Teaching Physics for Pre-Medical Students at UCLA.

Undergraduate Curriculum

• General science requirements:
  • Math with calculus: three quarters (freshman)
  • Physics with calculus: same (sophomore)
  • General Chemistry: same
  • Organic Chemistry: same

• Life-Science requirements:
  • Biochemistry
  • Molecular, Cell and Developmental Biology
  • Genetics
  • Physiology

*Acceptance by UCLA medical school: requires average of A-. 

Heavy course load
Students

20 %  First time exposure to Physics.
30-40%  “Algebra-based” Physics in high school.
30-40%  Advanced Placement physics class with some calculus.

• Student quality and preparation: very heterogeneous pool.
• Top 15% compares well with physics and engineering majors.

Physics 6

• 1, 100 - 1, 500 students per year; more than 2/3 pre-med.
• Typical class size: 200 - 300.
• Last physics-based class for life-science student. No biophysics!
• Major “service-class” of UCLA Physics Department.
Three contact hours per week + one hour recitation session. Homework problems + “equation drill”. Weekly lab class.

- Physics 6A: Mechanics
  6B: Electricity and Magnetism
  6C: Waves, Optics, Modern Physics

* Soft version of “Halliday-Resnick” general physics.

- Taught by mixture of ladder faculty (often HEP) and “soft-money” instructors.
1994: Dean Roberto Peccei:

- Reform of General Science Requirements.

- Reorganize Physics 6 to reflect needs of Life-Science students.

Life Science faculty: dissatisfied about General Science curriculum. No consensus about content for an appropriate physics class.

- Department and Dean supported hiring Biological Physics faculty.
Why should Life-Science students have to take a physics class?

• Essential part of scientific literacy. Foundation of a rational, scientific analysis of nature. “Lewis Thomas argument”

But how does “equation drill” serve that purpose?

• Life science students practically never use an equation of Physics 6 in the remaining Life Science curriculum. Only rarely as MD’s or as career Life Science professionals.

• Physics is imbedded in the “protocols” for experimental procedures or operation of equipment (NMR, Xray, laser, ultrasound, ..)
Existing Physics 6 could be dropped from the Life Science curriculum without serious negative impact.

- What **concepts** will Life-Science students encounter in their Life Science **required classes** that require physics for a serious understanding?

  * Can the Halliday-Resnick curriculum be updated to achieve this?
Physiology and Animal Anatomy ("Marieb")

• Mechanics:
  • Forces on skeleton. ("Biomechanics")
  • Physics of senses: Vision, Hearing, & Speech.
  • Hydrostatics and Hydrodynamics:
    • Blood pressure.
    • Blood circulation. Laplace Law.
    • Swimming and Flight.

• Thermodynamics:
  • Metabolism.
  • Thermoregulation.
  • Osmotic Pressure.

• Electricity.
  • Transport of Nervous Signals
Molecular Biology and Biochemistry ("Alberts", "Stryer").

- Macromolecule Interaction (hydrophobic interactions, van der Waals, ...)
- Electrophoresis.
- Sedimentation.
- X-ray crystallography and NMR.
- Thermodynamics of Energy Transfer.
- Membrane Electrical Potential.
Can the H-R curriculum be upgraded? Add problem sets and/or extra chapters. (Giancoli, Serway, ..)

- Time-constraint Problem. Extra material is dropped.

- “Wrong Physics” Problem

Example: Electrical Transport

H-R Curriculum: Definition of EMF, Ohm’s Law, Equivalent Resistance, Kirchhof’s Laws, “Circuit Drill”.

Electrical circuits in water: short-circuit.
Electrical potential of a cell in water.

Chemical potential of ion.

\[ \mu = \mu_0 + eV + k_B T \ln c \]

Second Law of Thermodynamics:

Thermal equilibrium: \( \mu_{in} = \mu_{out} \)

\[ \Delta V_{eq} \cong \left(\frac{k_B T}{e}\right) \ln \left(\frac{c_{in}}{c_{out}}\right) \]  
Universal voltage scale (about 20 mV)
Ohm’s Law: current density of ion $i$:

$$J_i = g_i \left( \Delta V - \Delta V_{eq}^i \right)$$

Conservation of Electrical Charge:

$$J_{total} = \sum_{\text{ion species}} J_i$$

For a cell: must vanish under steady state conditions.

Membrane potential:

$$\Delta V = \frac{\sum_i g_i \Delta V_{eq}^i}{\sum_i g_i}$$
- four fundamental physical principles!

- Can an undergraduate physics curriculum be constructed that does support the Life-Science curriculum?

- Is relevant undergraduate material even available?

1996-1999:

* Wrote lecture notes for Physics 6A, B, & C
  Published by a custom publishing house (Hayden-McNeill) (teaching relief from Dean). Aim: book form.
* Lab reconstruction (funded by Dean and NSF).
* Pilot classes 50-100 students.
  Students response to new lectures was very positive. Did better in MCAT exams
* Problems with new labs (mechanics arm, heat diffusion,..).
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dynamics
1999-2001: Full Scale

Growing problems

• Faculty members not comfortable with new material. TA’s could not deal with problem sets involving new material (example: hydrodynamics). Faculty communicated negative attitude to TA and soft-money instructors.

• Faculty Angst: “Students ask me questions about photon absorption in eye by retinal molecules (“cis-trans isomerisation”) that I am teaching. They know more than me about subject!”

• Violation of “Social Contract”: “It is 11 pm. I have to prepare next day’s class. I don’t want to learn about membrane potentials. This is a large class which already takes a lot of my time”
Dean Peccei: suggests a teaching manual to assist faculty.

**2001**: Faculty votes to return to the old format.

**2003**: Physics 6 is *split*:
- Regular series: “old” format.
- Honors series: “new” format.
  Maximum class size: 100 students, taught by Biological Physics/Soft Matter faculty (three experimentalists, two theorists).

**2005**: Biophysics Major at UCLA.


Regular series: *Revitalized* (by Katshushi Arisaka). Student seminars on topics like special relativity, black holes, super nova’s.....
Conclusions

• Teaching physics appropriate for a Life Science curriculum in a research-based institution requires faculty members with research programs in Biophysics or Biological Physics.

• The graduate students of these faculty members are the “natural” TA’s of the class.

• Offering a choice to the Life-Science student about the type of Physics class they can take works well for a large, heterogeneous student body.

• “Top-down” teaching reforms may run into faculty resistance.