Disparities in Prerequisites Between Anatomy and Physiology for Health Majors and Physiology for Biology Majors

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Disparities in Prerequisites Between Anatomy and Physiology for Health Majors and Physiology for Biology Majors

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Abstract

Learning physiology requires students to apply physical and chemical principles to the study of biological systems. Unfortunately, many undergraduate anatomy and physiology (A&P) students are unprepared for this due to a lack of prerequisite knowledge in physics and chemistry. This lack of prerequisite knowledge of chemistry and physics makes learning physiology especially difficult and may contribute to the high failure rates among A&P courses nationwide. However, undergraduate physiology courses catering to biology majors often require more stringent chemistry and physics prerequisites that help prepare students to learn physiology. This study compared prerequisite requirements in chemistry and physics between A&P classes for health-related majors and physiology classes for biology majors across numerous four-year institutions and found striking differences in prerequisite preparation between the two groups. 62% of physiology courses for biology majors required a chemistry prerequisite while only 18% of A&P classes for health-related majors had the same requirement. As a result, students entering physiology courses for biology majors may have a better foundation upon which to learn physiology than students entering A&P for health-related majors. https://doi.org/10.21692/haps.2022.019

Key words: anatomy and physiology, prerequisite, physiology, chemistry, biology, student success

Introduction

Physiology is a branch of the biological sciences that focuses on understanding the functions of living organisms across various levels of biological organization (Martini et al. 2018). Effective learning of physiological concepts requires students to integrate knowledge of chemical and physical principles as they relate to the functions of biological systems (Hill et al. 2008; Michael et al. 2017). Thus, many would regard a functional understanding of chemistry and physics to be a foundation upon which physiological knowledge is built (Figure 1).

College-level physiology is taught to two main student audiences. First, physiology is a core component of the biology major curriculum. Depending on the program and the concentrations chosen by the student, physiology courses for biology majors can include animal physiology, human physiology, plant physiology, or even more specialized subdivisions of physiology. The second major audience for physiology is comprised of students pursuing careers in health-related fields, such as nursing or dental hygiene. While the curricula differ among programs, many health-related majors take physiology through a combined anatomy & physiology (A&P) course that focuses on human-specific topics and is commonly taught across two semesters. Many students take A&P in their first year of college, and in many instances, success in A&P can be a determining factor for entrance into competitive-admission programs like nursing.

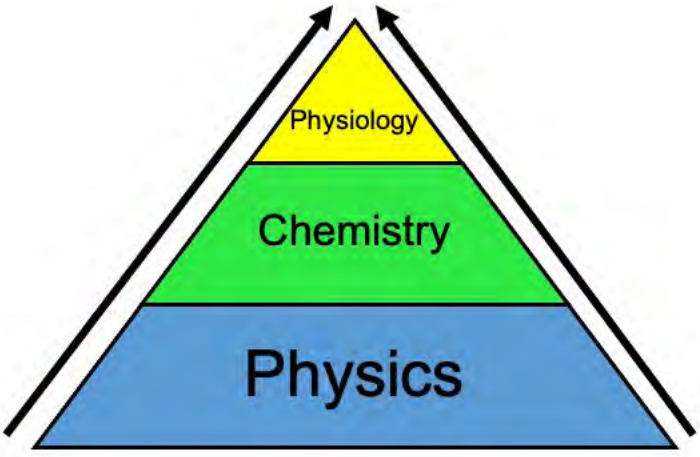

Figure 1. *Knowledge foundation for physiology.*

Without question, physiology is considered a difficult subject as it requires the integration of numerous concepts spanning different scientific disciplines. A survey conducted by Michael (2007) found that many post-secondary physiology educators believe the "characteristics" of the discipline of physiology, such as a requirement for causal reasoning and knowledge integration, was a major reason

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students have difficulty learning physiological concepts. Additionally, this same survey found that physiology educators believe a student's prerequisite knowledge and skillsets are important determinants of success in learning physiology (Michael, 2007). Furthermore, Michael et al. (2017) pinpointed the need for students of physiology to apply their existing knowledge of chemistry and physics to grasp physiological concepts. They also noted that students often struggled to transfer knowledge between subjects (e.g., from chemistry to cellular physiology) or within subjects (e.g., from one physiological system to another within an organism).

A&P is often considered a "weed out" or "gatekeeper" course with high rates of attrition (i.e., failure and withdrawal) across institutional types and locations. In a study conducted from 2005 to 2010 at a two-year open access institution in the midwestern United States, Gultice et al. (2015) found an attrition rate of 32.7%. In a similar study from 1999 to 2005 at Houston Baptist University, Hopp (2009) reported an attrition rate of 43.6%. At the University of Southern Indiana, Hopper (2011) found a failure rate (grade of D or F) of about 58%. The same trend of high attrition has also been seen internationally (Higgins-Opitz and Tufts 2014).

Studies have attempted to elucidate the causal factors behind this high failure rate. Gultice et al. (2015) found high school grade point average (GPA), college GPA, number of college credits earned at the time of course enrollment, math skills, and math placement testing scores to all be significant predictors of student success in A&P. In a similar study, Harris et al. (2004) found that A&P course grades were positively correlated with both high school mathematics and science courses taken and undergraduate math and sciences credits obtained.

Course prerequisites are a common feature of higher education curricula and restrict registration access to only those students who have successfully satisfied the course-specific entry requirements. While prerequisites vary, the most common prerequisite is the completion of another course in the curriculum sequence. For example, a student must successfully complete Biology 101 with a certain grade before enrolling in Biology 102. This ensures that students move through the curriculum in a defined manner and possess the requisite knowledge from previous classes to effectively learn new course material. Studies have looked at the effects of prerequisites on student success in undergraduate A&P and biology classes, and this has been the subject of major review by the Educational Research Task Force of the Human Anatomy & Physiology Society (Hull et al. 2016). In a longitudinal study at the University of South Florida, McCoy and Pierce (2004) found that enforcement of undergraduate prerequisites resulted in a marked drop in both failure and withdrawal rates for biology courses.

Effective prerequisite courses should provide students with the foundational knowledge and skillsets needed to succeed in later courses. Michael et al. (2017) provided a list of 15 core concepts that physiology education must cover for students to effectively understand the functionality of physiological systems. One of these core concepts revolves around the student's ability to apply laws of chemistry and physics to understanding the functions of biological organisms. Other core concepts of physiology include cell-cell communication, cell membrane transport, energy, flow down gradients (e.g., diffusion, transport), and mass balance (Michael et al. 2017). These concepts build upon topics that could first be introduced and mastered in an introductory chemistry or physics course. From these core concepts, it becomes apparent that for students to successfully understand physiological systems, they must possess a baseline knowledge of both chemistry and physics. Therefore, it can be reasoned that the study of physiology should be preempted by the study of chemistry and physics.

Research testing the effectiveness of prerequisites for a course in biology remain limited (Forgey et al. 2020; Harris et al., 2004). However, data suggest that chemistry prerequisites can be effective at increasing A&P performance. Hopp (2009) compared the mean GPA earned by A&P students who either had or had not successfully completed chemistry. Results showed that students who had completed chemistry earned a mean A&P GPA of 2.64 compared to 1.88 for A&P students who had not.

The core concepts of physiology (Michael et al. 2017) taught in A&P and physiology courses for biology majors are largely the same. Topics range from cellular physiology and energetics to systems-level physiology (e.g., function of the nervous system). Because the topics covered are largely the same, one would expect that curricula for both groups are organized similarly and that both courses require the same prerequisite knowledge for enrollment. However, in practice, the prerequisite requirements for the two classes can be wildly different. This study compares the prerequisite requirements for both A&P for health majors and physiology for biology majors across colleges and universities that offer both courses. The analysis of this study focused specifically on chemistry and physics courses as prerequisites as they are the most directly related to the understanding of physiology (Michael et al. 2017). Differences found between the two curricula suggest potential contributing factors to the high attrition rates seen in A&P that may be mitigated by taking a standard approach to physiology curricula.

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Methods

Institutional and Course Selection Criteria

Fifty 4-year colleges and universities in the Midwestern United States were surveyed. Only institutions that offered both physiology for health-related majors and physiology for biology majors were included in the analysis. The most common method of offering physiology for health majors was via a combined Anatomy & Physiology course. However, some colleges and universities separate these into distinct courses, and thus courses listed as covering physiology for health majors were included in this analysis.

Data Collection

Data for this study was collected from public-facing course catalogs and course descriptions found on college and university websites. A detailed course search was performed in each institution's online registrar system to determine the course offerings and prerequisite requirements for course registration (Figure 2). Course title, course number, and any listed prerequisites for registration were documented. Special consideration was given to recording whether the institution listed either chemistry or physics courses as prerequisites for physiology course registration. When a non-chemistry or non-physics course was listed as a course prerequisite, the catalogue was searched to determine the prerequisite for that non-chemistry or non-physics course. For example, many physiology courses for biology majors required a lower-level biology course as a prerequisite. In those instances, the lower-level biology course was searched to determine if a chemistry or physics prerequisite existed for the lower-level course. If found, this prerequisite was included in the prerequisite requirements for the courses in this analysis since students would ultimately need to satisfy that prerequisite for registration in physiology.

Results

Figure 3 shows the percentage of institutions that implemented chemistry and physics prerequisite requirements for physiology courses for health majors and physiology courses for biology majors. Chemistry was the more common prerequisite in both instances compared to physics. Of the institutions surveyed, only 18% required students enrolling in physiology for health majors to complete a chemistry prerequisite course. The vast majority of institutions (82%) had no requirement for students to complete formal chemistry prerequisites prior to enrolling in physiology for health majors. Alternatively, these same institutions were far stricter about requiring chemistry prerequisites for biology majors enrolling in physiology, with 62% of institutions requiring a chemistry prerequisite. Surprisingly, 0% of institutions surveyed required a physics prerequisite for A&P and only 4% required physics as a prerequisite for biology majors.

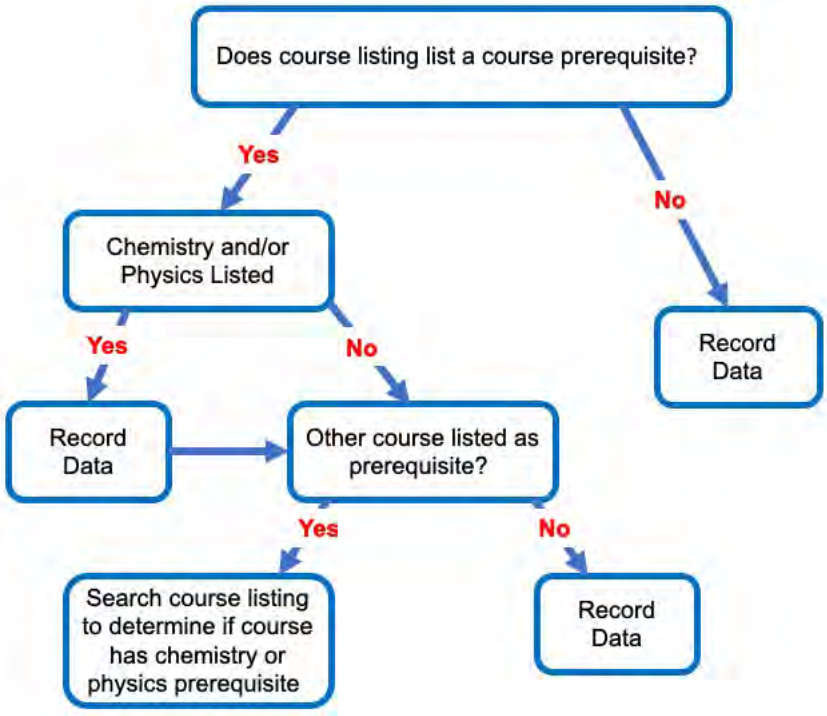

Figure 2. *Methods for determining course prerequisites from course catalogues.*

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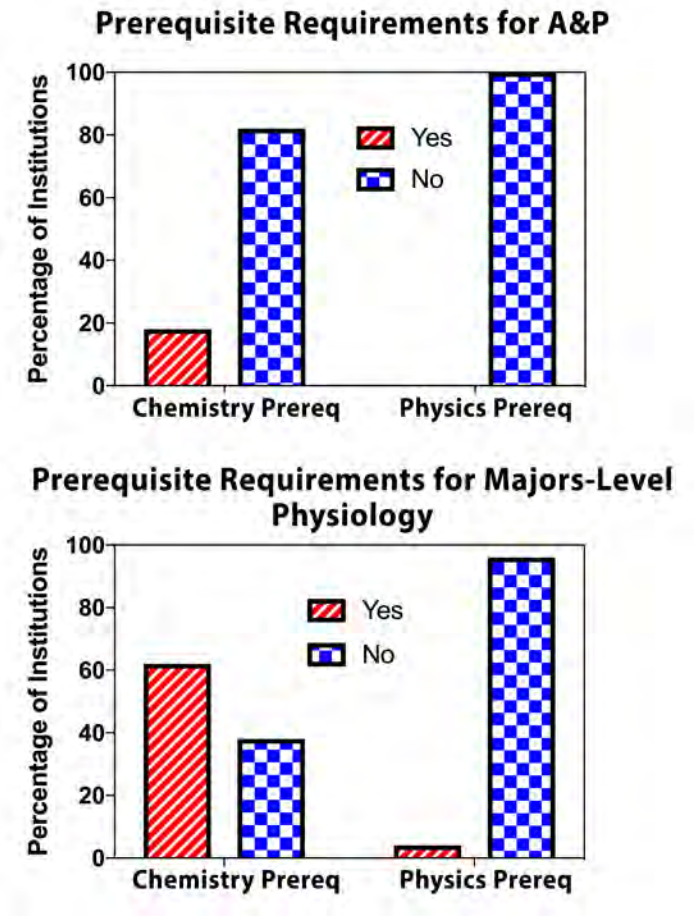

Figure 3. *Chemistry and physics prerequisite requirements for physiology courses.*

Many institutions that were surveyed required alternative prerequisites other than chemistry or physics. Table 1 shows the most common alternative requirements for enrollment into both A&P for health-related majors and physiology for biology majors. Physiology for biology majors frequently required the completion of another college-level biology course (96% of institutions), but this was much less prevalent among A&P courses (26% of institutions). Instead, high school biology was a suitable replacement for college-level biology for 14% of A&P courses, but 0% of physiology courses for biology majors.

Discussion

Physiology is a subdiscipline of the biological sciences that integrates chemical and physical properties into the understanding of how biological systems function. To fully grasp physiological concepts, students need foundational knowledge of chemistry and physics so they can build upon pre-existing knowledge and apply it to the understanding of physiological systems (Michael et al. 2017). The data presented here demonstrate that many institutions are preparing physiology students differently according to their majors. Physiology for biology majors appears to require more stringent prerequisites that frequently include both chemistry and lower-level biology courses that can help build foundational knowledge needed to succeed in physiology. A&P courses appear to require less stringent prerequisites, with less emphasis on requiring prior chemistry and biology courses.

The extent to which this discrepancy in prerequisite preparation impacts overall student performance in physiology is still relatively unexplored (Forgey et al. 2020). It is important to note that the scope of this study was not to collect data to test the hypothesis of whether prerequisite

Prerequisite	Required for A&P	Required for Physiology for Biology Majors
Biology college course (including health sciences/ excluding anatomy)	26%	96%
Biology course high school	14%	0%
Math placement score	4%	0%
Math college course	8%	4%
Special permission granted by instructor	6%	18%
Anatomy	4%	0%

Table 1. *Non-chemistry and physics prerequisites across institutions surveyed. Data show the percentage of institutions that listed the prerequisite.*

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status influences outcomes in physiology courses. Instead, the goal was to explore how institutions are approaching the implementation of prerequisites for different student populations. The findings presented here open an avenue for future exploration into the impact these prerequisites have on the outcomes seen in both student populations.

One challenge to pinpointing a cause-and-effect relationship between prerequisite preparation and outcome of A&P courses is the existence of numerous confounding variables that may impact student performance and attrition rates. In their analysis of the topic, Hull et al. (2016) identified several "non-controllable" factors that may impact student attrition in A&P. These include demographic factors such as gender, socioeconomic status, and minority status. Characteristics of the institution itself, such as affordability of tuition, may also play a role in attrition rates (Hull et al. 2016). Although not specifically measured in this analysis, it is also likely that students are enrolling in these two courses at different stages of their undergraduate education. The lack of prerequisite requirements for A&P, in addition to program structure, likely result in students taking A&P early in their undergraduate studies. Alternatively, more extensive prerequisite requirements for physiology for biology majors likely delays enrollment in the course until later years of undergraduate study. This difference may influence outcome data on success, failure, and withdrawal rates when comparing the two courses.

Regardless of the cause, when students enter a physiology course lacking prerequisite knowledge, there are two major options to get students "up-to-speed." The first option is to provide students with a list of topics that they should already know and point them toward resources that can be used to acquire the knowledge outside of class. This may include students working on their own, reading texts, participating in tutoring, or working with the instructor outside of class (e.g., during office hours). The second option is for the instructor to utilize class time to cover the necessary background information needed to understand the physiological concepts of the course. This requires A&P instructors to carve time out of their already packed course schedules to front-load their classes covering basic chemistry and physics principles.

Table 2 shows a sample lecture schedule from A&P I during the Fall 2021 semester at an institution where students are not required to complete chemistry or physics prerequisites. The sample schedule shows that the instructor is spending 2.5 of the total 15 weeks, or 16.67% of the total in-class instructional time, covering and assessing principles of chemistry. The remaining extensive learning outcomes of the course must then be covered in the remaining 12.5 weeks, leading to a crammed schedule and a need to cover topics at a faster pace. This leaves both students and instructors at a disadvantage and with less class time to devote to covering the actual physiology learning objectives set by the institution.

Week	Lecture Topic
1	Introduction to A&P
	Homeostasis
2	Chemistry Review
	Organic Chemistry & Biochemistry
3	Organic Chemistry & Biochemistry
	Organic Chemistry & Biochemistry
4	**Lecture Exam 1**
	Cell Biology
5	Cell Biology
	Cell Biology
6	Cell Biology
	Tissues & Integumentary System
7	Skeletal System
	Skeletal System
8	No Class – University Closed
	Lecture Exam 2
9	Neural Tissue
	Neural Tissue
10	Neural Tissue
	Muscular System
11	Muscular System
	Lecture Exam 3
12	CNS
	No Class – Veterans Day
13	CNS
	CNS
14	Sensory Pathways & Neural Integration
	No Class Thanksgiving
15	Sensory Pathways & Neural Integration
	Autonomic Nervous System
Finals Week	**Lecture Exam 4**

***Table 2**. Sample A&PI schedule. Schedule was taken from the Fall 2021 semester.*

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There are numerous potential approaches that institutions can take to ensure that students entering A&P have adequate chemistry and physics knowledge to succeed in A&P. First, students could be required to complete prerequisite courses in college before enrolling in A&P. While requiring students to take full courses as prerequisites may not be feasible, Abdullahi and Gannon (2012) showed that students who participated in a two-week pre-A&P workshop performed significantly better and had lower attrition rates than students who did not participate. Additionally, Hopper (2011) found that students enrolled in a supplement course to A&P had improved performance and lower attrition. If the option of additional coursework is not feasible, a requirement could be set that necessitates students to have successfully completed high school chemistry and/or physics within a meaningful timeframe (e.g., less than five years before enrolling in A&P). Yet another option would be to have students wishing to enroll in A&P complete a chemistry and/or physics placement test. Preferably, these placement tests would be designed by A&P faculty and cover the most pertinent chemistry and physics principles required for A&P success.

It remains unclear why institutions would require prerequisites for enrolling in physiology for biology majors but not for A&P. One potential reason is the timing within the program when students take their respective physiology courses. Students often take A&P in the freshman year and the course is required for entry into programs such as nursing or dental hygiene. Requiring students to complete a prerequisite before enrolling in A&P would therefore delay entry into these health-related programs, elongate the time to graduate, and potentially increase the likelihood of dropping out of the program (Abou-Sayf 2008). While this may be true, it does not consider the fact that many students who enroll in A&P must retake the course, sometimes repeatedly, in order to pass.

In their analysis, Higgins-Opitz and Tufts (2014) found that 64% of students who failed their A&P course were taking the course for the first time, and thus would need to repeat the course to be able to pass. Additionally, they found that the remaining 36% of students failing their A&P course were students repeating the course. These students would need to take the class a third time to pass (Higgins-Opitz and Tufts 2014). It could certainly be argued that many students would have the same or shorter time to graduation by enforcing stricter prerequisites. It should also be noted that increasing or strictly enforcing prerequisite requirements may have a negative impact on enrollment (Abou-Sayf 2008). As institutions suffer from enrollment declines and compete for students, they are therefore less likely to implement curriculum strategies that may reduce enrollment, even if these same strategies are effective at increasing student success.

Finding the appropriate curriculum balance between prerequisite requirements and time-to-degree completion is paramount to ensuring student success in health-related programs. While the pros and cons of prerequisite requirements for A&P have been widely debated, the data presented in this study show that the approach taken by institutions in implementing prerequisites varies widely. Future studies should link this disparity in prerequisite requirements to metrics of student success in A&P to better guide curricular development and enhance student success.

About the Author

Dr. Mark Tran is an associate professor of biology at the University of Cincinnati Blue Ash College. He teaches courses in anatomy & physiology and general biology.

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