September 5, 2013 Physics 131 Prof. E. F. Redish

- **<u>Theme Music:</u> Paul Simon**
  When numbers get serious
- **<u>Cartoon:</u> Bill Waterson**
  Calvin & Hobbes

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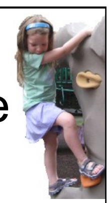
Foothold Ideas:
Estimation – Quantifying experience



- **Measure your body parts**
- **Don't** look up data online or get it from friends!
- **Don't** use your calculator! Use 1-digit arithmetic
- **Do** figure out your estimations by starting with something you can plausibly know and scale up or down
- **Do** check your answer to see if it's reasonable
- **Do** learn a small number of <u>Useful numbers</u>

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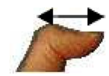
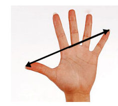
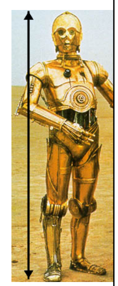
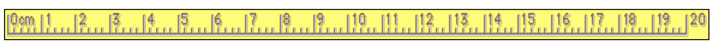
My personal scales

	inches	centimeters
First digit of thumb		
Open handspan		
Forearm (cubit)		
Full height		

Useful numbers (people)

Numbers	
Number of people on the earth	~7 billion (7 x 10^9)
Number of people in the USA	~ 300 million (3 x 10^8)
Number of people in the state of Maryland	~ 5 million (5 x 10^6)
Number of students in a large state university	~30-40 thousand (3 x 10^4)

Useful numbers (distances)

Macro Distances	
Circumference of the earth	~24,000 miles (1000 miles/time zone at the equator)
Radius of the earth*	$2/\pi \times 10^7$ m
Distance across the USA	~3000 miles
Distance across DC	~10 miles

Useful numbers (bio)

Bio Scales	
Size of a typical animal cell	~10-20 microns (10^{-5} m)
Size of a bacterium, chloroplast, or mitochondrion	~1 micron (10^{-6} m)
Size of a medium-sized virus	~0.1 micron (10^{-7} m)
Thickness of a cell membrane	~5-10 nm (10^{-8} m)

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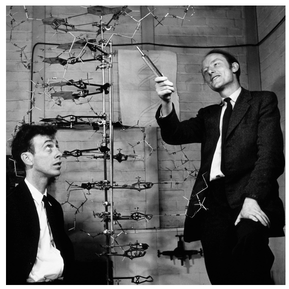
Models

- What's a "model"?



Navier–Stokes equations *(general)*

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \nabla\cdot\mathbf{T} + \mathbf{f}$$

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Models in science

- A model is something used to represent a system.
- It should have the most important features of the system being represented but leave out less essential details.
- A good model lets you figure out things about the real system that you might have trouble doing if you tried to pay attention to everything.
- A model may be almost anything –
  - A physical structure
  - An analog
  - An equation
- In a very real sense, everything we "know" in science is a model.

Is "species" a model? If so, of what?

How about "genome"?

How about "protein"?

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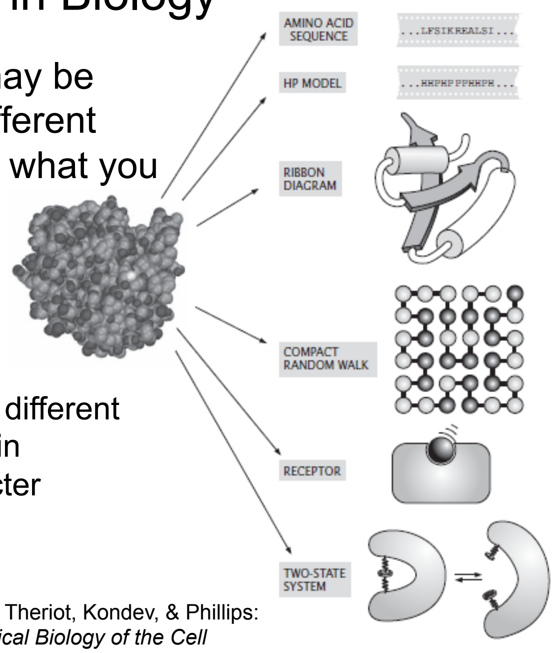
Modeling in Biology

The same system may be modeled in many different ways, depending on what you want
to pay attention to.



Each model highlights different properties of the protein
- Hydrophobic character
- Folding property

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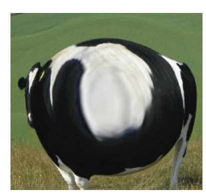
From Theriot, Kondev, & Phillips: *Physical Biology of the Cell*

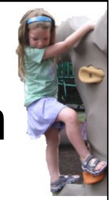
Modeling in Physics

- Many of the models we use in intro physics are highly simplified ("**toy models**") to let us focus on just a few properties.
  - Point masses
  - Rigid bodies
  - Perfect springs

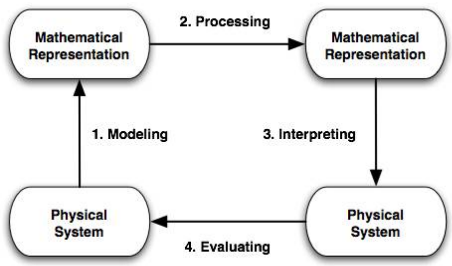


- These models let us first get a clear understanding of the physics. Then, more complex systems can be treated by building around that understanding.

Foothold ideas: Modeling the world with math



- We use math to model relationships and properties.
- From the math we inherit ways to process and solve for results we couldn't necessarily see right away.
- Sometimes, mathematical models are amazingly good representations of the world. Sometimes, they are only fair. It is very important to develop a sense of when the math works and how good it is.
- Mostly, the math we use differs in important ways from the math taught in math classes.



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An example from a math exam

- Writing the equation in this problem on a physics exam would receive 0 credit and the comment: "This is a meaningless equation!"

The population density of trout in a stream is

$$r(x) = 20\frac{1+x}{x^2+1}$$

where *r* is measured in trout per mile and x is measured in miles. *x* runs from 0 to 10.

(a) Write an expression for the total number of trout in the stream. Do not compute it.

Why?

How would you fix this?

Dimensions and units

- The simplest mathematical model we use in science is we assign numbers to physical quantities by measurement.
- Each kind involves an arbitrary choice of scale.
  - Different types ↔ **dimensions**
    - Distance, time, mass, …
  - Equations that represent physical relationships must maintain their equality even when we change our arbitrary choice.
- The quantity we create by adding a unit is NOT just a number but a blend.

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