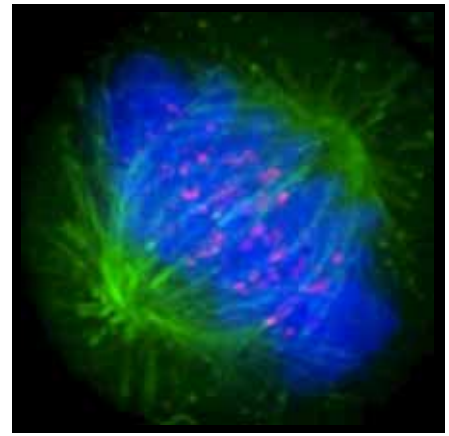
$$\Delta V_1 = \frac{KQ}{(x^2+b^2)^{1/2}}\Bigg|_{x=0}^{x=a} = \frac{KQ}{(a^2+b^2)^{1/2}} - \frac{KQ}{(0^2+b^2)^{1/2}}$$

$$\Delta V_2 = \frac{KQ}{(a^2+y^2)^{1/2}}\Bigg|_{y=b}^{y=c} = \frac{KQ}{(a^2+c^2)^{1/2}} - \frac{KQ}{(a^2+b^2)^{1/2}}$$

$$\Delta V_3 = -\frac{KQ}{(x^2+c^2)^{1/2}}\Bigg|_{x=0}^{x=a} = -\frac{KQ}{(a^2+c^2)^{1/2}} + \frac{KQ}{(0^2+c^2)^{1/2}}$$

$$\Delta V_4 = -\frac{KQ}{(0^2+y^2)^{1/2}}\Bigg|_{y=b}^{y=c} = -\frac{KQ}{(0^2+c^2)^{1/2}} + \frac{KQ}{(0^2+b^2)^{1/2}}$$



UNIVERSITY OF MARYLAND 1856

# Reforming Physics for Biologists and Pre-Meds: Disciplinary Barriers

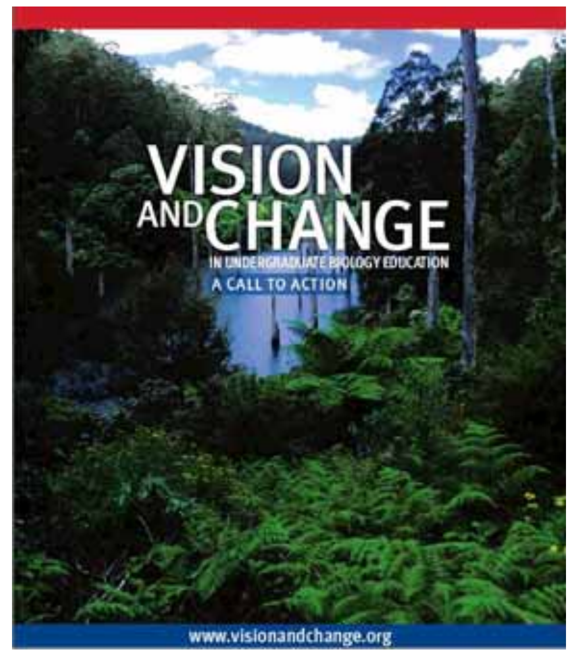

Edward F. Redish
University of Maryland


HHMI

# Calls for Bio Education Reform


NAS 2003


HHMI-AAMC 2008




AAAS 2009

# + Project NEXUS

- National Experiment in Undergraduate Science Education
  - A 4-year $1.8 M project of the Howard Hughes Medical Institute
- Interdisciplinary science education stressing competency building
  - UMCP (physics)
  - UMBC (math for bio)
  - Purdue (chemistry)
  - University of Miami (capstone case study synthesis)

# Interdisciplinary conversations

- As part of our role in project NEXUS, we have begun to hold extended interdisciplinary conversations.
  - A major task of each group is to negotiate with biologists the <u>content</u> and <u>competencies</u> on which the courses will focus.
- In addition, for a CCLI project, we have been interviewing biology students in a course in organismal biology that uses significant physics.

# + Discussants

- Physicists
  - Joe Redish
  - Wolfgang Losert
  - Catherine Crouch
  - Jessica Watkins
  - Chandra Turpen
  - Ben Dreyfus
  - Michael Fisher
  - Peter Shawhan
- Biologists
  - Todd Cooke
  - Jeff Jensen
  - Karen Carleton
  - Joelle Presson
  - Kaci Thompson
  - Marco Colombini
  - Kristi Hall-Burke
- Education Specialists
  - Janet Coffey
  - Dan Levin
  - Jen Richards
  - Julia Svoboda
  - Gili Marbach-Ad

# Some early observations

- These conversations have turned up differences among the professionals in the different disciplines (and even within the disciplines).
- Our interviews with biology students show expectations and perceptions of the disciplines that can affect how they react to “interdisciplinization”.

# Epistemology?



- Many of the differences we encounter (and many of the arguments we have – and there are many!) are epistemological: – about the nature of the knowledge to be learned and what needs to be done to learn it.

# Epistemological differences

- In the next few slides I will summarize my view of some of these differences.
- These do not necessarily reflect differences between the way the professions look – but rather the way typical introductory courses look to the students.

# Physics

- Intro physics often stresses reasoning from a few fundamental principles.
- Physicists often stress building a complete understanding of the simplest possible examples – and often don't go beyond them at the introductory level.
- Physicists often quantify their view of the physical world.
- Physicists think with equations.
- Introductory physics typically restricts itself to the macroscopic level and almost never considers chemical energy


UGH...
WHAT HAPPENED?
WHERE AM I?
FWOOOOOOOSH
HELP! SOMEONE
HELP ME
HUH. LOOKS LIKE PHYSICS PROFESSORS DON'T LIKE WORKING IN FRICTIONLESS VACUUMS AFTER ALL.
THEY'RE SUCH LIARS.

# Biology

- By its very choice of subject biology is complex.
- Most introductory biology is qualitative.
- Biology is fundamentally historical.
- Much of introductory biology is descriptive (and introduces a large vocabulary) though
- Biology – even at the introductory level – looks for mechanism and frequently considers micro to macro connections.
- Chemistry is much more important to intro bio than physics (or math).

# + Chemistry

- By its very choice of subject, chemistry is about the atom and molecular level (micro scale).
- Chemistry (especially intro chem) is about the connection between what happens at micro and macro scales.
- As a result, much of what is important in chem takes place in an environment, not in vaccuo – but in a gas, liquid, or crystal.
- Chemical energy is crucial to chemistry, but chemists often talk about binding energy (the negative of chemical energy).

# Mathematics

- Mathematics is about mathematical structures and abstract relationships. It's not "about" anything physical.
- When we map physical meaning onto a mathematical structure, we inherit the mathematical tools that go with that structure – but that restricts our interpretation and freedom to use those tools.
- The transition to applications may be more challenging for students than those of us who have mastered the "hidden rules" of math-in-science might expect.

# Implications

- Epistemological differences between the disciplines have two broad implications.
  - Faculty in the different disciplines don't typically communicate well concerning service courses – if at all.
    - When they do communicate, they may not understand each other.
    - Service courses may not serve – or connect.
  - Students taking courses in multiple disciplines may not understand why they need them.
    - They may "silo" – refusing to transfer.
    - They may resist efforts to bring in knowledge across disciplines

# Designing a physics course for biologists

- In designing a new physics class specifically for biologists we want the course to
  - contain physics content that is useful for bio instructors teaching upper division bio classes;
  - help students develop general scientific thinking and reasoning skills and competencies;
  - “feel” biologically authentic to the students in the class – that is, they see that learning this physics helps them make sense of and better understand important results they have learned in biology.

# It's not so easy!

- A lot of critically important physics for biology is complex and relies on a lot of other physics.
  - We can't just do the groundwork and assume they will teach the later physics in upper division bio.
- A lot of critically important physics for biology relies on macro-micro connections.
  - We can't just stick to basic macro treatments.
- We need to figure out what to leave out as well as what to include!

+
# Our decisions

- Present the class as a second year class with prerequisites
  - two semesters of bio (some intro so cellular, molecular, evolutionary, and ecological bio)
  - one semester of chemistry
  - one year of math (basic calculus and probability)
- Rely on a familiarity with biological systems and language to replace traditional macro examples by micro ones.
- Rely on a familiarity with chemistry to include chemical energy and molecular modeling.

# Physics / Biology Barriers: 1

- Even biologists who want to use physics in their bio classes might be satisfied in choosing bits and pieces and ignoring coherence and deep structure.
  - “You don’t need to study forces in physics for biologists. Just teach energy.”
  - “Most of the places where we need physics takes place in fluids where Newton’s laws don’t hold.”

# Physics / Biology Barriers: 2

- Even biologists who want to use physics in their bio classes may reason with physics differently than physicists do.

  - "The worm problem" – an example of trying to be authentic to both physics and biology in the first week of class (dimensional analysis and scaling).

# Dimensional analysis, units, and scaling

- Authentic physics
  - One of the basic tools in "thinking like a physicist."

- Authentic biology
  - Scaling and functional dependence plays a crucial role in a lot of biological processes.
  - Rated of as one of the most important topics in physics in *Ratings of the Importance of Topics in the Natural Sciences, Research Methods, Statistics, and Behavioral Sciences to Success in Medical School* (AAMC, 2010).

# + A problem

- A problem posed by a biologist for a bio class was rewritten by a physicist.
  - The bio version focused on numerical comparisons and changes that were biologically relevant.
  - The version “improved” for the physics class focused on reasoning with symbols, equations, and graphs.
  - The biologist deemed that the problem was now physics – useful for a physics class but without biological validity.
- A compromise was reached.
- How will bio students respond? Stay tuned. We try it in the fall.

# What did we learn from this activity?

- Biologists and physicists look at things differently.
- These are not trivial differences.
- How will this play out with students?
- Students are aware of these differences early – indeed, sometimes they select their choice of science in part because of their perceptions of these differences.

# + Physics / Biology Barriers: 3 Biology students bring expectations to their physics and biology classes.

Ashlyn prefers silos – keeping physics and math in physics  and math classes and out of biology.

Ellen “doesn’t mind” physics but doesn’t like phsyics abstroctions and prefers staying entirely in a bio context.

# + Conclusion

- Creating a physics course for biologists that "looks right" (authentic) to both biologists and physicists is going to be a challenge, both in content and in epistemology – the way we each look at knowledge.

- Student expectations can play a major role, yielded unexpected resistances and failures to connect.

- But it'll be fun, right?