Degree requirements of physiology undergraduate programs in the Physiology Majors Interest Group

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Wehrwein EA, VanRyn VS, Kelly K. Degree requirements of physiology undergraduate programs in the Physiology Majors Interest Group. Adv Physiol Educ 44: 613–619, 2020; doi:10.1152/advan.00179.2019.—Physiology undergraduate degree programs operate in isolation relative to other biological science programs, with little to no understanding of how other institutions structure their course requirements and other degree requirements. The purpose of this report is to preliminarily describe the collective curriculum of physiology programs represented at the Physiology Majors Interest Group (P-MIG) annual meetings from 2018 to 2019. A short preconference survey was sent to attendees that inquired about degree requirements of their respective physiology programs. The requirement for Physiology I (69.2%) with laboratory (66.7%) and Anatomy I (57.1%) with laboratory (42.9%), or combined Anatomy and Physiology I (16.7%) and laboratory (18.2%), were common requirements, but many programs did not require Physiology II (27.3%) or Anatomy II (11.1%). There was nearly consensus on required prerequisites such as Biology (2 semesters with laboratories, 85.7%), Chemistry (2 semesters with laboratory, 88.9%), Physics (2 semesters with laboratory, 75%), Calculus I (61.1%), and Statistics (Biostatistics 42.9%; General Statistics 13.3%). There was less agreement among programs in regards to Calculus II (20.0%), Organic Chemistry (2 semesters, 55.6%), and Biochemistry I (47%), which may be reflective of individual department focus. There was considerable heterogeneity among physiology program course requirements for disciplinary core courses and upper division electives. This report is meant to generate discussion on physiology program curricula in efforts to improve physiology education for majors and assist P-MIG in determining minimal points of consensus as they write the first set of national curricular guidelines for degree programs.

course requirements; physiology curriculum; Physiology Majors Interest Group; undergraduate education

INTRODUCTION

Physiology is one of the few science disciplines that lacks national program-level curricular guidelines or accreditation at the program level for undergraduate degrees (8). For example, recommended undergraduate degree curricular guidelines at the program level are provided by the American Kinesiology Association, American Society for Microbiology, Mathematics Association of America, and American Association of Physics Teachers. Certification of undergraduate programs is the model used by the American Chemical Society and National Association for Biology Teachers. Accreditation for undergraduate programs also exists (National Accreditation Agency for Clinical Laboratory Science and American Society of Biochemistry and Molecular Biology). To date, similar guidance is lacking for physiology programs, although there are a number of course level objectives defined. The Human Anatomy and Physiology Society has robust learning objectives for one- and two-semester combined anatomy and physiology courses, but this includes courses in a range of disciplines and not necessarily for Physiology majors. In addition, the student population (pre-healthcare) and degree focus (human physiology) in physiology programs in this network are different from the American Society for Plant Biologists and Cell Physiology, each of whom offers course level guidance for physiology courses in their respective fields. The American Physiological Society has partnered with the Association of Chairs of Departments of Physiology to promote learning objectives for medical school physiology courses, but this is not used at the undergraduate level.

Since no program-level curricular guidelines for physiology have existed, each program has organized and developed individually. Without the scaffolding offered by common curricular standards, students earning a physiology degree may have vastly different course work, experiences, and, ultimately, different qualifications upon earning their degree. This may cause some uncertainty in employers, graduate schools, and professional schools, who may struggle knowing what to expect from a college graduate with a degree in physiology. These issues may impact thousands of students each year, as many of these programs are very large in enrollment (1).

The Physiology Majors Interest Group (P-MIG) formed to address concerns about lack of standardization or consensus about what makes a physiology degree. P-MIG is a grassroots collective that creates a space for peer physiology undergraduate degree programs to engage with each other in a broader discussion about best practices, programmatic learning objectives, program assessment, and course offerings. P-MIG is in the process of gathering data about physiology programs to inform the authorship of national curricular guidelines for undergraduate degree programs in physiology (7). The P-MIG vision is that the national guidelines would provide recommendations in three key areas: curriculum/content, professional skills, and career/advising. This paper contains the pilot phase of program-level data collection on the required courses and extracurricular experiences.

To generate consensus guidelines, there must first be a comprehensive curriculum survey to determine the required
courses and experiences of each program identifying as “physiology” (regardless of formal degree name). It is important to note that P-MIG is inclusive to all programs that self-identify as physiology undergraduate degree programs, regardless of department affiliation or program title. That is to say, there are some biology programs with a physiology track that are highly similar to “physiology” programs and are, therefore, included in the analysis. This initial assessment will reveal points of commonality and can serve as the basis for building consensus guidelines to be used nationally.

The current paper shows data on course requirements in undergraduate degree programs collected between 2018 and 2019 from P-MIG conference attendees. The original analysis of course requirements in programs was done only for those with the name “physiology” included in the degree title (6) and was from 18 programs in the United States with “physiology” in the degree title. It was collected by the authors using web-based data from program websites. The value of the present analysis of course requirements in a major is that it has expanded the definition of a physiology degree to include more programs and was self-reported, ensuring a high degree of accuracy, whereas the original data set could be flawed if program listings in the online course catalogs were out of date or misunderstood.

The current curricular data in this paper on course requirements was collected informally as part of a conference survey and is being used by the P-MIG curriculum committee as a framework for the ongoing detailed analysis of course objectives and learning outcomes from all P-MIG programs. Together, the data being collected by P-MIG will serve to find points of consensus on which a common set of standards can be written that would be applied to all degree programs. As P-MIG works on data collection and authors’ consensus guidelines, we hope that this preliminary data set (i.e., not originally intended for formal distribution nor advanced statistical analysis) will be helpful to a range of entities. It can be used by community college programs that are known “feeders” to 4-yr pre-health programs, departments wanting to start a physiology program, peer 4-yr degree programs that serve pre-health students worldwide, and related professional societies that have an interest in physiology education at the undergraduate level.

METHODS

The sample for this report consists of physiology educators who attended the 2018 \((n = 47)\) or 2019 \((n = 51)\) P-MIG conferences. Of the physiology educators who registered for the 2018 or 2019 P-MIG conferences, 26 (58%) and 45 (88%) participated in a series of preconference surveys for 2018 and 2019, respectively. A total of 19 unique institutions completed the detailed curriculum parts of the survey, and their data are reported here. Survey data were collected in Qualtrics (Provo, UT) and analyzed in R version 3.5.3 (RStudio, Boston, MA). All data are presented as \(n\) (% total respondents). Number discrepancies exist due to some institutions not responding to all questions. If the same question was asked in multiple surveys, the most recent response from an institution was used. Only one response per school was used, as each school self-selected a designee to complete the curricular survey, and that part of the survey regarding courses in the major was only opened to that individual. The prompt used was, “This portion of the survey needs to be completed by only one person at each institution. Are you that designee? If yes, select

“yes” below and answer the subsequent questions. If no, select “no” below.”

Survey respondents were asked about the course requirements, extracurricular opportunities, program learning objectives, and course structure of their undergraduate physiology program. Specifically, participants were asked to indicate if each curriculum component was a required course, elective course, selective course, or if the course was not offered. The nonphysiology courses queried were mathematics, biology, chemistry, physics, advanced biomedical sciences, and professional skills courses. Flipped courses were defined as courses in which didactic content is completed outside of course work, and activities occur in the classroom. Hybrid courses were defined as courses in which classroom time is reduced by requiring time outside of class interacting with and learning content. For exact language used in questions, please see the Appendix in the Supplemental Material. (All Supplemental Material is available at https://github.com/kellyke5/Supp-ADV-00179-2019R1.)

Survey respondents were also asked to provide details on the specifics on the nature of their anatomy laboratories, physiology laboratories, and core physiology courses. These questions and responses can be found in the Supplemental Material.

RESULTS

Programs Included

Table 1 lists the 19 schools that participated in the curriculum survey.

Types of Courses Offered

The style of courses in the major was surveyed as to whether courses in the major were online, hybrid, or flipped classroom design. Data are shown in Table 2. Respondents answered if all, some, or none of the required courses were in these formats: for online courses, 0.0% said all courses were online,

| Institution                     | Degree | Major                        |
|--------------------------------|--------|------------------------------|
| Colorado State University       | BS     | Biomedical Sciences          |
| Emory University                | BS     | Biology                      |
| Indiana State University        | BS     | Exercise Science             |
| Metro State University          | BS     | Biology                      |
| Michigan State University       | BS     | Physiology                   |
| Southern Illinois               |        |                              |
| University–Carbondale          | BS     | Physiology                   |
| St. Olaf College                | BA     | Biology                      |
| University of Arizona           | BS     | Physiology                   |
| University of British Colombia  | BSc    | Cellular Anatomical and Physiological Sciences |
| University of California–Irvine | BS     | Physiology and Exercise Sciences |
| University of Colorado–Boulder  | BA     | Integrative Physiology       |
| University of Colorado–Colorado Springs | BS | Biology–Biomedical Science |
| University of Dayton            | BHS    | Health Science–Integrative Physiology |
| University of Iowa              | BS     | Human Physiology             |
| University of Kentucky          | BS     | Biology–Physiology Emphasis  |
| University of Minnesota–Twin Cities | BA | Human Physiology             |
| University of Scranton          | BS     | Physiology                   |
| Villanova University            | BS     | Biological Sciences          |
| West Virginia University        | BS     | Exercise Physiology          |

BA, Bachelor of Arts; BHS, Bachelor in Health Science; BS and BSc, Bachelor of Science.
Table 2. Course format

| Courses               | n (%)       |
|-----------------------|-------------|
| Online                |             |
| All                   | 0 (0.0)     |
| Some                  | 7 (38.9)    |
| None                  | 11 (61.1)   |
| Hybrid                |             |
| All                   | 0 (0.0)     |
| Some                  | 8 (50.0)    |
| None                  | 8 (50.0)    |
| Flipped               |             |
| All                   | 1 (5.6)     |
| Some                  | 9 (50.0)    |
| None                  | 8 (44.4)    |

Values are n, no. of respondents (with percentages of total respondents in parentheses).

38.9% some, and 61.1% none; for hybrid, 0.0% said all, 50.0% some, and 50.0% none; and for flipped courses: 5.6% said all, 50.0% some, and 44.4% none.

Anatomy and Physiology

Anatomy and physiology course requirements are shown in Table 3. Physiology I was required by 69.2% of programs, and Anatomy I was required by 57.1% of programs, with an additional 16.7% requiring combined Anatomy and Physiology I. Physiology Laboratory I was required by 66.7% of programs, and Anatomy Laboratory I required by 42.9%, with 18.2% requiring combined Anatomy and Physiology Laboratory I.

Physiology II was required by 27.3% of programs, and Anatomy II was required by 11.1% of programs, with an additional 16.7% requiring combined Anatomy and Physiology II. Physiology Laboratory II was required by 27.3% of programs, and Anatomy Laboratory II was required by 11.1% of programs, with 18.2% requiring the combined Anatomy and Physiology Laboratory II.

Introduction to Physiology (intended by the authors to be a 400-level advanced or capstone course in addition to the primary core physiology courses above) was required by 42.9% of programs, offered as an elective by 28.6%, and not offered by 21.4%. Senior-Level Physiology Laboratory was required by 10% of programs, offered as an elective by 30%, and not offered by 60% of programs.

Additional information on the core physiology series and the nature of the physiology lectures and laboratories can be found in the Appendix in the Supplemental Material.

Mathematics

Mathematics course requirements are shown in Table 4. Calculus I was generally a required course, being required by 61.1% of programs. An additional 22.2% offered it as an elective, and 16.7% did not offer it. Calculus II, however, was required by only 20.0% of programs, with 40.0% offering it as an elective, 13.3% offering it as a selective, and 26.7% not offering it.

Biostatistics was required by 41.2%, offered as an elective by 17.6%, offered as a selective by 35.3%, and 5.9% did not offer it. The generic introductory statistics course was required by 13.3%, with an additional 17.6% and 35.3% offering it as an elective and selective course, respectively. Statistics was not offered by 20.0% of programs.

Biology

Biology course requirements are shown in Table 5. Biology I and II, and their respective laboratory components, were almost ubiquitously required (>85.7% each).

Physics

Physics course requirements are shown in Table 5. Physics I and II, and their respective laboratory components, were almost universally required (>75.0% each).

Chemistry

Chemistry course requirements are shown in Table 5. Chemistry I and II, and their respective laboratory components, were almost all required (>88.9% each).

Organic Chemistry I and II were required by 66.7% and 55.6% of programs, respectively. Their laboratory components were required by 70.6% and 68.8%, respectively. An additional 22.2% and 27.8% offered Organic Chemistry I and II, respectively, as electives.

Biochemistry I was required in 47.1% of programs, with 29.4% offering it as an elective, 11.8% offering it as a selective course, and 11.8% not offering it. Biochemistry I Laboratory

Table 3. Physiology and anatomy course requirements

| Courses                  | Required | Selective | Elective | Not Offered |
|--------------------------|----------|-----------|----------|-------------|
| Physiology I             | 9 (69.2) | 0 (0.0)   | 2 (15.4) | 2 (15.4)    |
| Physiology Laboratory I  | 8 (66.7) | 0 (0.0)   | 0 (0.0)  | 4 (33.3)    |
| Physiology II            | 3 (27.3) | 1 (9.1)   | 0 (0.0)  | 7 (63.6)    |
| Physiology II Laboratory | 2 (22.2) | 0 (0.0)   | 1 (11.1) | 6 (66.7)    |
| Anatomy I                | 8 (57.1) | 1 (7.1)   | 2 (14.3) | 3 (21.4)    |
| Anatomy I Laboratory     | 6 (42.9) | 3 (21.4)  | 3 (21.4) | 2 (14.3)    |
| Anatomy II               | 1 (11.1) | 0 (0.0)   | 2 (22.2) | 6 (66.7)    |
| Anatomy II Laboratory    | 0 (0.0)  | 0 (0.0)   | 3 (33.3) | 6 (66.7)    |
| Anatomy and Physiology I | 2 (16.7) | 1 (8.3)   | 2 (16.7) | 7 (58.3)    |
| Anatomy and Physiology I |          |           |          |             |
| Laboratory               | 2 (18.2) | 1 (9.1)   | 1 (9.1)  | 7 (63.6)    |
| Anatomy and Physiology II|         | 2 (16.7)  | 1 (8.3)  | 7 (58.3)    |
| Introduction to Physiology|        | 2 (18.2) | 1 (9.1)  | 1 (9.1)     | 7 (63.6) |
| Introduction to Physiology|        | 2 (25.0) | 0 (0.0)  | 0 (0.0)     | 6 (75.0) |

Values are n, no. of programs that require the course (with percentages of total programs in parentheses).

Table 4. Mathematics course requirements

| Courses       | Required | Selective | Elective | Not Offered |
|---------------|----------|-----------|----------|-------------|
| Calculus I    | 11 (61.1)| 0 (0.0)   | 4 (22.2) | 3 (16.7)    |
| Calculus II   | 3 (20.0) | 2 (13.3)  | 6 (40.0) | 4 (26.7)    |
| Biostatistics | 7 (41.2) | 6 (35.3)  | 3 (17.6) | 1 (5.9)     |
| Statistics    | 2 (13.3) | 5 (33.3)  | 5 (33.3) | 3 (20.0)    |

Values are n, no. of programs that require the course (with percentages of total programs in parentheses).
was only required by 18.8% of programs, but 37.5% offered it as an elective, 18.8% as a selective, and 25.0% not offering it. Biochemistry II and Biochemistry II Laboratory were generally not required by programs (0.0% each).

Advanced Biomedical Sciences

Various advanced biomedical sciences courses were generally offered as electives, with the exception of Genetics, which was listed as required by 43.8% of programs. The following courses were listed as required, elective, or selective in a majority of programs: Genetics (93.8% of programs), Microbiology (93.3% of programs), Neuroscience (93.3% of programs), Microbiology Laboratory (84.6% of programs), and Psychology (71.4% of programs). Additional advanced biomedical science courses can be found in Table 6.

Career Skills Courses

Four options for professional development and career skills courses were queried. These were presented to survey respondents as four separate course options that could meet the goal of formal career and professional development. Career skills course requirements are shown in Table 7. Professional development courses geared toward career skills were generally not part of physiology program curricula. Only an upper-level writing course was a part of the curriculum in more than 50% of programs, being required by 38.9%, elective in 33.3%, and selective in 5.6%.

Extracurricular Activities

Requirements independent of curriculum are shown in Table 6. Generally, these were not required. Outside of course work, 75% of programs offer internships to their students, 94.1% offer study abroad experiences, 81.2% offer participation in outreach activities, 60% offer study skills advisement, 84.6% offer career services, and 94.4% offer research experience (Table 8). In regards to research opportunities, 94.4% of programs allow working with campus faculty, 61.1% provide classroom-based research opportunities, 55.6% offer clinical research opportunities, and 61.1% offer research in an off-campus faculty setting.

DISCUSSION

Despite the lack of national guidelines, the curricular survey data on course requirements show many points of commonality among programs that were developed in isolation. These points of overlap provide the key scaffolding on which P-MIG can base minimal consensus guidelines and provides the important courses and features of programs to further investigate as we build consensus guidelines. In a series of companion papers, the authors describe student interests, career goals, and programs demographics. The intersection of those papers is addressed in the discussion.

Program Foci

As discussed in the companion paper by Steele et al. (4a), the main focus among physiology programs was fairly consis-

Table 5. Biology, chemistry, and physics course requirements

| Courses                      | Required | Selective | Elective | Not Offered |
|------------------------------|----------|-----------|----------|-------------|
| Biology                      |          |           |          |             |
| Biology I                    | 15 (88.2)| 0 (0.0)   | 2 (11.8) | 0 (0.0)     |
| Biology I Laboratory         | 15 (93.8)| 0 (0.0)   | 0 (0.0)  | 1 (6.2)     |
| Biology II                   | 14 (87.5)| 0 (0.0)   | 1 (6.2)  | 1 (6.2)     |
| Biology II Laboratory        | 12 (85.7)| 0 (0.0)   | 0 (0.0)  | 2 (14.3)    |
| Chemistry                    |          |           |          |             |
| General Chemistry I          | 16 (88.9)| 0 (0.0)   | 2 (11.1) | 0 (0.0)     |
| General Chemistry I Laboratory| 16 (94.1)| 0 (0.0)   | 0 (0.0)  | 1 (5.9)     |
| General Chemistry II         | 16 (88.9)| 0 (0.0)   | 2 (11.1) | 0 (0.0)     |
| General Chemistry II Laboratory| 16 (100.0)| 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Organic Chemistry I          | 12 (66.7)| 0 (0.0)   | 4 (22.2) | 2 (11.1)    |
| Organic Chemistry I Laboratory| 12 (70.6)| 0 (0.0) | 3 (17.6) | 2 (11.8) |
| Organic Chemistry II         | 10 (55.6)| 1 (5.6)   | 5 (27.8) | 2 (11.1)    |
| Organic Chemistry II Laboratory| 11 (68.8)| 1 (6.2) | 3 (18.8) | 1 (6.2) |
| Biochemistry I               | 8 (47.1) | 2 (11.8)  | 5 (29.4) | 2 (11.8)    |
| Biochemistry I Laboratory    | 3 (18.8) | 3 (18.8)  | 6 (37.5) | 4 (25.0)    |
| Biochemistry II              | 0 (0.0)  | 0 (0.0)   | 2 (18.2) | 9 (81.8)    |
| Biochemistry II Laboratory   | 0 (0.0)  | 0 (0.0)   | 3 (30.0) | 7 (70.0)    |
| Physics                      |          |           |          |             |
| Physics I                    | 16 (88.9)| 0 (0.0)   | 2 (11.1) | 0 (0.0)     |
| Physics I Laboratory         | 15 (93.8)| 0 (0.0)   | 0 (0.0)  | 1 (6.2)     |
| Physics II                   | 12 (75.0)| 0 (0.0)   | 4 (25.0) | 0 (0.0)     |
| Physics II Laboratory        | 13 (86.7)| 0 (0.0)   | 2 (13.3) | 0 (0.0)     |

Values are n, no. of programs that require the course (with percentages of total programs in parentheses).

Table 6. Advanced biomedical sciences course requirements

| Courses                                      | Required | Selective | Elective | Not Offered |
|----------------------------------------------|----------|-----------|----------|-------------|
| Epidemiology/Public Health Laboratory        | 0 (0.0)  | 1 (7.7)   | 3 (23.1) | 9 (69.2)    |
| Epidemiology/Public Health Laboratory        | 0 (0.0)  | 0 (0.0)   | 2 (16.7) | 10 (83.3)   |
| Genetics                                     | 7 (43.8) | 2 (12.5)  | 6 (37.5) | 1 (6.2)     |
| Genetics Laboratory                          | 2 (15.4) | 2 (15.4)  | 3 (23.1) | 6 (46.2)    |
| Genomics                                     | 1 (8.3)  | 0 (0.0)   | 3 (25.0) | 8 (66.7)    |
| Genomics Laboratory                          | 1 (8.3)  | 0 (0.0)   | 2 (16.7) | 9 (75.0)    |
| Medical Terminology                           | 2 (12.5) | 0 (0.0)   | 4 (25.0) | 10 (62.5)   |
| Medical Terminology Laboratory               | 0 (0.0)  | 0 (0.0)   | 3 (23.1) | 10 (76.9)   |
| Microbiology                                 | 2 (13.3) | 3 (20.0)  | 9 (60.0) | 1 (6.7)     |
| Microbiology Laboratory                      | 1 (7.7)  | 2 (15.4)  | 8 (61.5) | 2 (15.4)    |
| Neuroscience                                 | 1 (6.7)  | 3 (20.0)  | 10 (66.7)| 1 (6.7)     |
| Neuroscience Laboratory                      | 1 (7.1)  | 2 (14.3)  | 5 (35.7) | 6 (42.9)    |
| Nutrition                                    | 3 (18.8) | 1 (6.2)   | 7 (43.8) | 5 (31.2)    |
| Nutrition Laboratory                         | 0 (0.0)  | 0 (0.0)   | 3 (23.1) | 10 (76.9)   |
| Pharmacology                                 | 0 (0.0)  | 4 (30.8)  | 4 (30.8) | 5 (38.5)    |
| Pharmacology Laboratory                      | 0 (0.0)  | 1 (7.7)   | 1 (7.7)  | 11 (84.6)   |
| Psychology                                   | 3 (21.4) | 1 (7.1)   | 6 (42.9) | 4 (28.6)    |
| Psychology Laboratory                        | 0 (0.0)  | 0 (0.0)   | 3 (27.3) | 7 (63.6)    |
| Research Methods                             | 2 (14.3) | 2 (14.3)  | 6 (42.9) | 4 (28.6)    |
| Virology                                     | 0 (0.0)  | 1 (9.1)   | 3 (27.3) | 7 (63.6)    |
| Virology Laboratory                          | 0 (0.0)  | 1 (7.7)   | 2 (15.4) | 10 (76.9)   |

Values are n, no. of programs that require the course (with percentages of total programs in parentheses).
Also required the accompanying laboratory courses. Interestingly, organic chemistry appears to be a course that is not required by a majority of programs. Programs that had integrated anatomy and physiology courses always had both Anatomy and Physiology I and II, along with the accompanying laboratories. Introduction to Physiology courses were generally not offered, but Senior-Level Physiology was required or offered by most programs. The Senior-Level Physiology Laboratory was offered by one-half of the programs. The authors acknowledge that interpretation of Introduction to Physiology and Senior-Level Physiology may have been interpreted differently among respondents and from the original intent of the question.

While the course requirements for Physiology I and Anatomy I are not surprising, the low number of programs offering Physiology II is. The reason for this is unclear, but may be due to curriculum structures that are not captured in this survey, or reflective of programs that offer degrees in Biology with concentrations in Physiology. The Senior-Level Physiology lecture course may also serve as an effective Physiology II in some programs. The scarcity of Introductory Physiology courses is not surprising, but may be related to a reliance on biology prerequisites to teach basic physiological content as an introduction. Anatomy II, which has a low number of programs offering it for degree credit, may be regarded as unnecessary by a majority of programs.

**Types of Courses Offered**

Recently, attention has been brought to how content is delivered to students, when students learn didactic information, and what occurs in the classroom. Online courses have increased in popularity, allowing students to engage with the material remotely. Flipped courses, in which students are expected to learn didactic material at home and then discuss and interact with the content in class, have been shown to improve academic performance and improve faculty and student satisfaction with the course (3). With the hybrid structure, classroom time is reduced by mandating interaction with the content before or after class.

Across the physiology programs surveyed, there was variation in how courses are structured. It appears that a plurality of the courses within these programs operate under traditional didactic lecture structure, with some in each program that adopt flipped or hybrid structures. Relatively few programs have online courses. A discussion on best practice for physiology courses regarding structure is warranted, given the heterogeneity of structures across programs.

**Course Work: Key Similarities and Differences**

*Physiology and anatomy courses.* A vast majority of programs required Physiology I and Anatomy I or the combined Anatomy and Physiology I courses. A majority of programs also required the accompanying laboratory courses. Interestingly, Physiology II, Anatomy II, or combined Anatomy and Physiology II and the accompanying laboratory courses were not required by a majority of programs. Programs that had integrated anatomy and physiology courses always had both Anatomy and Physiology I and II, along with the accompanying laboratories. Introduction to Physiology courses were generally not offered, but Senior-Level Physiology was required or offered by most programs. The Senior-Level Physiology Laboratory was offered by one-half of the programs. The authors acknowledge that interpretation of Introduction to Physiology and Senior-Level Physiology may have been interpreted differently among respondents and from the original intent of the question.

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**Common courses.** Courses nearly universally included in physiology program curricula appear to include Biostatistics, Calculus I, Biology I and II (plus associated laboratories), Physics I and II (plus associated laboratories), and Chemistry I and II (plus associated laboratories).

These courses generally are the foundation for programs in the natural sciences and are often college requirements independent of any physiology department or track. Additionally, these courses are important in the standardized testing that many physiology students take at the end of their degrees, such as the Medical College Admission Test. Including these courses in a physiology curriculum is best practice for laying a foundation for physiological concepts and preparing students to be successful in their careers.

**Disparate courses.** Courses that were not universally required as curriculum components in programs include Calculus II, Organic Chemistry, Biochemistry, a variety of Advanced Biomedical Sciences courses, and Upper-Level Writing.

The status of these courses in curricula may reflect differing priorities by individual departments. For example, a more integrative or systems-level physiology department may not place emphasis on cellular and molecular courses, such as biochemistry. Additionally, the content in these courses may be considered excessive for a physiology student by some departments. Depending on the content in required physics courses, Calculus II may or may not be necessary.

Interestingly, organic chemistry appears to be a course that not all physiology students are required to take. This may be a combination of the two above points. Perhaps in some institutions, the content applicable to physiology students is covered in the introductory chemistry courses, rendering a full mechanical organic chemistry course excessive. The courses that rely on a firm grasp of organic chemistry, such as biochemistry, may not be required of students. Furthermore, a departmental focus that does not place an emphasis on molecular physiology might not expect students to take organic chemistry. Regardless, organic chemistry is covered on many preprofessional
Several advanced biomedical sciences courses, such as genetics, microbiology, and neuroscience are curriculum components for physiology programs. In some institutions, this may reflect an umbrella biology program in which physiology is a concentration. In a majority of the programs included in this survey, these types of courses are electives, which suggest that they are not a major facet of the program. These courses broaden the scope of a student’s expertise beyond traditional physiology.

Upper-Level Writing being required by some programs could be due to institution-level requirements, but overall this course could dramatically help physiology students express ideas in a multitude of ways, ranging from formal academic writing to public outreach settings. Given that good communication skills are essential to professional success, it is notable that instruction on disciplinary writing is not consistently part of mandatory courses in the major. This is an area where programs could expand and improve.

Generally excluded courses. Of the major curriculum components assessed, the only major subset of courses that was excluded from a majority of programs was career skills. These courses are designed to help students understand the role of physiology at an early stage, how a physiology degree can be used, and establish habits to succeed in the program or future careers. It is possible that these courses could help students make mindful decisions about pursuing a degree in physiology, understand what their career prospects might be, and ultimately achieve their goals. Given that career and professional development will be suggested as part of the P-MIG guidelines, these types of courses are wonderful additions to a curriculum and could greatly assist students as they progress through the major to employment. An outstanding example of program-wide professional development in a physiology major is from Monash University (2).

Extracurricular. The availability of required or optional extracurricular activities, such as study abroad, likely reflects the heterogeneity in program resources. Access to populations and venues for outreach, internships, and research vary between programs and institutions. Sharing how programs have built infrastructure to provide these opportunities may allow other programs to develop activities for their students. Very few programs are able to require internships, research experiences, study abroad, outreach, study skills courses, or career services. Many do have these options available to students on campus, even if not within the major. Encouragement of students to participate in these resources should be part of the program, and it would be positive if more of these services were mandatory to ensure that all students can grow from these experiences as they choose their career path.

Limitations

The use of the terms, required, elective, selective option, introduction to physiology, and senior-level, to describe courses could be open to interpretation of each survey respondent. There are indeed scenarios in which the authors acknowledge would be difficult to bin into a category above. For example, if a course exists on campus (e.g., Nutrition) but is not listed on the list of approved courses in the major that would count for degree credit, respondents may have noted this as either “elective” or “not offered.” The survey prompts did not clearly define Introduction to Physiology or Senior-Level Physiology, so this was defined by the respondent. Finally, some institutions did not complete all questions in the survey, and, therefore, it is unclear in some cases how to interpret their nonresponses.

Next Steps

There are two key areas for next steps: 1) a detailed follow up on this publication to learn more about program requirements beyond a simple listing of course offerings, and 2) authoring national guidelines that take into consideration the state of existing programs. To the first point, the P-MIG curriculum committee is planning to survey programs about the nature of prerequisite courses (4), the learning objectives for the major and for required courses in the major, assessment of the evolving nature of introductory biology, chemistry, physics, and math, including any examples of programs using biologically focused physics and math courses, assessment of professional skills development options, and more. In regards to specific physiology and anatomy curriculum, we plan to analyze syllabi to determine the approximate time spent on each major organ system in efforts to inform the structure of those courses.

Summary

In conclusion, physiology programs across the United States have a similar focus in program content and remarkably similar student career aspirations. There are numerous points of common course structure, on which further research and national guidelines can be built. A forum to discuss matters such as advising, learning objectives, course sequencing, and extracurricular opportunities is necessary. This is where P-MIG seeks to exist: a dedicated space for faculty to collaborate on program-level best practices and sharing of resources to improve the quality of physiology education and student outcomes. This paper is published as part of a special collection/special issue from P-MIG, a grassroots organization that has formed to help develop programmatic guidelines and serve those engaged in undergraduate physiology or physiology-related programs. To find out more about this collective, or get involved, please visit our website (https://www.physiologymajors.org/) and consider joining our listserv.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

E.W. and K.K. conceived and designed research; E.W. and V.V. performed experiments; K.K. analyzed data; E.W. and K.K. interpreted results of experiments; E.W., V.V., and K.K. drafted manuscript; E.W., V.V., and K.K. edited and revised manuscript; E.W., V.V., and K.K. approved final version of manuscript.

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