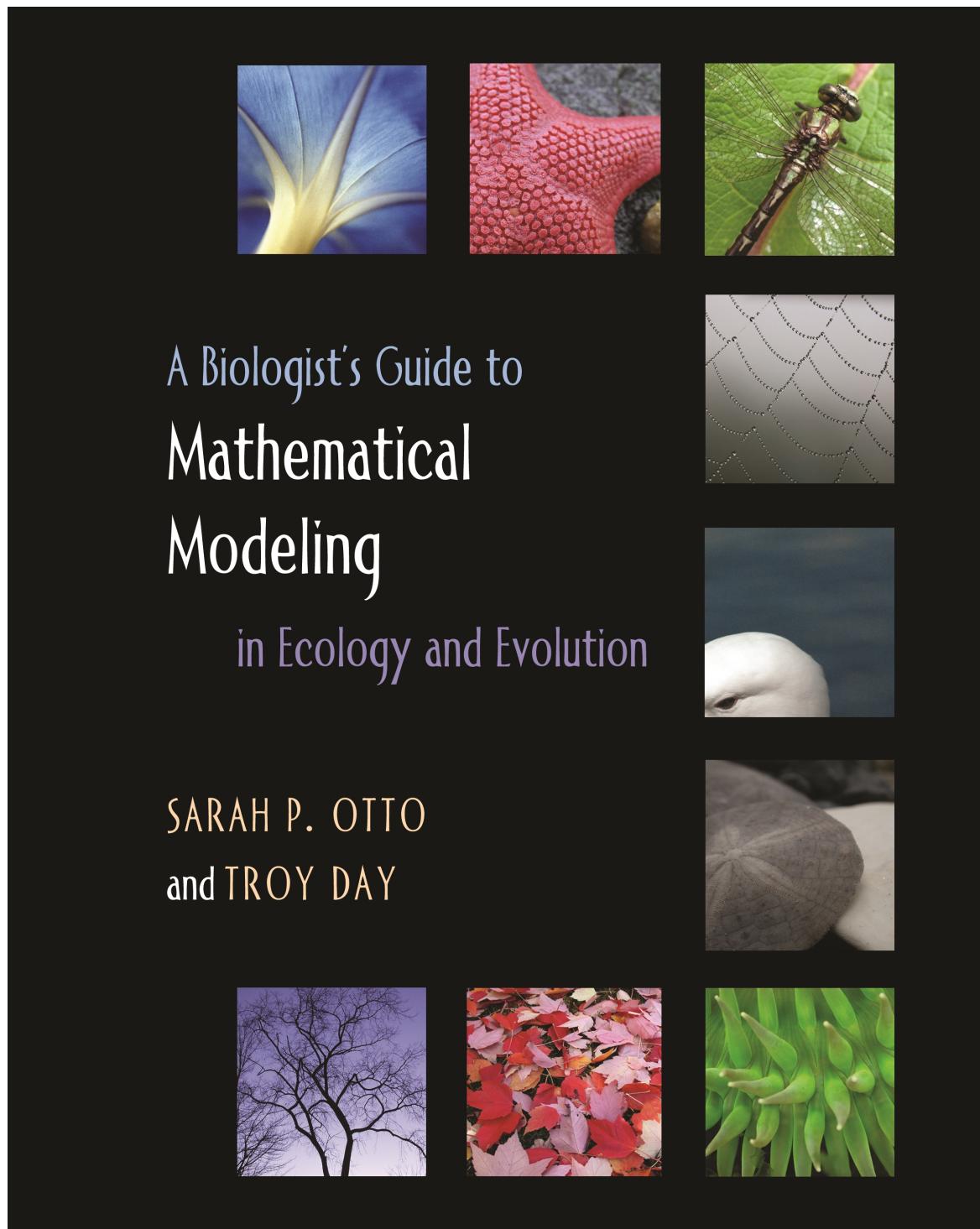
Piled Higher and Deeper by Jorge Cham

www.phdcomics.com



IT'S IN THE SYLLABUS

Textbooks

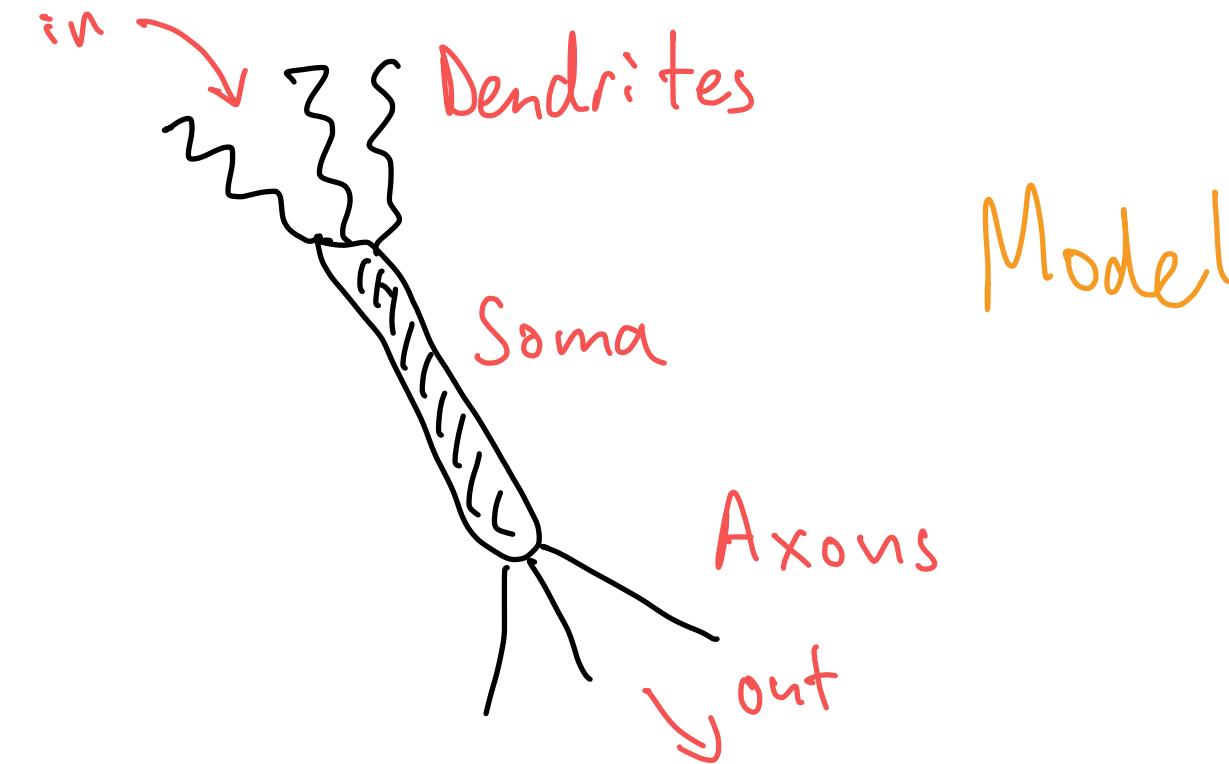


Quiz

Mathematical models & linear algebra

Point 1: Our understanding of biology *is* a model—an abstraction or simplification.
Not all models are mathematical.

- Neuron



- Structure of DNA

Mathematical models & linear algebra

Point 2: Mathematical models are wonderful.

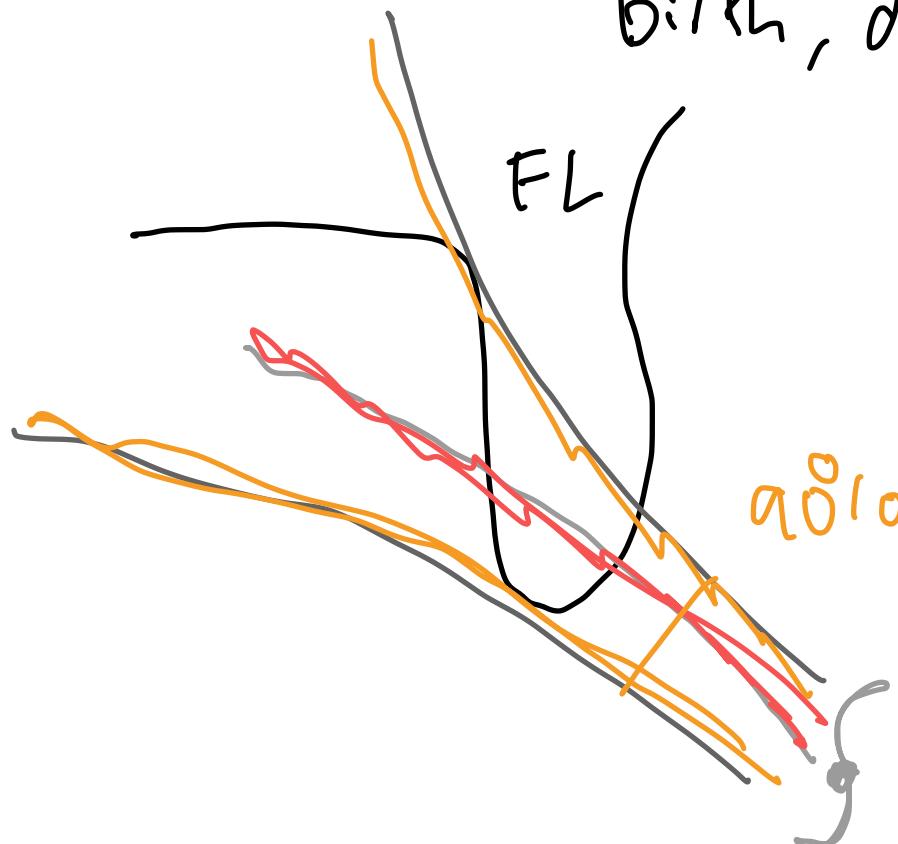
We get *quantitative predictions* and mechanism.

- Population models

- rabbits
- bacteria
- viral variants

growth
competition
emigration (out)
immigration (in)
birth, death

- Uncertainty



There is value in
math models that
transcends conceptual
models!

Key modeling vocabulary

Climate

COVID-19

Variable: a quantity that changes (e.g. over time). Vary is in the name.

What we want to track

Temp. Air Pressure

Infections, Hospitalizations

Dynamics: the patterns of changes that occur over time.

in the variables

Drought cycles

Extreme Events

Epidemic Curves

ICU bed
shortages

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

Location, Time

Policy

vaccine eff.

R_0

Some of the classics:

discrete
time
(Excel)

Population growth:

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

Logistic growth:

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

Disease dynamics:

$$\dot{S} = -\beta S I$$

$$\dot{I} = \beta S I - \gamma I$$

$$\dot{R} = \gamma I$$

FitzHugh Nagumo Neuron:

$$\dot{v} = v - \frac{v^3}{3} - w + R I_{\text{ext}}$$

$$\tau \dot{w} = v + a - b w$$

variables

parameters

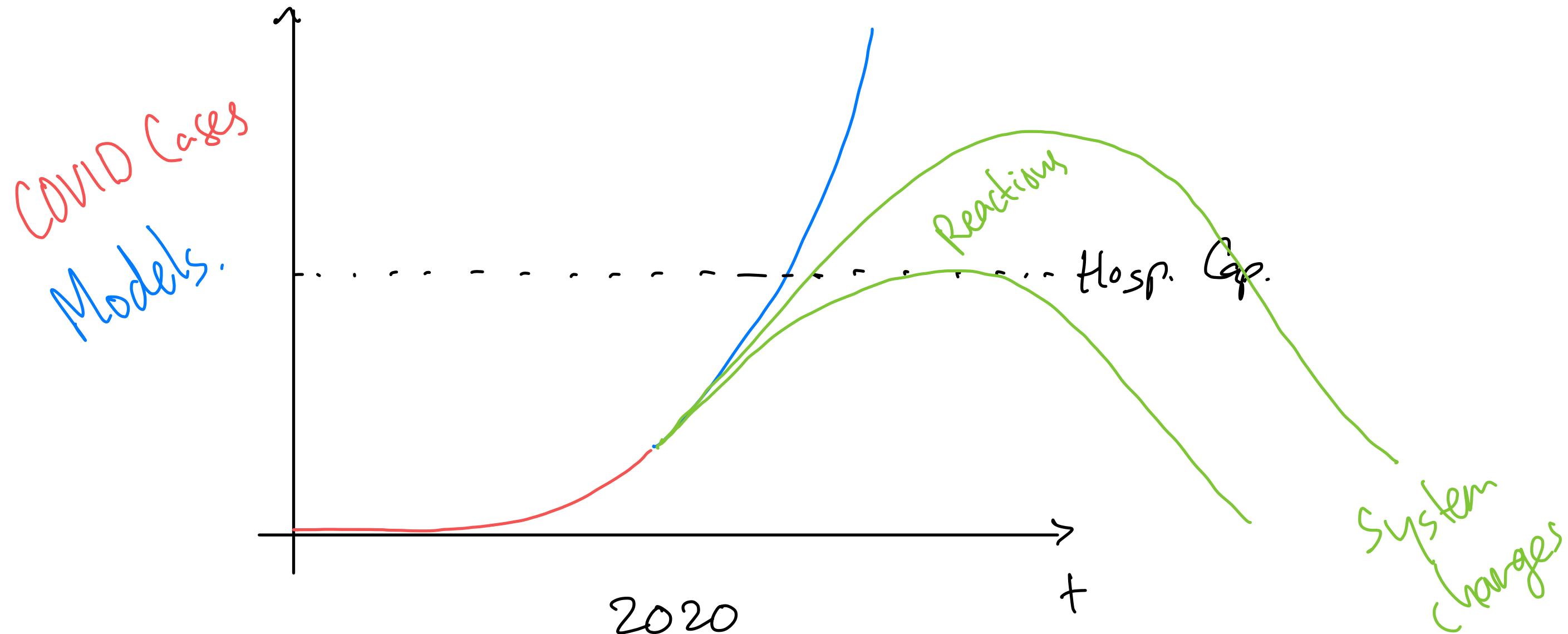
continuous
time

$$\dot{x} \equiv \frac{dx}{dt}$$

rate of change
of x w.r.t. time

Mathematical models & linear algebra

Point 3: Mathematical models are stories we tell about how the future comes about.
Sometimes *being wrong is the point!*



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



Linear algebra is...algebra.

But simplified (or lazy? or elegant?)

$$3x + 5y = 8$$

$$x + 2y = 11$$

- 1) solve 1st for x
- 2) plug into 2nd
- 3) solve for y
- 4) back into first

matrix vector vector

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

$$\vec{M}\vec{x} = \vec{b}$$

$$\vec{x} = \vec{M}^{-1}\vec{b}$$

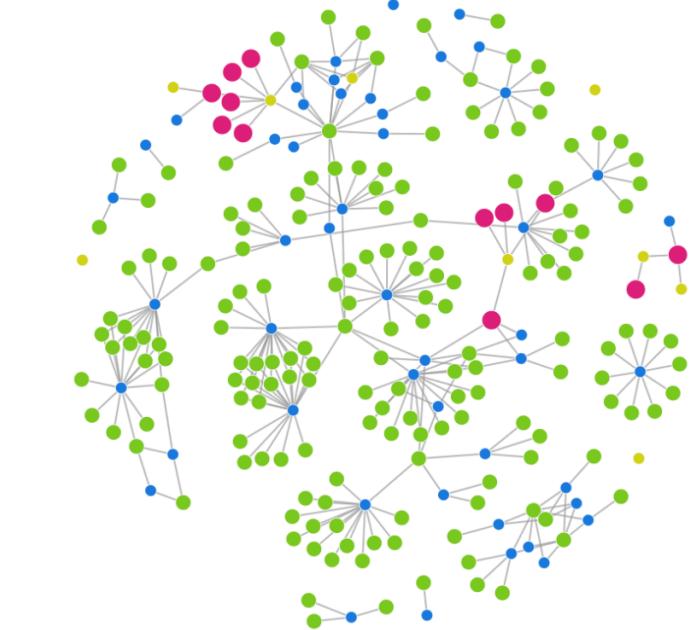
↑
inverse
matrix

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

Fibonacci
(Fibonacci ?)

→ Matrix → Analyze → Golden Ratio

Linear algebra comes up everywhere



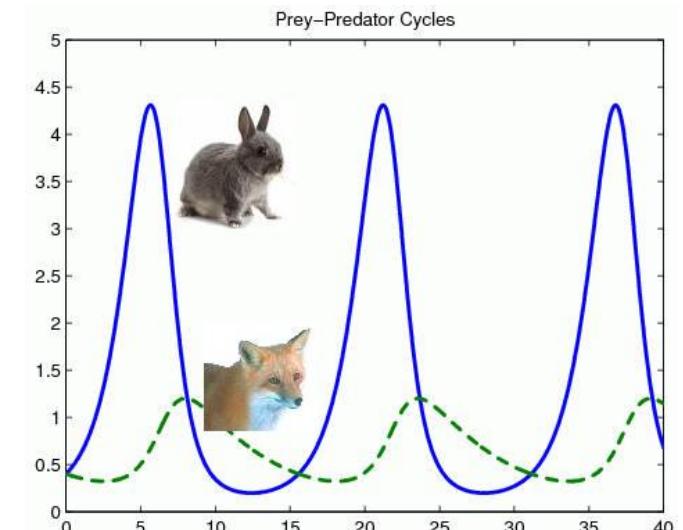
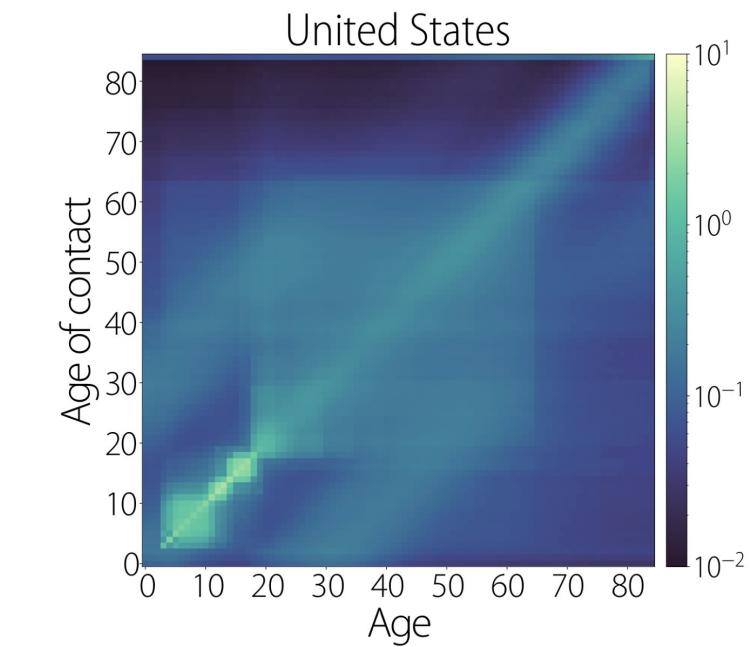
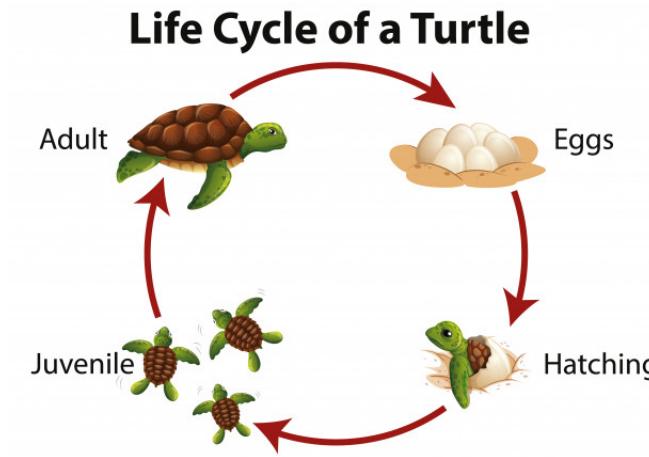
Computer Graphics

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

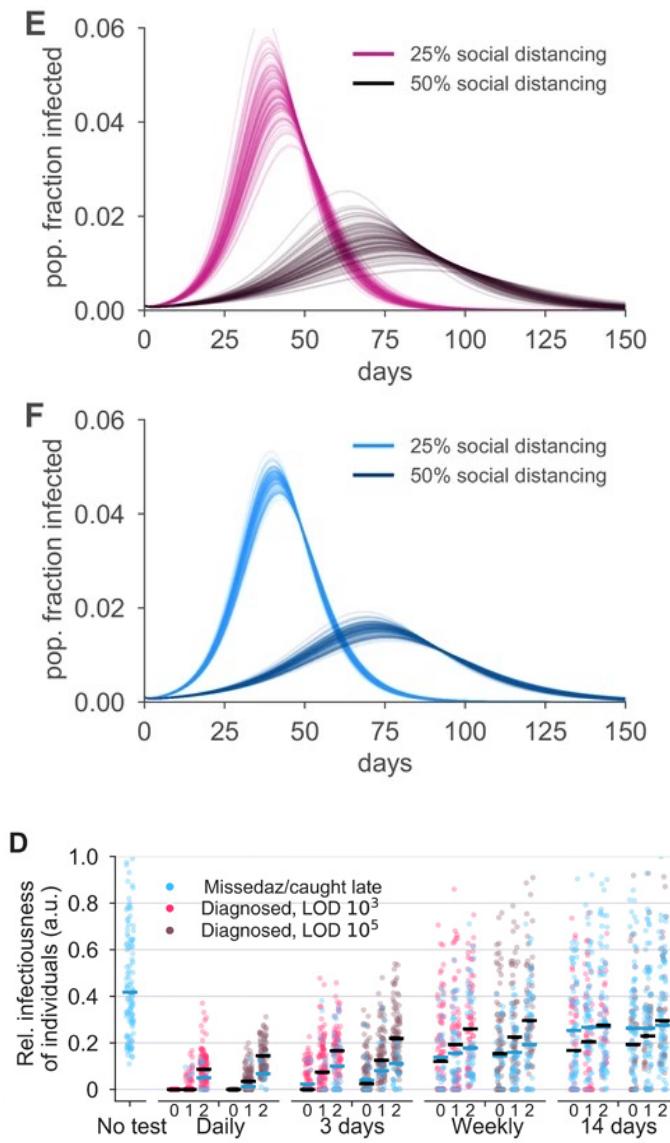
Coding to Explore
and Understand

Concept, Application, Practice

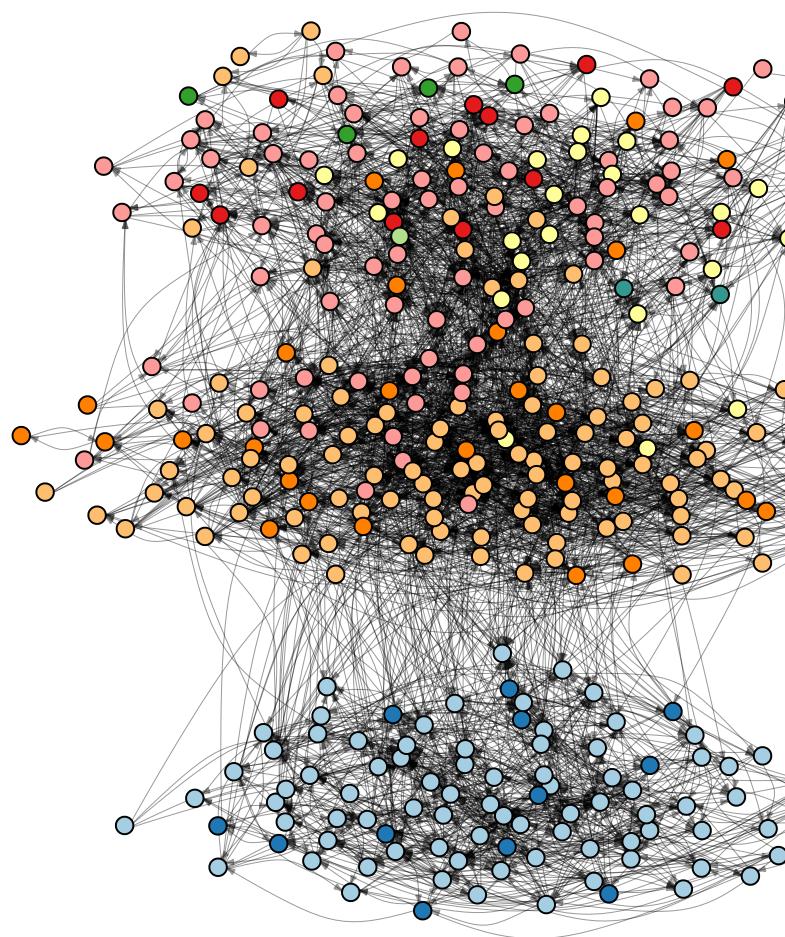
About me

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

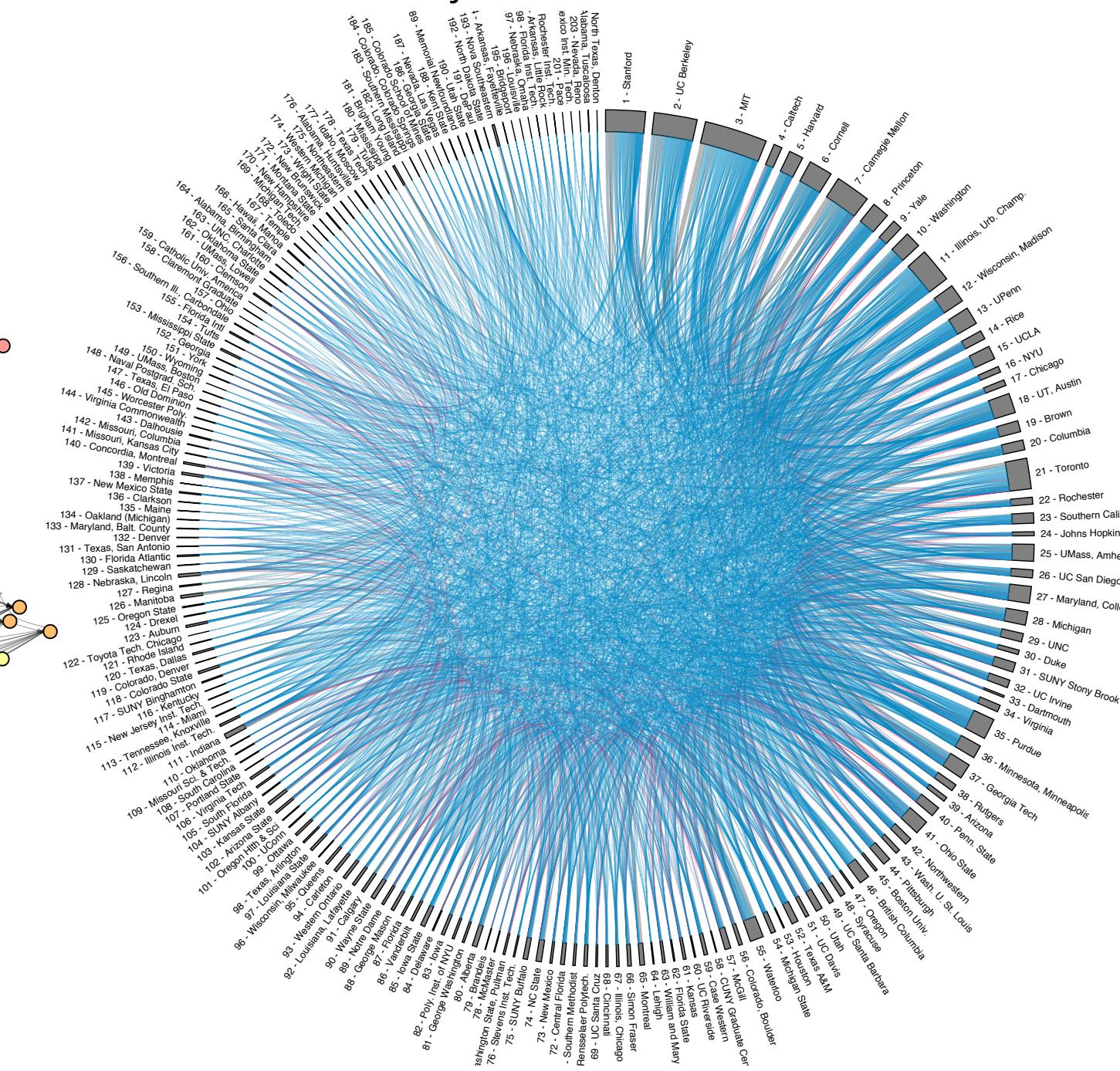
infectious disease
epidemiology



mathematical methods for
statistical inference/analysis



the scientific ecosystem & the science of science



Research should be **fun**



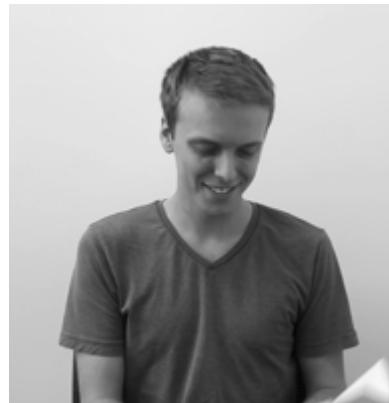
**Epidemiology
& Applied Math**



**Networks
& Theory**



**Computational
Social Science**



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. Download the textbooks. ✓
4. Read the Twitter Thread on the schedule.
 1. Write a paragraph in response — exciting? inspiring? dorky? confusing? why?
 2. Print your response, with your name on it.
 3. Bring it to my office and hand it to me or slip it under my door.
5. Read Otto & Day Chapter 1

Canvas
Due Next Tues.