Electricity, Magnetism, and Optics with Biomedical Applications
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Physics topic sequence with biology contexts

This chart shows the life science contexts used with each physics topic in my second semester course in introductory physics for the life sciences. Each serves to anchor that particular physics topic to the life sciences. When we begin each new topic, I introduce and motivate it in terms of the context. These contexts are used in class, on homework, and when possible, explored in the laboratory.

Some are manifestations of the physics in living systems; others involve technology used widely by life scientists and/or physicians. I developed this list in consultation with colleagues in biology or medicine, and in most cases, I have learned about where each of these examples comes up in the chemistry, biochemistry, or biology curriculum at Swarthmore and try to make direct connection to it.

Physics Topic	**Biology Context**
Geometric optics	**Overarching context: vision and imaging**
Ray propagation	Pinhole imaging (invertebrate vision)
Total internal reflection	Optical fibers, endoscopes
Image formation with single lenses	Human eye
Image formation with lens combinations	Vision correction, optical instruments
	Blood vessels & blood flow
Electrostatics	
Electric force and field	Electrophoresis, charged cell membranes
Electric nature of matter: conductors and insulators, electric dipoles, polarizability of insulators	Molecular dipole moments, electrocardiography
Conductors in electric fields	Faraday cage shielding for sensitive electrophysiology measurements; screening in electrolyte solutions
Electric potential energy and potential, energy storage, capacitance	Charged cell membrane as capacitor, medical defibrillator
Effect of dielectrics on electric field, potential difference, and energy	Binding energy/solubility of salts in dielectric solvent; membrane dielectric constant affects amount of charge stored for given membrane potential difference
Electric circuits with batteries	**Nerve signaling**
Current, resistance, and resistivity	Resistivity of ionic solutions depends on ionic concentration; resistance of extracellular space is lower than resistance within nerve cell because of greater cross-sectional area
Resistor circuits	Gel electrophoresis
RC circuits	Factors affecting action potential propagation speed, role of nerve myelination

Magnetism	
Magnetic forces on charged particles	Mass spectrometry
Magnetic forces on currents	Issues for medical devices such as pacemakers in strong magnetic fields
Sources of magnetic fields	Electromagnets for MRI
Current loops as magnetic dipoles, magnetic dipoles in magnetic fields	NMR spectroscopy, magnetic navigation, magnetotactic bacteria
Electromagnetic induction	Pacemaker design issues
	Semiclassical model of chemical shifts in NMR as an inductive (diamagnetic) phenomenon
Electromagnetic waves and wave optics	**Overarching context: confocal microscopy**
Polarization	polarization sensitive vision in marine invertebrates and some insects
	circular dichroism spectroscopy as probe of helicity/handedness of molecules[†]
Multiple source interference	X-ray "diffraction" to determine crystal structure, basis for shape of DNA diffraction pattern*
Thin film interference	Morpho butterfly colors, antireflective and UV-reflective coatings for lenses
Diffraction (especially through circular apertures) and limits of resolution	Diffraction-limited focusing and imaging

*I haven't done this yet but intend to incorporate it into my next course, based on Lucas et al, J. Chem. Ed. 1999.

[†] I usually have to omit this due to shortage of time.