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Research and education at the crossroads of biology and physics

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EDITORIAL

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The fields of biology and physics have a long history of interconnection. While modern formal curriculum in biological physics is relatively new, research in the many subfields of biological physics have a rich history. For example, experiments in physiology and optics occurred as far back as the mid 1800s. The subfields of medical physics, synthetic biology, biotechnology, and single-cell physics, to name just a few, are tied together by models and methodologies from both physics and biology. This melding often allows researchers to explore exciting science over wide ranges of length, time, and energy. Biological physics is a field that parameterizes nature across many orders of magnitude: from bond lengths within a DNA molecule to the size of ecosystems, from chemical reaction and cell diffusion times to mammalian life spans and evolutionary timescales, and from weak bonding and oxidation energies to the global output of photosynthetic harnessing species. This merging of disciplines leads to exciting and diverse instructional opportunities.

Despite the history of biological physics research, there is often a disconnect between biology and physics. This disconnect often manifests itself in high school and college physics instruction as our students rarely come to understand how physics influences biology and how biology influences physics. In recent years, both biologists and physicists have begun to recognize the importance of cultivating stronger connections in these fields, leading to instructional innovations. One call to action comes from the National Research Council's report, *BIO2010*, which stresses the importance of quantitative and computational training for future biologists and cites that sufficient expertise in physics is crucial to addressing complex issues in the life sciences.[1] In addition, physicists who are now exploring biological contexts in instruction need the expertise of biologists. It is clear that biologists and physicists both have a great deal to offer each other and need to develop interdisciplinary workspaces. Philip Sharp, a world leader in molecular biology and biochemistry research at MIT, talks about the importance of "convergence" in meeting the health needs of the 21st century. He describes convergence as the "coming together of different fields of study—particularly engineering, physical sciences, and life sciences—through collaboration among research groups." It is a "broad rethinking of how all scientific research can be conducted so that we capitalize on a range of knowledge bases, from microbiology to computer science to engineering design."[2]

The world is becoming more and more interdisciplinary. New findings, applications, and technologies in biological physics are having far reaching consequences. Their influence can be felt on the scientific community, the educational approaches for future scientists and biotechnology workers, and the general population. Biology and physics educators and education research communities now face an imperative to understand how to support students in bridging these fields. As new advances in biophysics and medical physics emerge, new advances in physics and biology education emerge.

This theme issue on the intersection of biology and physics includes papers on new advances in the fields of biological physics, new advances in the teaching of biological physics, and new advances in education research that inform and guide instruction. By presenting these strands in parallel, in a single issue, we hope to support the reader in making connections, not only at the intersection of biology and physics but also at the intersection of research, education, and education research. Understanding these connections puts us, as researchers and physics educators, in a better position to understand the central questions we face.

This theme issue aligns well with AJP's mission to provide a diverse community of students, educators, and researchers with physics content to broaden their understanding of different topics and expand their "pedagogical toolkit." For instance, in this issue, you will find papers that present novel instructional tools that allow students to apply concepts in electricity and magnetism to medicine and biology. You will also find a series of papers from education researchers in physics and biology that tackle the issue of making physics exciting and relevant to life science majors. While many institutions offer a physics course for life science majors, this course often resembles a physics course for future engineers and physicists with the calculus removed. As colleagues jokingly stated in the title of a 2008 paper about curriculum design for an algebra-based physics course, "… just change the *d*'s to deltas?"[3] Unfortunately, this is often the actual extent of the differences in these courses. Articles in this theme issue challenge us, as educators, to take much greater steps and call for an "interdisciplinary repurposing of physics for biologists."[4]

The physics in this theme issue also highlights the importance of connecting biology and physics beyond the introductory course. Given the interdisciplinary nature of physics research, students majoring in physics, biology, and engineering are also in need of educational support in interdisciplinary thinking. The pedagogical tools included in this issue, therefore, span all levels of the undergraduate curriculum and even the beginning graduate curriculum. Novel experiments designed to support student understanding of lipid membranes in the advanced physics laboratory complement experiments in the elasticity of carrots, celery, and plasticware at the introductory level. In these papers and others, the interdisciplinary nature of physics showcased as novel curriculum brings in ideas from engineering, chemistry, and medicine.

Papers in this theme issue also highlight some of the cultural challenges we face in connecting these disciplines. For instance, they describe how researchers and educators in both physics and biology have different approaches to their science and the learning of their science, and suggest how developing a better cultural understanding of these differences can promote both fields. For example, in one paper, the authors address how biologists and physicists view and teach chemical energy differently. In another paper, authors investigate how physicists and biologists have differences in their views on what is central to the process of modeling. These particular themes also resonate with changes on the MCAT—beginning in 2015, the MCAT will require students to analyze interdisciplinary situations to reflect the "fact that medical schools want well-rounded applicants from a variety of backgrounds."[5]

We have organized this issue around three major areas. We begin with papers that use educational research to ground instructional efforts at the intersection of Biology and Physics. The next two areas focus on novel experiments and theory and computational techniques in both research and instruction. In all cases, the reader is invited to connect the science to the teaching of the science either implicitly or explicitly. These papers provide the AJP readership with exciting ways to infuse their courses, at all levels, with biological and medical examples.

The infusion of Biology into Physics and Physics into Biology provides exciting new avenues of study that can inspire and motivate students, educators, and researchers at all levels. The papers in this issue are, in many ways, a call to biologists and physicists to explore this intersection, learn about the challenges and obstacles, and become excited about new areas of physics and physics education. We invite you to read through these articles, reflect, and discuss this complex intersection, and then continue the conversation at the June 2014 Gordon Research Conference titled, *Physics Research and Education: The Complex Intersection of Biology and Physics*.[6]

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[1]National Research Council, *BIO 2010: Transforming Undergraduate Education for Future Research Bio* (National Academies Press, Washington, DC, 2003).
[2]Massachusetts Institute of Technology, "The third revolution: The convergence of the life sciences, physical sciences, and engineering, white paper," available at http://dc.mit.edu/sites/dc.mit.edu/files/MIT%20White%20Paper%20on%20Convergence.pdf.
[3]M. E. Loverude, S. E. Kanim, and L. Gomez, "Curriculum design for the algebra-based course: Just change the *d*'s to deltas?," in *2008 PERC Proceedings*, edited by C. Henderson, M. Sabella, and L. Hsu (AIP Publishing, NY, 2008), pp. 34–37.
[4]E. F. Redish *et al*., "NEXUS/Physics: An interdisciplinary repurposing of physics for biologists," Am. J. Phys. **82**, 368–377 (2014).
[5]More information on MCAT 2015, as well as other resources for aspiring doctors, medical students, and residents can be found at www.aamc.org.
[6]Detailed information on this conference can be found at www.grc.org/programs.aspx?year=2014&program=physres.