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Pages For:
Physicists/Scientists Go

The Back Page

Physics for Future Physicians and Life Scientists: a moment of opportunity

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How should we teach physics to future life scientists and physicians? The physics community has an exciting and timely opportunity to reshape introductory physics courses for this audience. A June 2009 report from the American Association of Medical Colleges (AAMC) and the Howard Hughes Medical Institute (HHMI), as well as the National Research Council's Bio2010 report, clearly acknowledge the critical role physics plays in the contemporary life sciences. They also issue a persuasive call to enhance our courses to serve these students more effectively by demonstrating the foundational role of physics for understanding biological phenomena and by making it an explicit goal to develop in students the sophisticated scientific skills characteristic of our discipline. This call for change provides an opportunity for the physics community to play a major role in educating future physicians and future life science researchers.

Photo by Margaret Throckmorton

Biology students studying diffusion are measuring Brownian motion of polystyrene beads.

A number of physics educators have already reshaped their courses to better address the needs of life science and premedical students, and more are actively doing so. Here we describe what these reports call for, their import for the physics community, and some key features of these reshaped courses. Our commentary is based on the discussions at an October 2009 conference (Conference on Physics in Undergraduate Quantitative Life Science Education), at which physics faculty engaged in teaching introductory physics for the life sciences (IPLS), met with life scientists and representatives of the NSF, APS, AAPT, and AAMC, to take stock of these calls for change and possible responses from the physics community. Similar discussion on IPLS also took place at the 2009 APS April Meeting, the 2009 AAPT Summer Meeting, and the February 2010 APS/AAPT Joint Meeting.

Reasons for Change

The great success of 20th century biology was to reveal the physical and chemical machinery of life. Biological molecules, cells, organisms, and ecosystems are all constrained and enabled by the same laws of nature that govern the inanimate world. In this new vision, life emerges as perhaps the richest and most complex example of a physical system. In the 21st century, the study of life requires an integrated, quantitative approach: physics, chemistry, and mathematics tightly interwoven with traditional biology.

This fundamental transformation has been widely recognized in recent education policy statements. The National Research Council report *Bio2010: Transforming Undergraduate Education for Future Research Biologists* argued that life science researchers need a strong grounding in mathematics and the physical sciences. In June 2009, a joint AAMC-HHMI committee issued an important report, *Scientific Foundations for Future Physicians* (SFFP). This report calls for removing specific course requirements for medical school admission and focusing instead on a set of scientific and mathematical "competencies." Physics plays a significant role in both reports: all life scientists ought to be able to apply the principles of physics to biological systems, to develop and adapt quantitative models for biological processes, and to understand the scientific basis of advanced technologies. The SFFP report provides recommendations that each medical school will now decide whether to adopt. Ongoing discussions among SFFP committee members, medical school deans and admissions officers, and undergraduate pre-health advisors indicate that the proposal to shift to a competency model is viewed very favorably. Although questions about implementation remain, it is certain to influence the revisions underway for the Medical College Admission Test (MCAT).

The call issued by these reports represents both a challenge to and an opportunity for the physics community. The challenge is to offer courses that cultivate general quantitative and scientific reasoning skills, together with a firm grounding in basic physics principles and the ability to apply those principles to living systems, all *without* increasing the number of courses needed to prepare for medical school. The opportunity is to craft new courses that not only serve life science students well, but reveal and celebrate the rich contributions that physics has made to our understanding of life.

The Scientific Foundations for Future Physicians: Recommendations for Change
The SFFP report identifies scientific and mathematical competencies that future physicians should acquire as undergraduates and in medical school. It encourages universities to develop innovative ways to help students meet the undergraduate competencies. How can an introductory physics course best accomplish this? Reading the proposed list is reassuring: traditional physics courses already cover most of the subject areas. (The complete report can be found at Creating Scientifically Literate Physicians; excerpts with the competencies relevant to physics can be found at Conference on Physics in Undergraduate Quantitative Life Science Education.) However, the SFFP report especially calls for developing the ability to apply physics knowledge in the context of understanding living organisms.

The content competencies most closely associated with physics include much material found in a traditional introductory physics course, but with significant omissions and some novel additions. These can be addressed through modifying the balance of topics and choice of examples in the introductory course. For example, while Newton's Laws remain central (indeed, biomechanics requires this), an extended discussion of kinematics and projectile motion could be replaced by more study of fluids and simple continuum mechanics. A more complete study of energy, with attention given to biologically appropriate topics such as diffusion and open systems, could replace the current focus on heat engines and equilibrium thermal situations.

In addition to content-based competencies, the SFFP report echoes the Bio2010 call for enhanced training in a broad range of scientific and quantitative skills–what many of us might be tempted to call "thinking like a physicist." Students should acquire both a rigorous grasp of physics concepts and the ability to understand and use quantitative models of physical systems based on those concepts. Specific skills mentioned in the SFFP report include: interpretation of a variety of representations of scientific information, including statistical and graphical analysis of data; dimensional analysis; the design and execution of experiments to test hypotheses, and the ability to critically read the scientific literature. Indeed, one of the overarching principles of the SFFP report is that "effective clinical problem-solving and the ability to evaluate competing claims" are essential skills for a physician.

Creating new IPLS courses
The primary purpose of an IPLS course is to teach fundamental physical principles, while examining how they shape and enable the organization and activity of living systems. As mentioned previously, the core topics covered by an IPLS course will look familiar to any physicist: mechanics, statistical and thermal physics, fluids, electricity and magnetism, waves and imaging, and some aspects of modern physics. Such a course need not venture far into the full interdisciplinary of modern biophysics. However, most current introductory physics courses use examples inspired largely by engineering. Why not instead choose biologically relevant topics and examples for the IPLS audience? The IPLS courses discussed at the October workshop and recent APS and AAPT meetings make only a modest number of changes to the core topics, with more extensive changes to the examples used to illustrate the core topics. Sample syllabi and lists of biologically relevant examples are available at the website for the October workshop.

We argue that it is not difficult for physics faculty members who have taught introductory physics to teach an IPLS course that addresses the SFFP competencies. They will have to invest time retooling their usual course examples to this life science-oriented approach, but they should find themselves on familiar ground with the subject matter being taught. Ideally, an experienced faculty member taking on an IPLS course will find her own appreciation of physics refreshed by a new approach. This has certainly been our experience. Those of us who have taught courses including biologically-inspired content find our students enthusiastic about that material and eager for more.

Well-designed introductory physics courses can also help students master broad scientific and quantitative skills, and the physics community is recognized as being at the forefront of undergraduate science education in teaching these skills effectively. Challenging, multi-step problems can develop general problem-solving skills as well as the ability to critically use mathematical models. Laboratories can offer practice analyzing and interpreting quantitative data, as well as learning the connections between physical principles and biological problems by direct experimentation. As described in *How People Learn* (National Academy Press, 1999), the transfer of skills and knowledge to different contexts is among the greatest challenges for students. Teaching strategies that help students develop and test physical models of biological phenomena will be particularly important in this regard, and an introductory physics for the life sciences course offers a rich context in which to explore these strategies.

Next Steps
Efforts to revise IPLS courses across the country will require resources and infrastructural support, including new curricular materials (textbooks, in-class activities, model homework and exam problems, laboratory experiments, etc.) and equipment for new life science-related demonstrations and laboratories. Many in the physics community are already working on new IPLS courses. How can we best share the wealth of good ideas already in existence or under development to speed the suggested changes in IPLS courses?

To start this process, we have set up a wiki on the October 2009 conference website, where we will gather available IPLS material. In particular, we are calling on the physics community to (1) post material on the wiki linked to the conference website, (2) use the material posted there and return feedback, and (3) post notices and summaries of meetings on IPLS courses. Experience shows that the process from creative exploration to the ultimate production of polished products for any significant curricular change, including the proposed changes for IPLS courses, will be long and complex and that flexible and effective ways to share ideas are essential.

Careful assessment of new materials and teaching strategies will be essential to this process. Assessment will help determine whether IPLS courses enable students to acquire the proposed competencies, including general scientific and quantitative skills. The physics education research community can provide expertise and experience that can help guide the development of the needed assessment tools.

The AAMC has convened an “MR5” committee charged with reviewing and revising the MCAT. MR5 currently is surveying undergraduate and medical school faculty to create a revised set of MCAT topics. It appears that the choice of those topics will be shaped by the competencies recommended in the SFFP report.

Where do we go from here?

The physics community faces a challenging opportunity as it addresses the issues surrounding IPLS courses. A sizable community we serve has articulated a clear set of skills and competencies that students should master as a result of their physics education. We have for a number of decades incorporated engineering examples into our physics classes. The SFFP report asks us to respond to another important constituency. Are we ready to develop courses that will teach our students how to apply basic physical principles to the life sciences? The challenges of making significant changes in IPLS courses are daunting if we each individually try to take on the task. But with a community-wide effort, we should be able to meet this challenge. The physics community is already moving to develop and implement changes in IPLS courses, and the motivations for change are strong. The life science and medical school communities stress that a working knowledge of physical principles is essential to success in all areas of life science including the practice of medicine. Thus we see significant teaching and learning opportunities as we work to answer the question that opened our discussion: how should we teach physics to future physicians and life scientists?

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