Welcome to Physics 498Bio

Understanding biology using "simple" ideas from physics.

Your host:

Professor Paul Selvin
Office: 365 Loomis
Office Hr: after class or 10:30-11:30 Friday.
(Can anyone NOT make it?)
selvin@uiuc.edu: 244-3371

Your co-host:

Dylan Reid, 1st year biology student
Office: 364 Loomis
Office Hrs: sEither Sunday OR Tuesday 1-2pm
Depending on whether HW due on Mon. or Wed.
reid2@uiuc.edu, 333-1850
HW due 1 week from date of assignment

Course Info:

Online.physics.uiuc.edu/courses/physics498bio/spring08
Or
people.physics.uiuc.edu/Selvin/PRS/PRS.html
then physics498bio Spr08
Or
physics.uiuc.edu, Courses, Intro to Biophysics Research (next to 498Bio)

Course Information Physics 498Bio

Introduction to Biological Physics

You've (hopefully) made a good choice!

Prerequisites

Physics 111, 112 (or equivalent)

Some knowledge of Statistical Mechanics

Gibb's Free Energy, $\Delta G = \Delta H - T\Delta S$;

Boltzmann's Constant, k;

Boltzmann Factor: $\exp(-E_i/kT)$

(Remember in useful units:

[kT = 4 pN-nm; ATP = 80-100 pN-nm ~ 25 kT])

Some elementary calculus.

No previous biology assumed. I teach it in course.

Required Reading

Essential Cell Biology, 2nd edition:
by Bruce Alberts et al.

Excellent introduction to biology,

Need to know biology in order to do biophysics!

Using physics to understand biology!

Not biology to understand physics!

Goals of course

1. Learn some basic molecular biology.

DNA (PCR, sequencing)

Proteins... can do everything!

2. Learn how to apply basic physics to biology.

Mechanics, Electricity & Light, Statistical Mechanics

(Example today – What planets are life possible on?)

3. Learn about/type problems biophysicists work on.

Biology...

Molecular motors (chemical → mechanical)

Ion Channels (chemical →Ion Gradients →electrical)

Photosynthesis (light → electrical→chemical energy)

Stochastic Nature of gene expression,

Magnetic Navigation, Vision...

4. Learn "back of the envelope" type calculations.

Example today: Strength of animals

5. Learn experimental (bio)physics

How to measure (nm distances, pN forces),

Single molecules (Fluorescence, Optical & Magnetic Traps), Patch Clamp Techniques

Some guest lecturers– people doing the stuff!

Klaus Schulten, --Magnetic Levitation

Yann Chemla…--Optical Traps.

Course Schedule

DNA & Proteins

1) Jan. 14th : Intro; King Kong; Temp. of Earth; DNA and Proteins; Evolution
2) Jan 16th : Nucleic Acids & Boltzmann Constant
3) Jan 23rd : Nucleic Acids & PCR, Amino Acids, Proteins
4) Jan 28th : DNA Fidelity, RNA Catalysis, & Gene Chips
5) Jan 30th : Gene Chips; Beginning of Enzymes

Imaging & Microscopy –seeing small things.

6) Feb 4th : Diffraction limit, different kinds of microscopy (EM, X-ray).
7) Feb 6th : Fluorescence: very useful form of microscopy. Can see single molecule!
8) Feb 11th : ATPase Operates at near 100% Efficiency
9) Feb 13th : FIONA; 1 nm accuracy (not resolution). Applied to Molecular Motors
10) Feb 18th : SHREC, PALM, STORM—20 nm resolution.
11) Feb 20st : STED, FRET
12) Feb 25th : FRET and DNA helicase—TJ's Science magazine article.

Magnetic Sensing: which way is home?

13) Feb 27th : **Klaus**—Magnetic sensing.

Mid-term Exam.

14) March 3rd : Review + tour of my lab
15) March 5th: **Mid-term Exam**

Optical Traps allow you to see Angstrom & Nanometer distance.

16) March 10th : **Yann Chemla**
17) March 12th : **Yann Chemla** + tour of his lab

March Vacation

Diffusion

18) March 24th : Freely jointed vs. Worm-like Chain of DNA: Magnetic Traps
19) March 26th : Diffusion: Inertia doesn't mean anything
20) March 31st : Diffusion and Bacteria Moving
21) April 2nd : **Student Presentation**
22) April 7th : **Students Presentation**

Vision & Ion Channels

23) April 9th : Ion Channels
23) April 14th : Ion Channels
24) April 16th : Vision

Most Genes are few in Number—some surprising results

25) April 21st : Studying Gene Activity in Individual Cells.
26) April 23rd : Studying Gene Activity in Individual Cells

Photosynthesis

27) April 28th : Photosynthesis.
28) April 30th : Instruction Ends
29) May 6th Tues., 8-11AM: Final Exam

Grading

(may be modified slightly if changes to course)

Grading

25%: Homework (about 9 total; drop lowest 1):
(You CANNOT drop the last homework!)
Work together, but turn in separately.
Hand in at start of class– in class! (Do not be late.)

25%: Written Project & Oral Project– Same topic
-- 12.5% on written report: 10 pg report.
-- 12.5% on oral report: 8-12 min plus 4 min for questions.

15% on midterm exam

15% on final exam

10% Quizzes (1% on each)
--5 min quizzes making sure that you've read readings

10% on classroom participation /class evaluation

Yes, you get to evaluate class!

Three (or 4) questions:

1. What was the most interesting thing you learned in class today?
2. What are you confused about?
3. Related to today's subject, what would you like to know more about?
4. Any helpful comments.

Answer, and turn in at the end of class.

(I'll give you ~5 minutes.)

I'll typically start class with some of your questions.

Get to know your neighbors

You will have to report to the whole class immediately afterwards! –so listen up!

With a partner (who you don't know)…

Tell your name, your year (undergrad, vs. grad.)

What you want to be when you "grow up"

Tell one thing that's surprising about yourself.

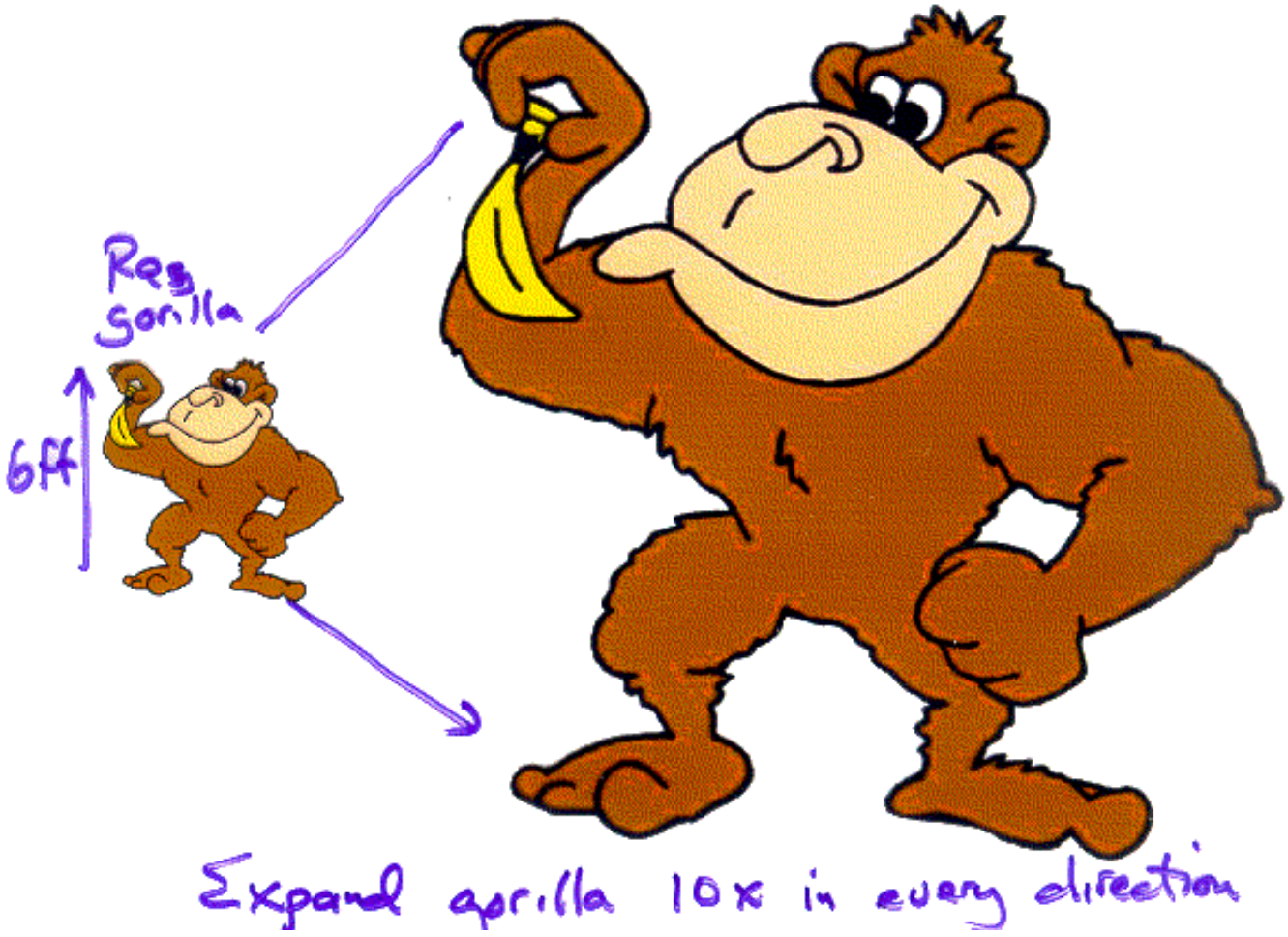
An example:

What determines size of you?

Example of Physical constraints & Scaling Laws.

Could King Kong have existed?

Why gymnasts are small; why ants are so strong.



Mass? (density is the same): $10 \times 10 \times 10 = 10^3$

Strength? α Cross-sectional area (rope): $10 \times 10 = 10^2$.

Strength/Mass ratio? 1/10… 1/dimension

King Kong is proportionally speaking is 10x weaker than regular gorilla!

Regular gorilla with 10 gorilla's on him—couldn't walk.

Example Strength & area

Bones of the deer-family

Bison & deer roughly same shape, but bison bigger.

Gazelle

Bison

Gymnasts…Elephants.

Whales? If really thick bones…

In water– held up by buoyant force.
Bones do not need to support weight
If have to, have super big bones– would sink.

If whale stranded on the beach?

Bones break; also overheat (because warm-blooded and water is going at conducting away heat, whereas air is not.)

Is there water-based life on other planets?

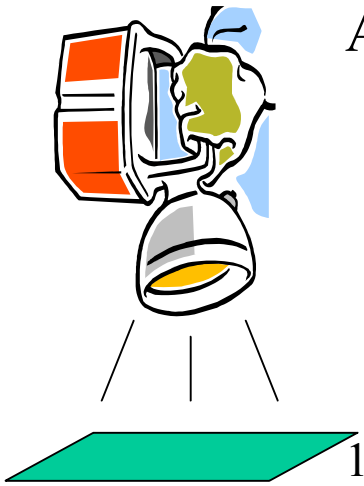
Example of physical limits to life.

Idea: For water-based life, $0^o < T_{ave} < 100^oC$

Can we calculate T_{ave} of planets in our solar system?

Earth

What determines (surface) temp?



Answer: Heat (photons) from sun

How much light?

$I_e = 1.4\ kW/m^2$

How many (flood)lights?

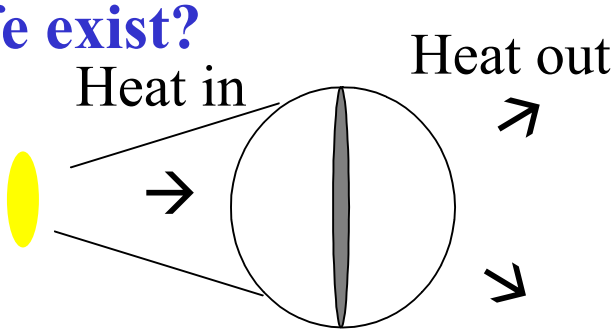
Floodlight ~ 30 (1 meter away)

(Incandescent light 3% efficient)

Why determines earth temperature?

Why can life exist?

Temp of earth constant
Heat in = Heat out



Heat In (Absorbed) = **Heat Out/ m^2**

$= \alpha I_e \pi R_e^2$ $= \alpha\sigma T^4$

α = reflectivity of object

σ = const (=5.7 x 10^{-8} $W/m^2 0k^4$)
T = absolute Temp.

(Stefan-Boltzmann Law)
Kittel, Thermal Physics pg 91-96

$\alpha I_e \pi R_e^2 =$
$(\alpha\sigma T^4)\ (4\pi R_e^2)$

[Note α, R_e^2 cancel]

$$\frac{I_e}{4\sigma} = T^4 \qquad \left[\frac{1400 w/m^2}{(4)(5.7\times10^{-8} w/m^2k^4)}\right]^{1/4} = \langle T_e \rangle$$

$$= 280° \text{ K}$$

Actual $\langle T_e \rangle = 289°$ K Amazingly accurate!

(Also shows temps of earth primarily determined by sun's photon, not earth's mantle.)

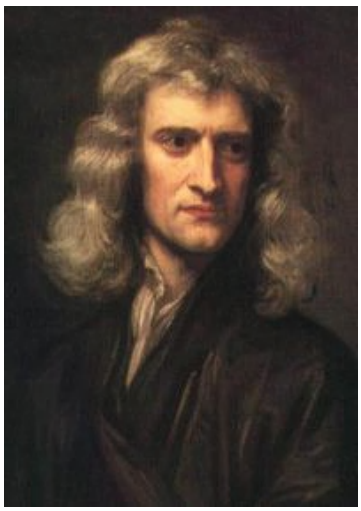
Homework (to be assigned today: see HW #1):
Given distance to each of our solar system's planets, calculation whether water-based life could exist.

Physics is about great laws

Some examples…

Newton's three Laws

(Mechanics)



Isaac Newton, 1642-1727

Maxwell's four Equations
(Electricity & Magnetism)

James Clerk Maxwell
1831-1879

Erwin Schrödinger 1887-1961

Schrodinger's Eq'n
(Quantum Mechanics)

Does Biology have any great theories/laws?

Charles Darwin, Age 51, 1860,
On the Origin of Species

Evolution

-- Life evolved from simpler forms

--One of the best tested scientific theories around

Evolution is a series of tricks/random events

Build complex beings from simpler parts

Often many ways of doing this
Our life form is just one.

Homework

Read

Intro by Stryer

On web-site under HW 1.

(PDF is there.)

Homework Set #1

On web-site under HW 1.
(PDF is there.)

Evaluate class

1. What was the most interesting thing you learned in class today?
2. What are you confused about?
3. Related to today's subject, what would you like to know more about?
4. Any helpful comments.

Put your name in upper right-corner.

Then tear off your name before turning in.
(That way you can be brutally honest!)

Answer, and turn in at the end of class.

(I'll give you ~5 minutes.)