Laboratory Development Efforts in a Physics for Biologists Course

Benjamin Geller[1], John Giannini[2], Kim Moore[1], Edward F. Redish[1], Wolfgang Losert[1,2]
[1]Department of Physics, University of Maryland, College Park
[2]Biophysics Program, University of Maryland, College Park

Motivation for the Course

In response to calls for greater integration of physics principles into undergraduate biology* and pre-health education, we have piloted the first iteration of a new physics course for biology majors at the University of Maryland. As part of the NEXUS (National Experiment in Undergraduate Science Education) project,** the course seeks to break down traditional barriers that have led to the construction of disciplinary "silos." The curriculum has been developed by an interdisciplinary team of physicists, biologists, and biophysicists, and has involved departures from the traditional introductory physics curriculum in order to emphasize the physics topics most relevant for biology (see Table to the right).

NEXUS NATIONAL EXPERIMENT in Undergraduate Science Education

Our Course –vs- Traditional Introductory Physics

- Prerequisites: One year of biology, one semester of chemistry, one year of calculus
- Incorporation of many biological examples in which students see the use (and methods) of physics as helpful in helping them make sense of important biology
- Emphasis on (a) coherence-seeking between and within disciplines, (b) modeling, and (c) development of metarepresentational competence

Biology components of HW Assignments

Worm / How Big is Protein	Moving through a cell / Listeria	Blood and Breath	Para-mecium	Exam Review	Wood-pecker	Water coat force / DNA charge	PIP2	Arteries / Speed of blood	Exam Review	None	Bound States / Deeper Well	Muscle Contract / Thermal-chemical	Diffusion

Math | Kinematics | Dynamics | Exam 1 | Dynamics | Macro | Energy | Exam 2 | Thermodynamics

Math Problems	Cat & Antelope	Force Problems	Friction Problems	Motion in 2D	Electric Forces (Balloons)	Electric Forces (clickers)	Buoyancy Force Problems	Elastic Collisions	Protein Unfolding	Energy Skate Park	None	Temp. Regulation	Micro-states

Biology-linked Recitation Tasks

Include atomic and molecular examples from the start

Expand the treatment of fluids and thermodynamics

Biology components of HW Assignments

PE analogs for chem. rxns	Polymer folding / Evolution	Evap. Membrane	Analyzing Dipoles	DNA Shielding	Nerve Cells	No assignment	No assignment	No Bio Content	Waves on an axom	No Bio Content	No Bio Content	Micro-scope	DNA and photons

Intro | Thermo | Electricity | Exam 1 | Waves | Light | Ex 2 | Light

Kinesin	Membrane 1	Membrane 2	Electro-phoresis	Big Square	DNA Salting Out	Circuits	Diatomic Vibrations	Pulse Tutorial	Ultrasound	Mirrors	Pulses and SHO	Models of Light	Vision

Biology-linked Recitation Tasks

Eliminate rotations, angular momentum and magnetism

Guiding Principles for Lab Development

- Labs must connect to and support relevant lecture materials (some flexibility, however, with timing).
- Labs ought to give students sufficient freedom for investigation (don't guide too much).
- Lab tools (ImageJ, Excel, Microscopy, Microfluidics) should be integrated into other elements of the class.

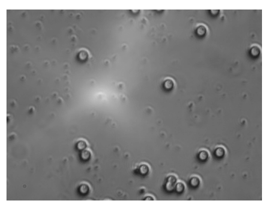
Equipment and Materials

Model IN300TC-3M inverted microscope from Amscope (~ $2500)
-- 4x, 10x, 20x, 40x objectives, adjustable XY stage
3.0 MP CCD camera (comes with microscope)
-- frame rate adjustable between 0.2 and 30 s^{-1}
-- can capture still images, record and stream video
Objects to be studied
-- 0.5, 1, 2, 5, and 10 µm beads (polystyrene and glass)
-- living systems from creek water (student-supplied)
Fluids (to tune viscosity and density independently)
-- distilled water, glycerol, high-density Ficoll
Fluid holder
-- chamber slide, microfluidics to minimize convection
Additional supplies
-- tubes/vials, pipettors, C-mount
Software
--ImageJ, Excel

Fundamental Capabilities

Allows for observation and analysis of the motion of microscopic objects due to Brownian motion, gravity, and fluid flow

Can vary the following parameters in a straightforward way: bead size, object density, fluid density, fluid viscosity



Exploring Directed Motion, Random Motion, and Forces in the First Semester (Fall, 2012)

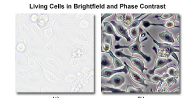
	WEEK	LABORATORY	KEY CONCEPTS & SKILLS
Directed Motion	1	Introduction to Excel	Software familiarity to analyze videos, standard kinematics, open-ended investigation and autonomy
	2	ImageJ, Analyzing Biologcial Motion Videos	
	3	Ball Falling Through a Fluid, Coffee Filter	Video capture and analysis, kinematics and resistive forces, dimensional analysis and scaling
	4	Ball Falling Through a Fluid (cont'd)	
Brownian Motion	5	Understanding and Quantifying Random Motion	Familiarity with microscope and random bead tracking, random –vs- directed motion, microscopic –vs- macroscopic connections, modeling motion
	6	Finding the Boltzmann Constant	
	7	Mystery Materials or Mystery Temperature: Find the Mass from Random Motion	Using Boltzmann, open-ended investigation and autonomy
	8	Mystery Materials or Mystery Temperature: Find the Mass from Random Motion	
Forces	9	Tilted Microscope, Varied Bead Size: Why Does Gravity Matter?	Random-vs-directed motion, microscopic –vs- macroscopic connections, balancing directed force with randomness
	10	Terminal Velocity and the Balance of Forces	
	11	Bring Your Own Question	Open-ended investigation and autonomy

Exploring Buoyancy, Microfluidics, and Optics in the Second Semester (Spring, 2013)

The lab syllabus for the second semester of the course is still under construction. The following topics are in the development stages:

Microfluidics (fluid flow and diffusion)
-- students will build their own microfluidic chamber during the first week of this unit
Buoyancy
-- use acrylic beads that are lighter than the surrounding fluid
Optics
-- phase contrast microscopy (particularly important in biology for imaging structures not visible using bright field microscopy)

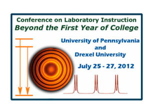
Living Cells in Brightfield and Phase Contrast



(a) Figure 2 (b)

See our AAPT posters for some interesting research results from the first year of the course:

PST2A10: Examining the Positioning of Ideas in the Disciplines, Vashti Sawtelle
PST2A20: Developing a Research-Based Introductory Physics Course for Biologists, Edward F. Redish
PST2A59: Research on Coherence Seeking Across Disciplinary Boundaries, Chandra Turpen
PST2A60: Research on Students' Reasoning about Interdisciplinarity, Benjamin Geller
FD07: Research on Students' Interdisciplinary Reasoning about ATP, Benjamin W. Dreyfus



References
* *Scientific Foundations for Future* Physicians (AAMC/HHMI, 2009), Vision *and Change in Undergraduate Biology Education* (AAAS/NSF, 2011)
** http://www.hhmi.org/news/nexus20110608.html

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Contact: geller@umd.edu

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