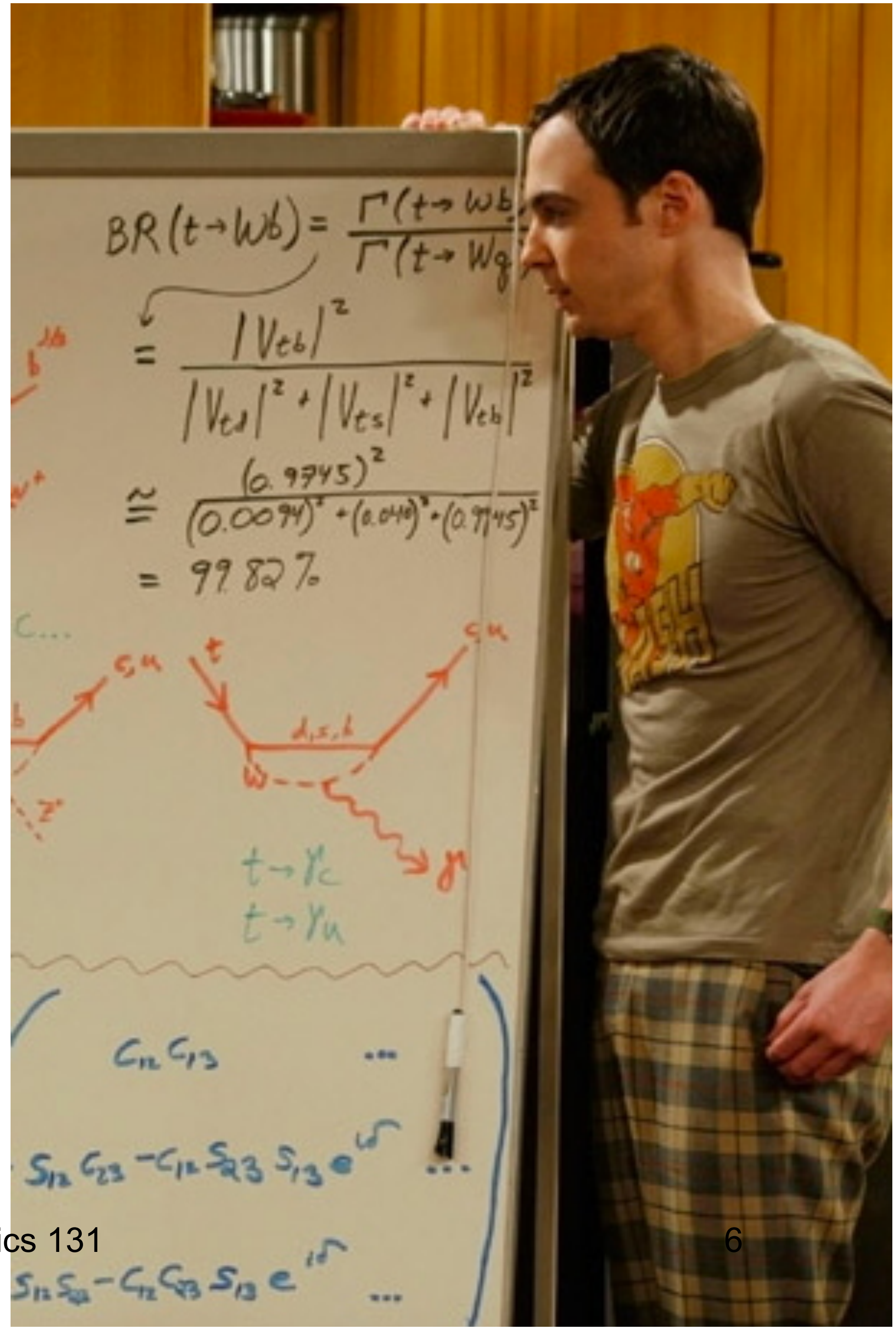
September 2, 2015 Physics 131 Prof. E. F. Redish

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

The Equation of the Day

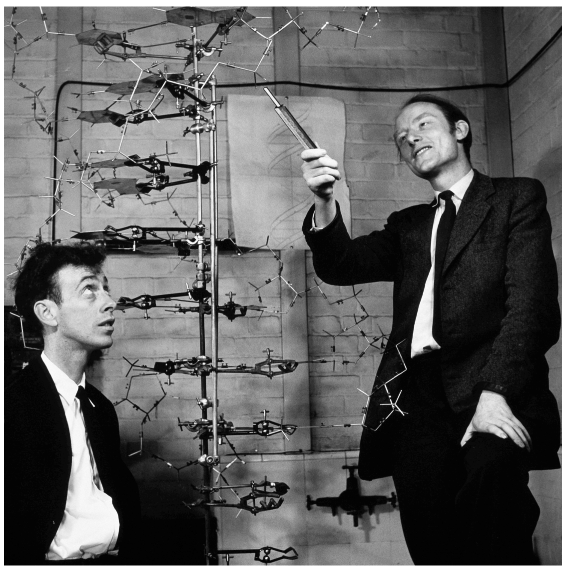
Dimensional analysis

$$L = L + L$$



Models

- What's a "model"?



Navier–Stokes equations *(general)*

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

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.

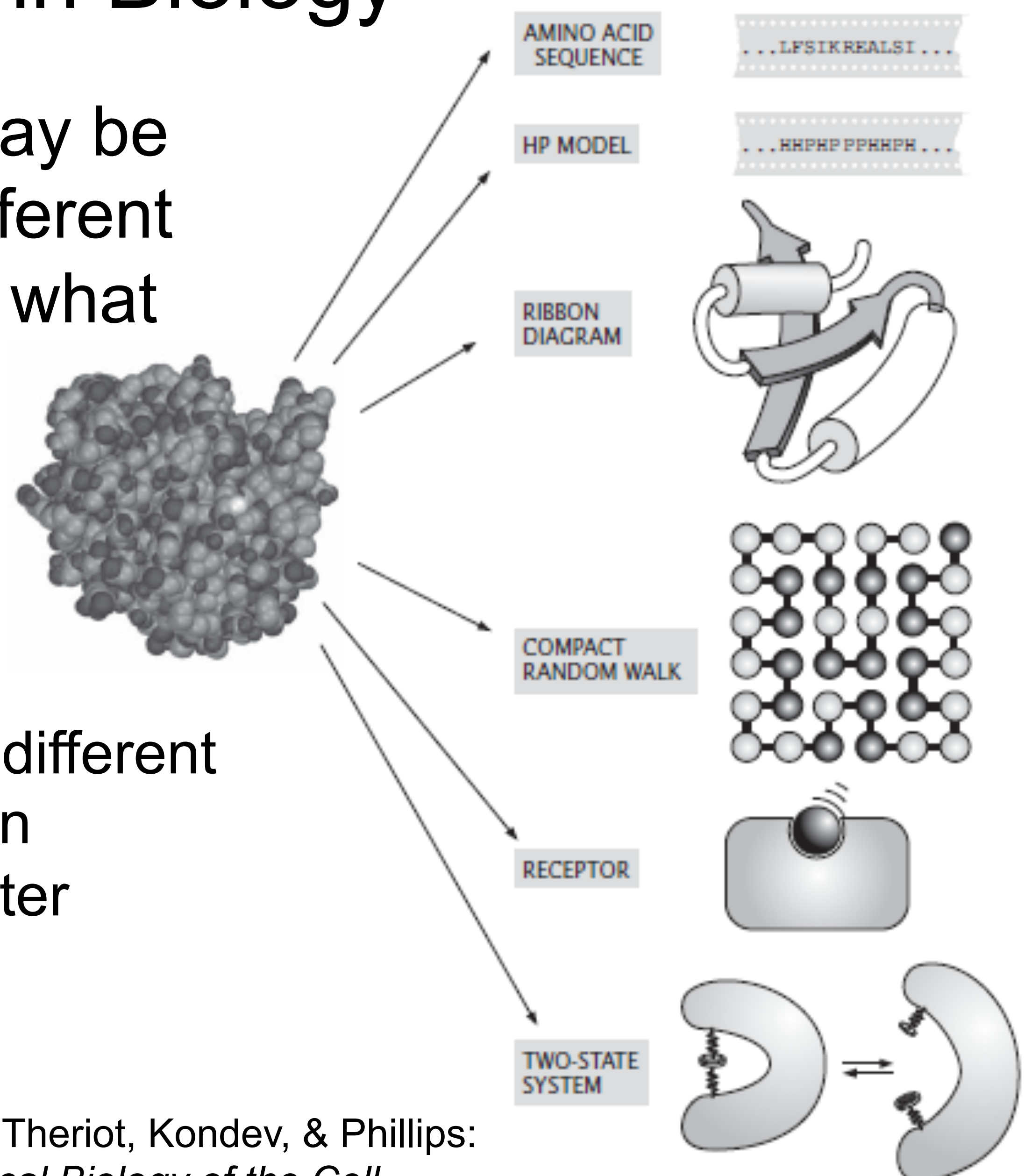
Is "species" a model?
If so, of what?

How about "genome"?

How about "protein"?
Come up with a model of your favorite protein.

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
- ...

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

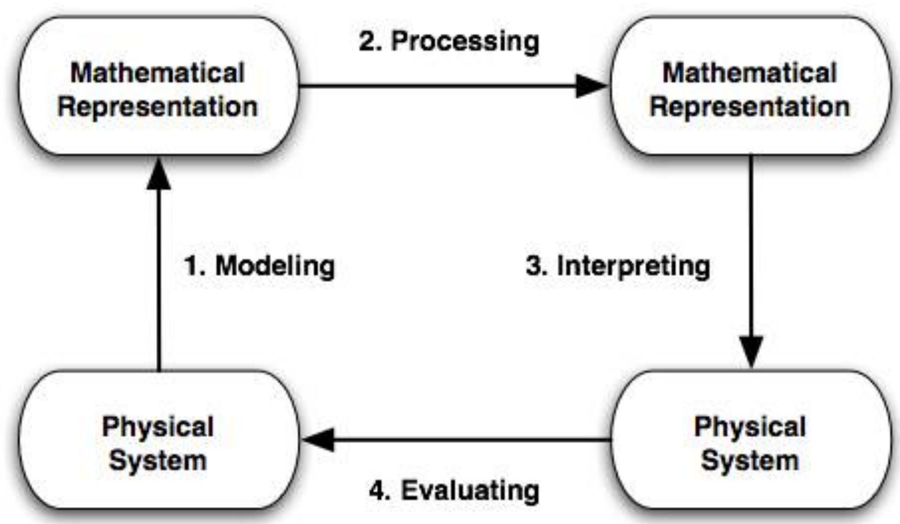
Modeling in Physics

- 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.



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.

Foothold ideas: Dimensional and unit analysis

- We label the kinds of measurement that go into assigning a number to a quantity like this:

  [x] = L means "x is a length"

  [t] = T means "t is a time"

  [m] = M means "m is a mass"

  [v] = L/T means "you get v by dividing a length by a time

L = L + L?

- Units specify which particular arbitrary measurement we have chosen.
  - Units should be manipulated like algebraic quantities.
  - Units can be changed by multiplying by appropriate forms of "1" e.g. 1 = (1 inch)/(2.54 cm)

Foothold ideas: Dimensional analysis

- In physics we have different kinds of quantities depending on how measurements were combined to get them. These quantities may change in different ways when you change your measuring units.
- Only quantities of the same type may be equated (or added) otherwise an equality for one person would not hold for another. Equating quantities of different dimensions yields nonsense.
- Dimensional analysis tells us *how* something changes when we either
  - Change our arbitrary scale (passive change)
  - Change the scale of the object itself (active change)