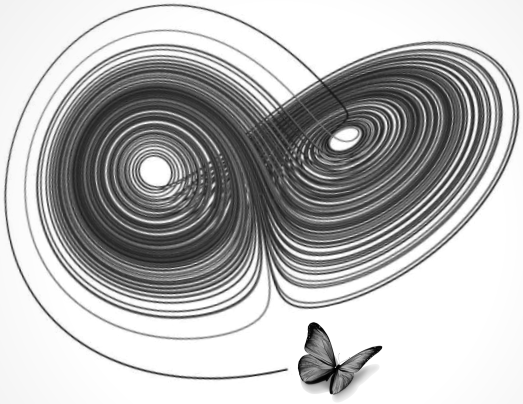
Biology and Dynamical Systems



How mathematical models make sense of complex biological processes.

Class Structure: This workshop is broken up to focus on each of ”the three Cs”

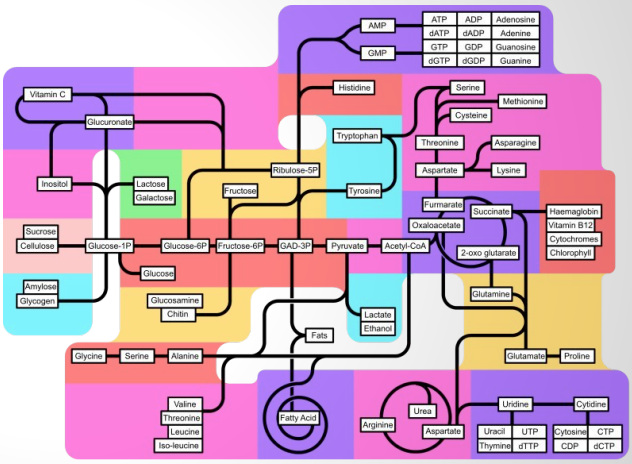
Collect: Part of what we are doing here is learning how to collect information. Every class starts with a simple content quiz over the short reading, followed by a 15 minute review of the day’s focus content.

Collaborate: The majority of the class time will focus on an in depth conversation between peers while solving a sample problem. The exercises are evaluated for their persuasiveness, teamwork, and communication.

Convey: The final portion of each class will involve an individual project assignment. This will involve both developing an appropriate answer to a question as well as clearly explaining the logical process.

Why is mathematical modeling important to biologists?

- Biological systems can be highly complex
- We explain complex systems with cartoon models of reaction pathways
- Most pathway models are built up by finding many pairwise interactions
- Predicting complex behaviors is only possible through quantitative modeling

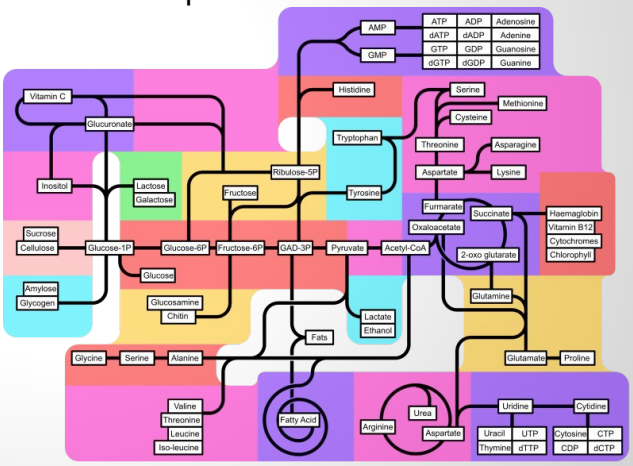


Biology is hard enough on its own. Why study mathematical modeling too?

1. Modeling isn't as hard as you think
2. Math models make predictions that cartoon models can't
3. Models clarify the key components of a system
4. Math skills make you more marketable after graduation

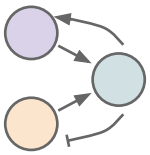
3. Models can clarify key components of reaction pathways

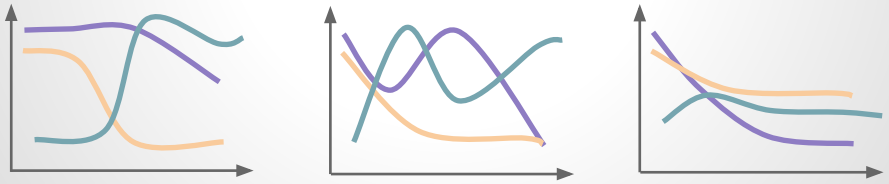
Wouldn't you like to tease apart a parasite's core metabolic pathway to find drug targets using just a system of differential equations?



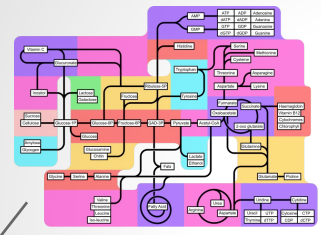
2. Mathematical models make predictions that cartoon models can't

Cartoons really aren't specific enough for surprisingly simple questions.

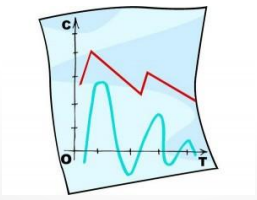




1. Mathematical models aren't that hard



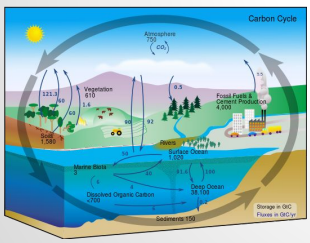
$$\frac{dc}{dt} = k \cdot a$$



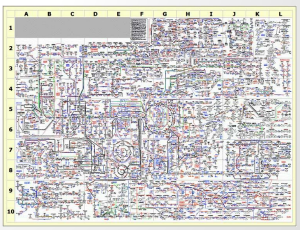
The balancing act behind scientific models

Complex Problem

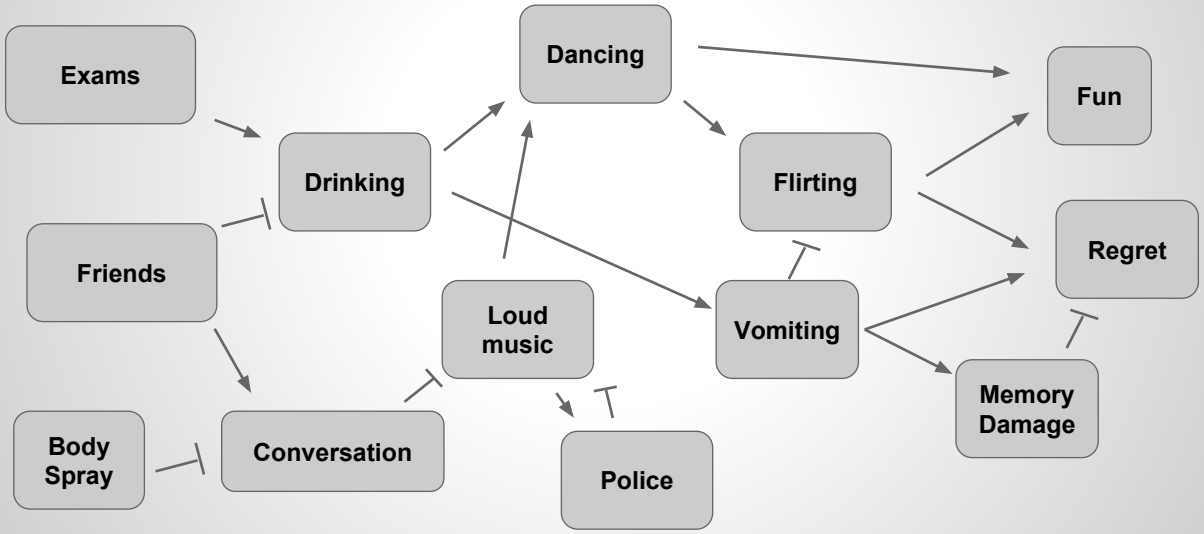
Simplification



Completeness



Scientific Model of Anything: party



Class activity: Build a model of ANYTHING

- Break up into groups (starting NOW)
- You'll have 8 minutes to figure out a model of anything you want
- Brainstorm a system quickly. You'll need to pick one after 1 minute.
- Define the most important things that happen in your system
  - Remember the party example
- Diagram how each important thing relates to each other
  - Use arrows for *upregulation* and crossbars for *downregulation*
- Clearly draw your model diagram for 5 points (put your names on it!)
- Groups can volunteer to present their model for 5 extra points
  - Each group gets 1 minute to present their system and how they are modeling it
  - We'll vote on the winners in 4 categories:
    - Complexity, Simplification, Completeness, and Creativity

Winning categories

1. Complexity (of the system)
   - Challenge yourself to break apart something that isn't trivial to understand
     - 👎👎: making a sandwich from cold cuts and bread,
     - 👍👍: making a sandwich from sunlight, water and CO2,
2. Simplicity (of the model)
   - Try to boil the system down to its most important components.
     - 👎👎: an exact 1:1 replica of every chemical that goes into the sandwich
     - 👍👍: summarizing multiple simple steps that all depend on the same inputs
3. Completeness
   - Include as much detail as you need to explain the process
     - 👎👎: oversimplifying a critical step (someone says "Hey what about….", defend yourself!)
4. Creativity
   - Entertain our brains! Make it funny, intelligent, provocative. Get your audience interested.

It's impossible to win in all categories. You have to make choices.

Recap: What did we learn?

Discussion: Let's generate a list of biological systems that have been modeled mathematically (40 pts)

1. Break into groups
2. Search the web for any mathematically modeled system you can find
3. Narrow in on 1 or 2 you like in particular
4. Get some of the details of the system
5. Be prepared to explain how the model helped
6. We'll discuss as a class in 15-20 minutes

Project: Find a particular biological system that you would like to model for the class project

1. You can use any of those discussed today, but everyone needs their own
2. Write 3 paragraphs of background on the system (10 pts)
3. Write 1 paragraph on a recent finding that needs modeling (5 pts)
4. Draw a summary figure that explains the process (20 pts)
    a. If applicable, draw a reaction diagram
    b. Otherwise, just draw a general illustrative figure
5. Download and install MATLAB or OCTAVE on a laptop (5 pts)

Reading: Read the one-page handout and be ready for a simple quiz at the start of next week

1. There will be a 5 minute, 4 question (10 pts each) quiz at the start of next class.
2. It is just designed to determine if you read the handout.
3. You probably won't even have to think if you do the reading.