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Changing undergraduate human anatomy and physiology laboratories: perspectives from a large-enrollment course

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Griff ER. Changing undergraduate human anatomy and physiology laboratories: perspectives from a large enrollment course. *Adv Physiol Educ* 40: 388–392, 2016; doi:10.1152/advan.00057.2016.—In the present article, a veteran lecturer of human anatomy and physiology taught several sections of the laboratory component for the first time and shares his observations and analysis from this unique perspective. The article discusses a large-enrollment, content-heavy anatomy and physiology course in relationship to published studies on learning and student self-efficacy. Changes in the laboratory component that could increase student learning are proposed. The author also points out the need for research to assess whether selective curricular changes could increase the depth of understanding and retention of learned material.

anatomy; physiology; undergraduate; laboratory

THIS ARTICLE derives from personal observations substantiated by a review of the pertinent literature. The laboratory component of large-enrollment courses provides an opportunity for more effective learning compared with lectures because of the small class size and extensive hands-on active learning (23). In large multisection classes such as human anatomy and physiology (A&P), the laboratory is a setting where the instructor can learn the names of all the students, observe each student in the learning environment, and interact with students individually (19). A study (25) at an Australian university demonstrated the importance of the A&P laboratory to student perceptions of their learning. In addition to helping students understand the lecture material, 85% of the students valued the hands-on aspects of the laboratory for its own sake. Thus, students generally view the A&P laboratory positively, and curricular changes could improve student learning.

There have been relatively few research studies of the A&P laboratory curriculum or its effectiveness. More attention has been paid to introductory biology courses (e.g., Ref. 5) and the basic science curriculum at medical schools (e.g., Ref. 38). The dearth of research on the introductory undergraduate A&P curriculum may reflect the facts that it is often a service course offered by Biology Departments for nursing and allied health students and that this introductory course does not fulfill any requirements for Biology majors. More research has been done on physics, chemistry, and biology laboratories, where there is evidence that inquiry-based laboratories produce more effective learning than laboratories designed mostly to reinforce lecture material (33).

Inquiry-based laboratories often include cycles of exploration and concept invention. Traditional chemistry laboratories that confirm knowledge and do not challenge the misconceptions that students may already possess do not increase their understanding of chemical concepts (17). Some instructors have argued that traditional chemistry laboratories have little value for learning chemistry content beyond exposure to simplified techniques (e.g., Ref. 22). A novel introductory college-level chemistry course was recently created, which develops a learning pathway for core concepts such as structure-function relationships of molecules (11, 12). Rather than relying on memorization and heuristics, the emphasis is on extending and relating core ideas throughout the course. For example, at the end of two semesters, the experimental group demonstrated a significant improvement in both the ability to draw Lewis structures that had been discussed in class (70% correct vs. 37%) and the ability to draw the structure for a novel compound (41% correct vs. 11%) (12). Similarly, A&P courses should be reevaluated in terms of what major concepts need to be emphasized.

Most A&P courses include a laboratory experience. Since an increasing number of instructors are already replacing some of the traditional physiology laboratories with inquiry-based laboratories, this may be the initial place to enact changes. For example, Casetti et al. (8) described very positive improvements in student learning after introducing three inquiry-based laboratories into an A&P curriculum for nonbiology majors. To make room for these new laboratories, a computer simulation muscle contraction laboratory, a sensory laboratory, and one laboratory exam were dropped. As another example, a process-oriented guided-inquiry learning (POGIL) strategy that was initially developed for chemistry has been used in both lecture and laboratory environments (e.g., Ref. 29), and this approach has been adapted for A&P (7). POGIL activities are highly structured, with leading questions to guide small groups of students to construct new conceptual knowledge from observations. Using POGIL in an A&P course, the mean final score of students in a class significantly increased from 76.04 ± 16.16 (n = 25) before the redesigned course (fall 2008) to 86.89 ± 12.16 (n = 31) in spring 2009 and 89.25 ± 8.72 (n = 17) in fall 2009 (7).

As a 30-yr veteran lecturer of large-enrollment introductory, undergraduate A&P courses, my first semester teaching a few A&P laboratory sections created the opportunity to review, relearn, and reframe the content and learning goals of the course based on this firsthand experience. I had to learn much of the material for the first time, as students or new teaching assistants do. I hope that my observations of the laboratory from this perspective provide some insights that will improve learning in laboratory and/or lecture/laboratory combined courses. After a description of the course, I provide a critical assessment of some aspects of the A&P laboratory and an enumeration of strategies that are aligned with laboratory instructional approaches that emphasize student learning (18).

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Course description. This A&P course is currently a two-semester course with 3 h of lecture and 2 h of laboratory per week. It is taught on the main campus of a large urban state university with no prerequisites. The course was developed 30 yr ago, primarily to serve prenursing students, but has grown to include allied health, physical therapy assistant, biomedical engineering (some years), and some premedical students. Enrollment in the course has grown to >650 students/semester, and more A&P content has been added over the years. Two large lecture sections are taught in the day and a smaller lecture section in the evening; often, three different instructors teach the lecture sections. In addition, two full-time staff run the laboratory and teach many laboratory sections. The textbook and laboratory manual are by major publishers and are used throughout the country. A single course grade is given based on 600 points from the lecture and 300 points from the laboratory.

In the lectures, there is flexibility in the details of content and teaching styles by the various instructors. However, the content of the laboratory is as consistent as possible between laboratory sections, and changes in laboratory content or laboratory tests are made only by agreement of the five key personnel. Problems of administration by committee are found primarily in large, multisection courses that are common in large universities. I have been arguing for reductions to the laboratory content over the past many years but had never actually taught a laboratory section until last year. Teaching the laboratory has given me new insights and ideas that can be tested and assessed. Although the issues below may apply more to large-enrollment classes, content overload is also a concern in many smaller enrollment classes.

The laboratory sections are taught by graduate students (teaching assistants), adjuncts, specialized staff, and faculty members. Students generally worked in pairs at tables designed for four students in a room where students can move around. Students work with a variety of materials, including labeled and unlabeled wall charts, anatomic models, preserved animal organs, X-rays, and microscope slides; each pair of students has use of a compound microscope. The laboratory should provide a great opportunity for students to integrate course material from the cell and molecular level to the organismal level and to reach a deeper understanding of anatomic and physiological concepts.

Critical assessment of A&P laboratories. In 2015, I taught sections of the laboratory for the first time, although I had regularly attended laboratory and staff meetings for years. At those meetings, I had argued unsuccessfully to modify the laboratory content and volunteered to teach the laboratory because I had thought about writing a new laboratory manual. The first thing that struck me was the overwhelming amount of information. The emphasis on covering content limited the time to discuss and reiterate core concepts and integrate the anatomy with the physiology. Even when the material at the beginning of each laboratory was reduced by posting narrated PowerPoint presentations, there was not enough time for activities that would strengthen learning. I am certainly not the first to make these observations. Several authors have discussed the problems of information overload in science and medical courses. In 2009, the Claude Bernard Distinguished Lecture, the highest honor within the Teaching in Physiology section, was entitled "Too much content, not enough thinking, and too little FUN! (15). In his talk, DiCarlo emphasized that we must reduce the amount of factual material physiology students must memorize and increase the connections we make between new material and material that has already been learned and understood. The general importance of linking new information to existing knowledge to facilitate learning has been well documented (e.g., Ref. 6).

Students forget much of what is taught shortly after an exam, although this varies widely. Medical students generally retain 40–60% of the basic science material for at least a year (e.g., Ref. 13). However, most students in an introductory undergraduate A&P course do not have the academic profile of first-year medical students (e.g., Ref. 24). This is certainly the case in the course that I teach, where most students are prenursing or allied health students. A retention study specific to allied health students found there was no difference in performance on an upper-level cardiovascular physiology unit between students who had taken an elementary college-level physiology course (in some cases by the same professor) and those with no prior physiology experience (32). Although much information is taught, much less is learned and retained.

These issues have been addressed at the national level. A 2000 Federation of American Societies of Experimental Biology (FASEB) symposium discussed "Important Concepts That All Undergraduates Should Understand about Human Anatomy and Physiology," and a paper followed (28). One take-home message was that rote memorization should be replaced by investigative or active learning approaches even though instructors must be prepared to go at a slower pace where less material is covered than in the traditional identification approach. Another point was that "the process of learning how to address concepts is as important as learning the concepts themselves." In developing the novel chemistry course referred to above, the research team found that, although students in traditional chemistry courses scored above average on standardized chemistry exams, they had a weak understanding of the core concepts related to the topics (Cooper, personal communication). In the typical standard anatomy laboratory, students expect to identify and memorize structures, but anatomists think more about the how and why. It was also interesting to note that even though three of the authors in the FASEB paper (28) taught an undergraduate A&P course, of the 105 citations to this article, the vast majority were about medical school anatomy courses. More research is needed to reevaluate the curriculum of introductory A&P courses.

There are many terms and structures to learn in A&P, but I did not appreciate the scope of the problem until I was preparing for my first laboratory of the fall semester. Students were told via e-mail and announcements that they were expected to view two narrated PowerPoint presentations and to know over 100 terms before coming to their first laboratory. There were 42 surface anatomy terms on a labeled figure, 10 directional terms (such as proximal, distal, and sagittal), 28 body cavities or regions, 19 organs, and 11 organ systems. Most laboratory manuals begin with similar lists. Students were responsible for learning these terms on their own; many of these terms are not used for months, until the second semester of the course. Even I had trouble learning all these terms during this short amount of time. The first laboratory dealt with the compound microscope, and there were 19 more terms.

The requirement to quickly learn all these terms as part of their first laboratory experience in their first semester in college has potential consequences for average or at-risk students in the class. I wondered how many students said "This course is impossible, and I'll be lucky to pass." Self-confidence is related to the social psychology theory of self-efficacy, and much has been written about its relationship to academic achievement (e.g., Ref. 9). Bandura (2) defined self-efficacy as "the belief in one's capabilities to organize and execute courses of action required to produce given attainments." Low academic self-efficacy may predispose a significant percentage of students, particularly students at risk because of first-generation status, family problems, inadequate previous knowledge, and/or low previous academic achievement, to failure (e.g., Refs. 1, 3, 16, and 35). In the fall semester of 2015, 27% of our A&P students either withdrew or received Ds or Fs. This number is lower than in some A&P courses (e.g., Refs. 19 and 20), in part because active learning, including peer groups and flipped classroom approaches, have been incorporated into the lectures.

There are studies with young children linking increased academic self-efficacy with positive learning outcomes and better grades (30). Studies have also indicated that self-efficacy is important at the college level (26, 27), and a few studies concern A&P students. Wilke (36) compared a control and an active learning approach for a human physiology course for nonmajors (e.g., nursing, medical technology) and found a significant increase in achievement and in self-efficacy in the active learning group. Active learning strategies have been linked with increased engagement, increased motivation and perseverance, and increased confidence, all of which are related to self-efficacy. The A&P laboratory is mostly active learning, but we should avoid intimidating students and lowering their confidence at the beginning of the course by overloading them with too much nonessential content. Rather, we need to build on what students know based on next-generation standards developed by the National Research Council for K–12. As students learn the foundations of A&P, new material should be presented so that "the meaning of knowing has shifted from being able to remember and repeat information to being able to find and use it" (4). Indeed, Daniel and Poole (14) have argued that efforts to improve grades based on "memory first" approaches may harm student learning, and they advocated an ecological approach to pedagogical research. Key to this approach is observing students in the environment where they are learning. When I moved from the lecture hall to the A&P laboratories, I had new opportunities to observe how students were approaching learning.

We need to minimize memorizing long lists of structures. Students merely highlight these on the appropriate figures in the laboratory manual, ignoring important information such as function and clinical significance and the anatomic and physiological relationships of structures to each other. They pick out the words on the list and make up pneumonic devices to memorize the names but do not make important connections to the physiology. They take pictures of the models and charts with their smart phones to study later rather than comparing the different representations of a given structure in the laboratory. They lose interest quickly in simple identification tasks. Students need time in the laboratory to participate in structured activities that encourage them to discuss the material in their groups, learn how to link material to what has been previously learned, do metacognition, and ask relevant questions. The current laboratory curriculum in our course does not allow time for this.

One easy change would be to only present terms and structures that will be used within the next few weeks of the course since numerous studies have shown that items are not retained for very long unless they are used, connected, and/or applied in new and varied contexts (e.g., Ref. 6). Repeating and using root words in different contexts throughout the year could increase self-confidence; psychologists have shown that interspersing easy items with more difficult items increases problem completion rates in both young children and college students (e.g., Refs. 10 and 31). Retention also is greatly improved by frequent formative assessments (e.g., Ref. 34). Providing less intimidating assignments followed by short formative assessments may reduce anxiety about the course and improve outcomes.

Many weeks of the A&P laboratory are spent on musculoskeletal anatomy using models and wall charts. Thirty years ago, our students dissected cat muscles for several weeks and learned firsthand about the relevant functional anatomy. They could pull on tendons and see the actions of those muscles. As more content was added to the laboratories, the time-consuming dissections were reduced and replaced by models and wall charts. The role of dissection in anatomy, particularly at medical schools, continues to be a hot topic, but this is beyond the scope of this short article. However, there is general agreement that dissection of a whole structure with skin, fat, muscles, ligaments, tendons, and bone provides an opportunity to review these topics and to stress that the human body functions as a whole while maintaining homeostasis. It is only divided into systems for pedagogy and clinical subspecializations. Given the reliance on charts and models, serious discussions and research are needed on which structures best illustrate key concepts, such as homeostasis.

Simple modifications of the existing curriculum could enhance student learning. For example, most muscles are organized as antagonistic pairs, and understanding the concepts of antagonism and synergism are key concepts. However, the tables of muscles and their functions that we provide to our students are in alphabetical order, and, in some cases, a muscle is listed without its antagonist. In our laboratory manual, the muscles are presented by region, but the order within each region seems random. Careful consideration should be given deciding which muscles students need to know, which origins and insertions, and how much anatomic detail for the bone markings. In our course, students are told to learn one origin, one insertion, and one action for selected muscles, although the action does not have to match the origin and insertion the student decides to learn/memorize. A better goal might be to predict the action when given the origin and insertion.

Having students figure out the muscles involved in a common but complex movement, such as raising your arm, would provide both repetition and integration of the factual material. Having all students in the laboratory try to raise their arms with the humerus abducted could spark a discussion of integrated muscle function and the role of synergism. Since our students have figured out that they will not be formally examined on palpating structures on their own bodies, they often skip doing this in the laboratory, although its relevance and clinical importance are clear. Having students palpate structures together as a group, where the instructor can observe and encourage participation, is more time consuming but could greatly increase learning.

Frequent formative assessment, scaffolding new information on what students have already learned, interweaving easy with challenging material, and repetition have all been shown to improve learning outcomes. Asking students, maybe as a group, to identify one or two of the easiest but conceptually important histology slides (using an image or a projection microscope) from a previous laboratory would take time but would set the stage for learning new organs containing that tissue. For example, a short activity recognizing red blood cells and lymphocytes on a blood smear slide could be part of the laboratory on the spleen. Using digital devices and high-resolution digital micrographs, students may be able to view the spleen at very low magnification to see the shape of the organ and then increase the magnification to see the red and white pulp and ideally increase the magnification to see macrophages and red blood cells. Reviewing the histology of bone cells should be part of the laboratory that includes the parathyroid gland and its hormones. Such integrative activities take time but would increase learning.

Research needed. More research is needed in the teaching of A&P, both in what content should be emphasized and how to improve student learning and success. Studies, reports, symposia, and meetings on science education have been sponsored by the National Research Council, the American Association for the Advancement of Science, and the National Academy of Science. Numerous books have been written summarizing evidence-based strategies consistent with research on learning. One of the overarching messages is that an emphasis on core concepts and critical thinking produces more learning. Since integrative strategies take time, in content-heavy courses such as A&P, something has to give. Significant changes have been made in introductory biology, chemistry, and physics curricula at the high school and college level and in K–12 next-generation science standards. Progress is being made in how we teach A&P. However, the typical A&P curriculum (content) is generally similar to what it was 50 yr ago, except that more cellular and molecular physiology has been added.

This article is based on observations in a large, multisection course at a large state university, and the students are very diverse in both their preparation for A&P and their professional aspirations. For smaller A&P courses where the content has been carefully selected to meet the requirements of specific programs, such as kinesiology or medical imaging, and the lecture and laboratory are taught by one instructor, changes may not be needed. However, in high-enrollment A&P courses, many students do not succeed. These larger courses with many laboratory sections provide an opportunity where the effects of change on student outcome and efficacy could be compared and assessed. For example, it would be relatively easy to compare the number of students who drop A&P in laboratory sections where surface anatomy terms are presented all at once or distributed throughout the semester. The results of such studies should be relevant to both large and small A&P classes (19). Williams et al. (37) concluded that increasing class size past 30–40 students up to several hundred students did not affect college student achievement in a wide range of courses.

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AUTHOR CONTRIBUTIONS

E.R.G. drafted manuscript; E.R.G. edited and revised manuscript; E.R.G. approved final version of manuscript.

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