Physics 131- Fundamentals of Physics for Biologists I

Professor: Arpita Upadhyaya

QUIZ 1

10 min

1. The Quiz was easy
2. The Quiz was hard
3. The Quiz was just all right

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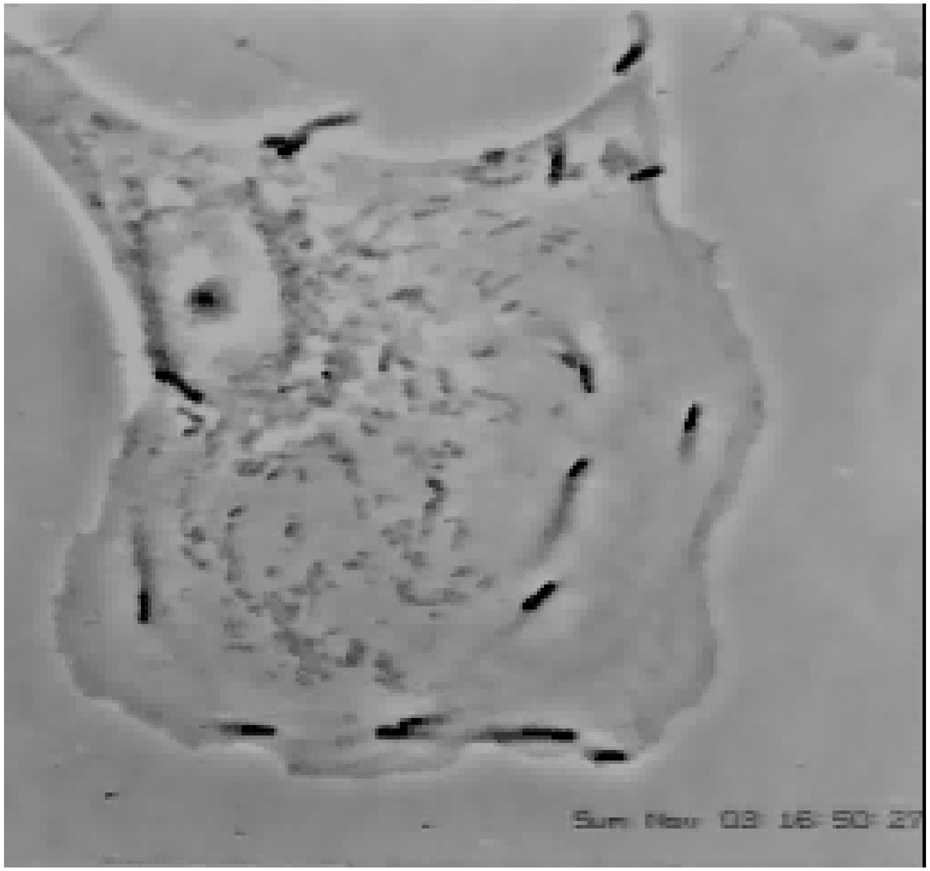

Topics

- Estimation
- Modeling the world
- Math in science
- Units and dimensions
- Scaling

Estimate the number of cells in your body

A. 10^4
B. 10^6
C. 10^7
D. 10^8
E. 10^9
F. 10^{10}
G. 10^{11}
H. 10^{12}
I. 10^{13}
J. 10^{14}

Given that the average size of a human cell is about 10 microns across, estimate the number of cells in your hand.

1. 10^0
2. 10^2
3. 10^4
4. 10^5
5. 10^6
6. 10^8
7. 10^{10}
8. 10^{12}
9. 10^{14}

Given that the average size of a human cell is about 10 microns across, estimate the number of skin cells in your hand.

1. 10^0
2. 10^2
3. 10^4
4. 10^5
5. 10^6
6. 10^8
7. 10^{10}
8. 10^{12}
9. 10^{14}

You should know that 1 cubic cm of water has a mass of 1 gram. What's the mass of 1 cubic meter of water?

A. 10 g
B. 10^2 g
C. 10^4 g
D. 10^6 g
E. 1 kg
F. 10 kg
G. 100 kg
H. 1000 kg
I. None of these

Topics

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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.

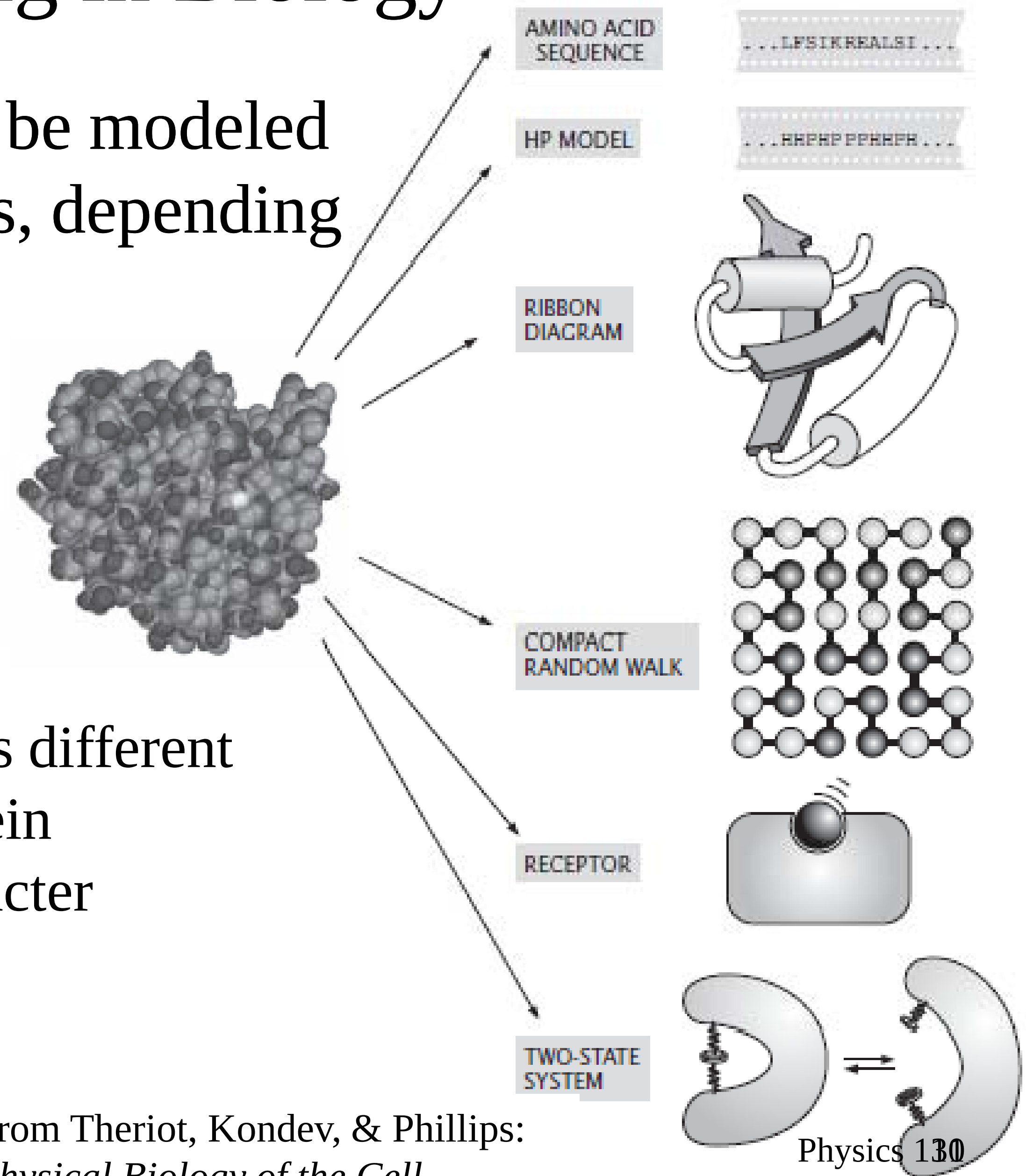
Is "species" a model?
If so, of what?

How about "genome"?

How about "protein"?

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

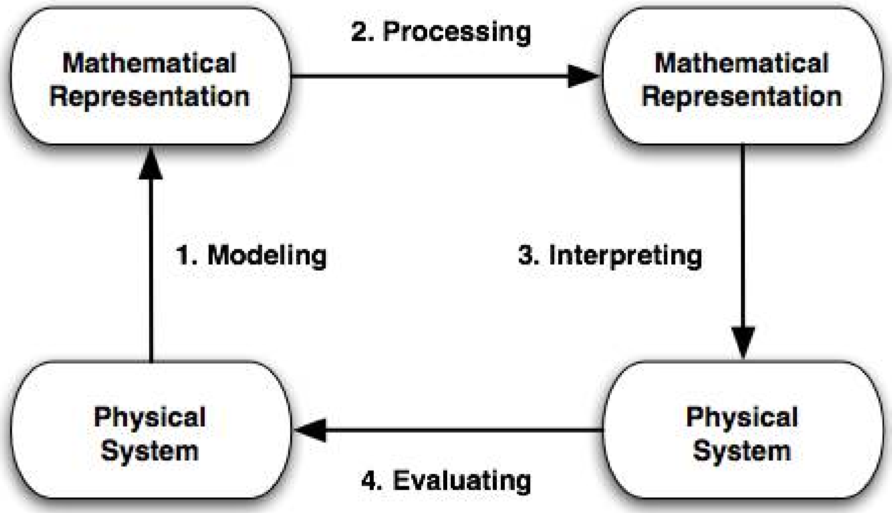
Modeling in Physics

- 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.



Reading Summaries

- Students often have difficulty mastering familiar mathematical concepts when viewed in a scientific context. This difficulty stems from the math use in science as a modeling apparatus rather than for pure calculation. When using math to represent the physical world, students must take into account units of measurement. They must deal with increased numbers of symbols that defy math convention and can switch between being variables and constants; these symbols have specific meanings in different contexts and represent quantities that may not be equatable.**
- The main purpose of this article was to highlight the point that math in science courses is not used as a computational tool but as a tool to model phenomena in the physical sciences. There are several differences between the way math is used in math classes and the way it is used in science classes presented in this article. First, math in math classes is about numbers, where in science classes it is not. The numbers used in science classes must have dimensions and units in order to make any sense when relating to a particular problem-they are ntot just numerical values. Math in math classes tends to use a small number of variables in clearly defined ways all of the time. In science classes math problems tend to have many more variables whose meaning can fluctuate depending on the context of the problem. …

Reading questions

- Physics is very math intensive by nature, what types and topics of math will we primarily apply in this course? I've heard a lot that physics for the life sciences is taught without calculus; is this true?**
- Even though math in science is more difficult than math in math, does a good understanding of math in math imply you can easily understand math in science?**
- What is a medical example of how math is used within science?**
- How is the concept of infinity in pure math applied in scientific disciplines?
- What sort of models are made with equations?**
- Why do we use mathematical homonyms so often instead of using more different letters from the English and Greek alphabets?**
- Is modeling a physical, chemical, or biological system with math the same as predicting what will happen within the system?**
- What types of physicals systems might be modeled in the sciences?**

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?

Consider two mathematical models of real world things: position and time. We map positions and times into numbers. What kinds of numbers are we mapping to?

1. Integers
2. All numbers (+,0,-)
3. Rational numbers
4. Non negative only
5. Real numbers
6. Positive only

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.

Units

- Units specify which particular measurement we have chosen (e.g. meter, kg, second).
  - 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)

Units are important:

A 125 Million $ Mistake

http://en.wikipedia.org/wiki/Mars_Climate_Orbiter

Mars_Climate_Orbiter

Unit Conversion

Convert the following

A. second to millisecond
B. millimeter to meter
C. Inch to centimeter
D. Kg to minute

1. 10^{-6}
2. 10^{-3}
3. 2.54
4. 100
5. 10^{3}
6. 10^{6}
7. Cannot convert
8. Do not know

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

- **Models allow us to think about how the numbers fit together**
- **<u>A first check on any model - Dimensional analysis:</u> Both sides of an equation have to have the same dimension**

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)

Reading Questions

- If two things have the same dimensionality does that necessarily mean they have the same unit? **
- Why do so many different units exist for the same dimension?**
- What will be more important in a real world question, the dimensions of something or its units when looking to classify material?**
- What's an example of the dimensionality of a biological variable?
- Can the variables which represent dimensionality also be manipulated just like any other variable?**
- Is it a goal of physicists to take different perspectives on one concept or thing?**
-

Which equation represents the quantity on the left?

A. The area of a circle.
B. The volume of a sphere.
C. The circumference of a circle.
D. The surface area of a sphere.

1. $2\pi R$
2. $4\pi R^2$
3. $\frac{4}{3}\pi R^3$
4. πR^2