In the United States, physiology education during much of the 20th century was concentrated in departments of physiology in professional and graduate schools, with more diffuse representation of mostly animal and exercise physiologists in undergraduate campuses. This model began to change in the waning years of the 20th century, however, as traditional discipline-based professional school departments gave way to more diverse units with a focus in education, often across multiple programs. A quick web search of the 20 U.S. medical schools obtaining full, provisional, or preliminary accreditation from the Liaison Committee on Medical Education (LCME) since 2002 reveals that only 1 of the 20 (CUNY School of Medicine in New York) has a traditional department that identifies itself with physiology in the title: the Physiology, Pharmacology and Neuroscience Department. A second school, Florida International University Wertheim College of Medicine, includes its physiologists in a Department of Cellular Biology & Pharmacology. The remaining 18 medical schools group their basic scientists into multidisciplinary units that go by broad names such as Biomedical Sciences or Medical Education.

Where does physiology education fit into these diverse collections of faculty? Many of the units identified as biomedical sciences have responsibility for teaching in multiple programs, ranging from undergraduate biology or physiology and exercise science to medicine and pharmacy. Is the disappearance of departmental silos named for specific disciplines a good thing for the future of physiology or does it foreshadow trouble? In this editorial, we look at the current state of physiology education in two areas: undergraduate institutions and medical schools.

**Undergraduate Physiology**

**Current state.** Undergraduate physiology has always been the “pipeline” of the discipline when students were drawn to the field as a result of physiology or anatomy and physiology coursework in a traditional biology or exercise science major. These individual courses are standard at undergraduate institutions in numerous programs of study but may or may not have a laboratory component. However, millennial students are increasingly interested in studying physiology in a focused degree program. This is seen both in increasing enrollments in Bachelor degree programs in physiology around the country as well as in the addition of new programs or conversion of programs from kinesiology to physiology. Without a formal accreditation body that oversees all programs, it is challenging to get complete data, but we have estimates of how physiology education is expanding at the undergraduate level.

For example, from surveying some existing programs, there has been a three-to fivefold increase in enrollment at the University of Arizona and University of Oregon in the past 10 years, with current enrollment at ~2,000 and 1,200, respectively (5). We estimate that there were 5 programs in 2000, 10 in 2006, and, as of 2016, at least 44 programs: 16 B.S. physiology programs (e.g., physiology, integrative physiology, human physiology), 3 combined physiology and neuroscience programs, and 24 biology programs with a track emphasizing physiology. Several new programs are being developed currently or being converted to physiology from exercise science.

**Administrative reorganization.** There are several key issues facing undergraduate institutions for administration of quality education to a growing number of programs and increasing enrollment. First, with the current enrollment trends, the time has come to have a substantive discussion about minimum requirements for an undergraduate degree program in physiology. A grassroots consortium was formed by four partner institutions (University of Oregon, University of Arizona, Gonzaga University, and Michigan State University) and has now expanded to form the Physiology Majors Interest Group (P-MIG) that will have its first conference in May 2017. The Association of Chairs of Departments of Physiology and the American Physiological Society are partners. P-MIG will serve as the platform for a national discussion on undergraduate physiology that is needed in the absence of any oversight or accreditation.

With growing enrollments in physiology degree programs, departments are challenged to hire enough faculty and teaching assistants to adequately cover large enrollment lecture and laboratory courses. At some institutions, resources are allocated back to units based on enrollment, whereas in other cases there is not matching support per student enrolled. The high enrollments also raise the issues of quality of educational experiences and learning in large classes. It is a challenge to departments to adequately fund and staff programs to maximize student learning and allow for inquiry-based and active learning approaches. This is particularly true for laboratory courses where large programs, such as at University of Arizona and University of Texas-Austin, cannot offer a laboratory course to all students, even though the pre-professional school requirements often require an undergraduate laboratory.

**Student perception.** In data gathered from several large physiology undergraduate programs, it is clear that, at the undergraduate level, physiology programs are largely populated with pre-health professional students, with 86% and 84% stating such career aspirations at Michigan State and University of Arizona, respectively. Medicine dominates the career aspirations listed by 55-60% of the students. With that in mind, it is not surprising that our published student survey data from undergraduate physiology majors at Michigan State University about their perspectives on physiology are aligned with the view of physiology as an
integrative discipline based in human body systems level function (7). Sixty-seven percent of students prefer systems/integrative physiology, whereas 11% have a blended interest in integrative and cellular physiology. In total, ~80% of our undergraduate students who choose to major in physiology see it as the basis for a career in the health professions because of its focus on the body as a whole.

Medical Schools

Physiology in medical schools is similarly being reshaped by demands of expansion, administrative restructuring, and student perception. As with all change, emergence of new opportunities is balanced by loss of previous advantages.

Current state. Expansion, both in the number of schools offering the MD or DO degree and class size in existing schools has put pressure on the cadre of physiologists involved in training physicians. In response to concerns about a physician shortage, physician enrollment (both MD and DO) is expected to increase by 55% over an 18-year period (1, 6). Over 10% of MD schools in the U.S. had their initial year of accreditation after 2011, and there are seven new applicant schools. Colleges of Osteopathic Medicine have expanded by 27% since 2011, and 12 new schools are in applicant status (3). Between 2002 and 2020, MD enrollment is predicted to expand by 30% and DO enrollment by 185%. At the same time, a key question that remains unanswered is from where the physiologists who teach these medical students will come.

Administrative reorganization. The increase in student population generating a need for additional physiology instructors is offset by a shift in instructional models away from an emphasis on lecture-based physiology courses. In 1984, Ron Harden summarized the directions that medical education should take to adapt to the changes in the clinical work environment (4). His proposal is summarized by the acronym SPICES: Education should be Student-centered, Problem-based, Integrated, Community-based, Electives, and Systematic. For physiologists, the shift to an integrated, student-centered instruction model resulted in a progressive decrease in the number of schools offering an identifiable physiology lecture-based course. The integrative nature of physiology, however, resulted in physiologists assuming leadership roles in the integrated curriculum model. The discipline of physiology has easily adapted to the emphasis of clinical relevance, data interpretation, and the need for mechanistic thinking that characterizes current curriculum structure.

Student perception. The decline in physiology courses, however, has not diminished the student awareness and appreciation of physiology as a fundamental medical science. The 2016 survey of graduating seniors (2) ranks physiology in the third position among 14 basic sciences, behind only pathophysiology and clinical skills as a preparation for the clinical clerkships and electives. Moreover, this ranking has remained stable for the past 5 years. Student perception of the discipline is strong, and the development of teaching tools and activities emphasizing the importance of physiology in clinical settings should further strengthen this perception.

What Next for Physiology Education?

The changing face of physiology education in the U.S. provides new opportunities to enhance the reputation of physiology and to ensure the future of our discipline. The formation of a national consortium of undergraduate programs [Physiology Majors Interest Group (P-MIG)] is an important step, and the first conference of P-MIG will discuss minimal requirements for a physiology major and the setting of national curriculum recommendations. Another topic under discussion will be a graduation competency exam for physiology undergraduate programs. Key to these discussions is a focus on going beyond content to employability and professional skills.

A second consideration is how we can ensure a pipeline of well-trained physiologist educators to run these programs. A detailed discussion of physiology graduate programs is beyond the scope of this essay, but it is critical that our physiologists-in-training be given the tools to be good educators as well as good scientists. With research funding being threatened, we owe it to our trainees to provide them with all the skills needed to be employable in a changing marketplace.

In summary, physiology education in the U.S. is expanding rapidly at the undergraduate level and holding its own in medical schools, where the shift away from traditional physiology courses is offset by increasing enrollments. Perhaps it is time to reexamine the entrance requirements for medical school and consider making an undergraduate course in physiology a prerequisite for admission. Many medical schools now require biochemistry before matriculation, and surely physiology is more fundamental to the practice of medicine. As medical schools decrease the time devoted to teaching basic sciences from 2 years to 18 months or even 12 months, we should ensure the competency of our physicians by seeing that they have a solid foundation in the physiological underpinnings of health and disease.

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