A Model for Creating Affordable Educational Resources for Anatomy and Physiology

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Abstract
The rising costs of college tuition, housing, and textbooks can be a barrier to many who seek a certification or degree in a health profession field. Affordable open educational resources (AOER) are an attractive alternative to expensive course materials. The Health Sciences Department at Weber State University created a comprehensive, two semester anatomy and physiology course using only openly available, copyright-free educational resources and an inexpensive, interactive laboratory program. The product is a collection of resources that includes a 1000+ page study guide, more than 230 small formative learning activities, recorded video lectures, and a comprehensive laboratory program that functions in both online and campus-based environments. This paper outlines the steps taken to transition from a traditional textbook-centered anatomy and physiology curriculum to one that offers students a wide range of learning resources for a fraction of the cost. The reduction of course materials costs will save health sciences students at Weber State University more than $375,000 every year.
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Key words: affordable educational resources, course materials, curriculum, textbook, open educational resources

Introduction
Institutions of higher education in the United States and abroad are constantly responding to public demand for more cost-effective certificate and degree options. For many colleges, affordability remains high on their list of priorities or goals, despite cuts in funding. School boards, legislators, and administrators work to control tuition costs, increase scholarship and grant offerings, and make a college degree more accessible to all students. Although often asked for input on these decisions, it is easy for department level administrators and faculty to feel that there is little they can do to directly impact education costs to students. Department chairs and program directors work to provide excellent learning experiences and state of the art instruction while managing slim budgets and dwindling purchase allowances. As the cost of technology, laboratory equipment, teaching models, and consumables increases, it becomes increasingly challenging to maintain modest course fees and other financial requirements for students.

One significant source of economic strain on college students is the cost of textbooks and other course materials. The average annual cost of textbooks and supplies is estimated at $1,240 and increasing every year (Ma et al. 2020). The U.S. Public Research Interest Group (PIRG) conducted student surveys at more than 150 different universities and found that 65% of students decided against buying a textbook because of cost. Furthermore, they found that 94% of students who did not purchase a textbook were concerned that not having the resources would negatively impact their grade. (Senack 2014). As tuition and housing costs continue to rise, the rising costs of textbooks, which has been many times the rate of inflation over the last 15 years, exacerbates the issues of affordability that face almost all institutions of higher education (United States Government Accountability Office 2013). Issues of affordability, especially those related to textbook costs, disproportionately affect low income and otherwise disadvantaged students (Allen et al. 2015).

Many factors, including time constraints and heavy teaching and research requirements limit educators' options for authoring novel course materials that could be used to help offset the costs associated with higher education. One potential solution could be to move away from traditional publisher-based textbook options towards what are commonly referred to as open educational resources, or OER. OER are resources developed and disseminated without the copyright restrictions that typically accompany published products. These resources range from simple illustrations and videos to complete textbooks. OER options have increased dramatically in quality over the last decade and are becoming increasingly more useful in a variety of settings. Due to their relative newness, there is a lack of substantial literature that explores the impact of OER on student performance in science fields like anatomy and physiology; however, the studies that do exist suggest increased accessibility and increased student and faculty satisfaction without negative changes to student performance (Delimont et al. 2016; Grinias and Smith 2020; Lin 2019).

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This paper presents the model that a large health sciences program in Ogden, Utah followed to transition from a publisher-based course materials paradigm to one that incorporates open-source activities, images, and content. The entire transformation involved the work of seven individuals and took less than a year to complete. Highlights of this article include the process of converting a published study guide (that made extensive use of copyrighted images) into one free of copyright restrictions, the steps taken to find, adopt, and give adequate attribution for open access images, the creation of small formative learning activities, as well as the incorporation of an interactive software program to enhance laboratory-based learning.

Background

Weber State University is an open-enrollment, Title III, state university with almost 30,000 students. More than half of all students at Weber State are over 25, married or in a committed relationship, or have children. About 80% of students report they work full or part time. In 2016/2017 the average student at Weber State received a little more than $1000 in federal Pell grant money, a figure that is more than five times the national average for institutions of higher education in the United States (US Department of Education, 2020a). Sixty percent of Weber State students receive federal grants and twenty five percent receive federal loans. Informal surveys done with Weber State students indicated that the majority of the student body had experienced some degree of financial hardship while attending school.

The Dr. Ezekiel R. Dumke College of Health Professions is the largest college at Weber State and accounts for almost half of all graduates; more than 1000 students every year. The college offers certificate, associate, bachelors, masters, and doctoral degrees in a number of healthcare areas including health sciences, nursing, radiologic sciences, medical laboratory sciences, respiratory therapy, emergency healthcare, health administrative services, and dental hygiene. The Department of Health Sciences offers the prerequisite foundational courses required by these programs. These courses include medical terminology, medical case studies, integrated human anatomy and physiology I and II, pharmacology and pathophysiology. Due to the popularity of the health profession programs at Weber State, the Department of Health Sciences sees more than 8000 student enrollments each year with about 1800 students declaring Health Sciences as their major. About one fifth of our total program enrollments are local high school seniors who take the classes at their high school but receive college credits upon successful completion.

Approximately 2900 students each year take the two semester Integrated Human Anatomy and Physiology courses and associated labs, with about 1700 taking the first semester course, Health Sciences 1110, and 1200 moving on to the second, Health Sciences 1111. For the better part of two decades, the Health Sciences Department enjoyed a mutually beneficial relationship with a large publishing company that provided a textbook in various formats, an access code to a computer-based learning program that was used to enhance labs, and a custom printing of a course study guide containing content written by Weber State Health Sciences faculty. The cost of these materials, purchased as a course materials bundle, ranged from $270 for an eBook version of the text to $320 for a hardbound textbook option.

A small portion of students (estimated ten to fifteen percent) did not purchase any course materials. These students attempted to complete the class without course materials, purchased second hand or third party materials, or shared resources with another student. Students were discouraged from sharing as it left them with less access to needed materials and required them to login to the program as someone they were not, a practice we considered a violation to our policies concerning academic integrity. Another five percent or so already had the study guide and textbook from a previous failed attempt to pass the course or bought those resources second hand and purchased only the access code, required for full participation in weekly labs, for $140. About five percent of students took advantage of a recent option to rent the course materials for a portion of the cost to buy them. Given these considerations we estimate about 1300 students purchased the course materials bundle from the bookstore, spending roughly $375,000 yearly. It should be noted that this is an estimate, as we did not directly survey the students or request bookstore sales records. Despite the hefty price tag, we felt the materials the students received were excellent in quality and facilitated effective lecture, online, and laboratory-based learning experiences.

The end of the 2019-2020 academic year brought with it an end to our contractual agreements with the publisher as well as the end to Adobe Flash player which was required for a strong portion of the interactive activities our students did as part of their weekly lab assignments. Finding a program that did not require Flash became a priority as more than one third of all those enrolled in HTHS 1110 take the course online and rely on web-based activities to complete their lab work. As we investigated many different commercial options, it became clear that the choice was going to be exceptionally difficult. Almost all publishers offered a wealth of high quality printed, online, and interactive materials. Although the cost of these materials was comparable to what our students had paid in the past, even less in some cases, the question eventually surfaced, "Can we do this ourselves and save our students a lot of money?"

What seemed like an almost preposterous idea quickly evolved and became a plan of action. After experiencing a certain degree of frustration with several different publishers and their hesitancy to create a learning unit using our outline and

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current study guide content, we decided to create our own learning materials using what was openly available without copyright limitations. The following is intended to serve as a how-to for anyone interested in creating or adopting low cost or open access educational resources for their anatomy and physiology courses.

Process

The process of redesigning our course materials in an attempt to create affordable, highly accessible content for our anatomy and physiology courses involved a number of steps and the efforts of many individuals. As a department, we were fortunate to start with a few key advantages. Most important was the fact that all six of our department's full-time professors as well as our lab manager taught the anatomy and physiology courses, so we were able to build off our collective experiences teaching the content. We had an extensive test bank, comprising more than 3000 unique questions (about 150 questions per learning unit) we had written and vetted over the course of about fifteen years.

Another significant resource was the custom study guide that we authored over the same period of time. The study guide was a collection of our own written content that followed chapter topics and included the publisher's images. It was just over 1000 pages and was the key resource used by our students to take notes during class as well as to study each learning unit. Informal surveys revealed students relied almost entirely on the study guide and only occasionally consulted the accompanying textbook for clarification. Initially we thought that all we would need to do is replace the publisher's images in our study guide with open source, copyright-free images. What ended up happening was a complete overhaul of the entire course.

Step 1. Planning and Building

Over the course of about 20 weeks, we discussed each of the 20 learning units and proposed additions, changes, or deletions to the content. One individual was tasked with the revisions for each learning unit. At our weekly meetings, the lead reviser would take extensive notes and guide decisions about changes to the study guide content and lab activities. We used our own learning objectives, the Human Anatomy and Physiology Society (HAPS) Learning Outcomes, as well as input from the various health professions programs in our college to guide what we focused on in each learning unit. Other learning activities, referred to as formatives, were developed to accompany the objectives for each learning unit.

Step 2. Content Revising

The intent for each lead reviser was to leave the weekly meeting with a solid idea of the intended changes, as agreed upon by the entire department. Using the study guide we already had in place, the reviser would build an outline and reorder the content, making sure to fill in any gaps with new written content. This process allowed us to remove content that was beyond the scope of the course or did not line up with the learning objectives mentioned previously, while ensuring complete coverage of necessary information. The guiding principle behind our study guide revisions was to create something readable and more easily understood by the average student than a textbook. We compared question banks from our exams to the learning objectives for each unit to verify that we were covering all objectives with our summative assessments. We wrote new questions or deleted old ones to bring congruency between assessments and content for all twenty learning units.

Both semesters of our integrated anatomy and physiology courses include a minimum of two hours of hands-on lab activities each week. The lab component of the previous course design included a substantial number of interactive activities using the publisher's content. To get away from a reliance on a publisher's proprietary activities, it was clear we would need a new program to enhance our campus-based instruction of anatomy and physiology concepts and provide the in-depth, psychomotor learning required for meaningful, effective online laboratory activities (Kuyatt and Baker 2014). We wanted something that would be engaging for students on campus, online, and at our concurrent enrollment sites. We also wanted to find something that would be long-lasting and inexpensive.

Our exploration of options lead us to a partnership with Visible Body (visible body.com). Their suite of mobile apps and online content was a good fit for our program and was adapted to replace what we had previously used. The Visible Body content includes interactive activities that utilize augmented reality (Figure 1) to help students explore anatomy and physiology concepts that can be challenging to teach in two dimensions. The cost of the program was less than one-tenth of the total cost of the previous learning materials and provides students with full, lifetime access to four different mobile apps that we believe will greatly enhance their learning and will serve as excellent references in the future as they move on to their individual health profession programs and careers. Visible Body offers a wide range of activities and teaching styles that help to engage the students in the content, making it more applicable and easier to understand (Figure 2).

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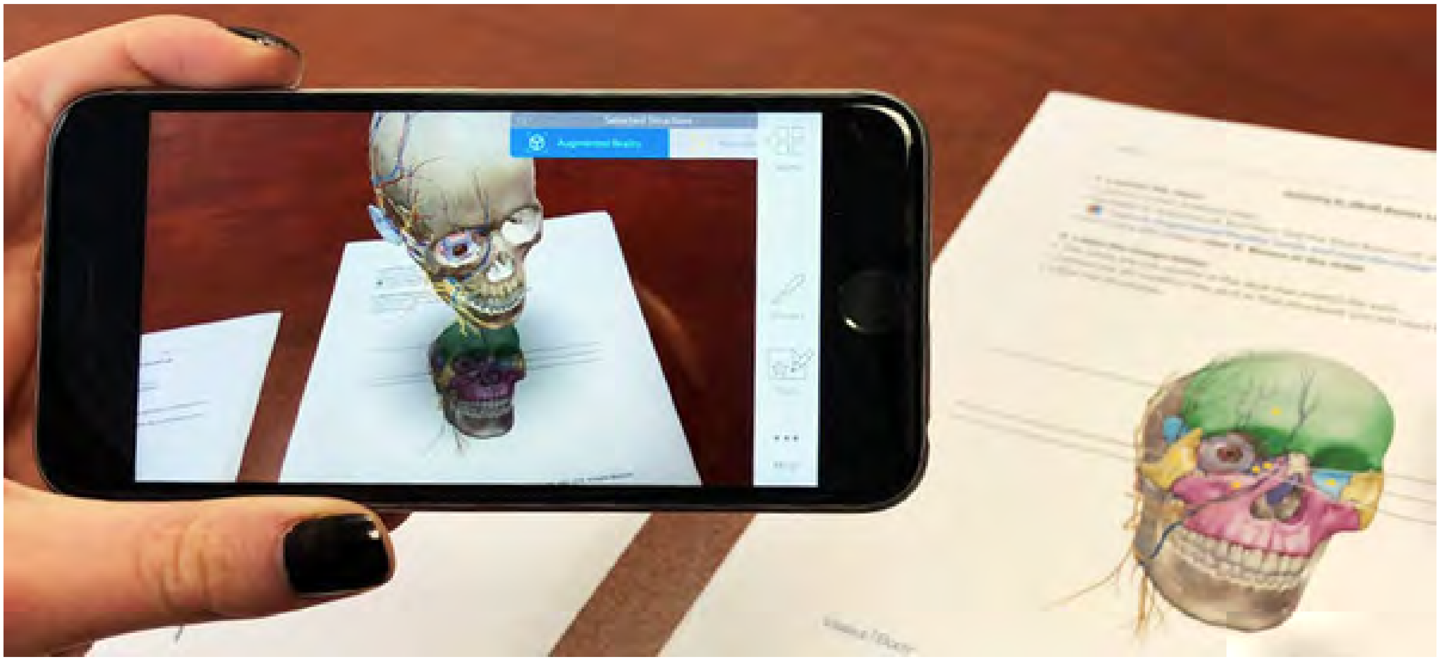

Figure 1. *Example of augmented reality tool of Visible Body*

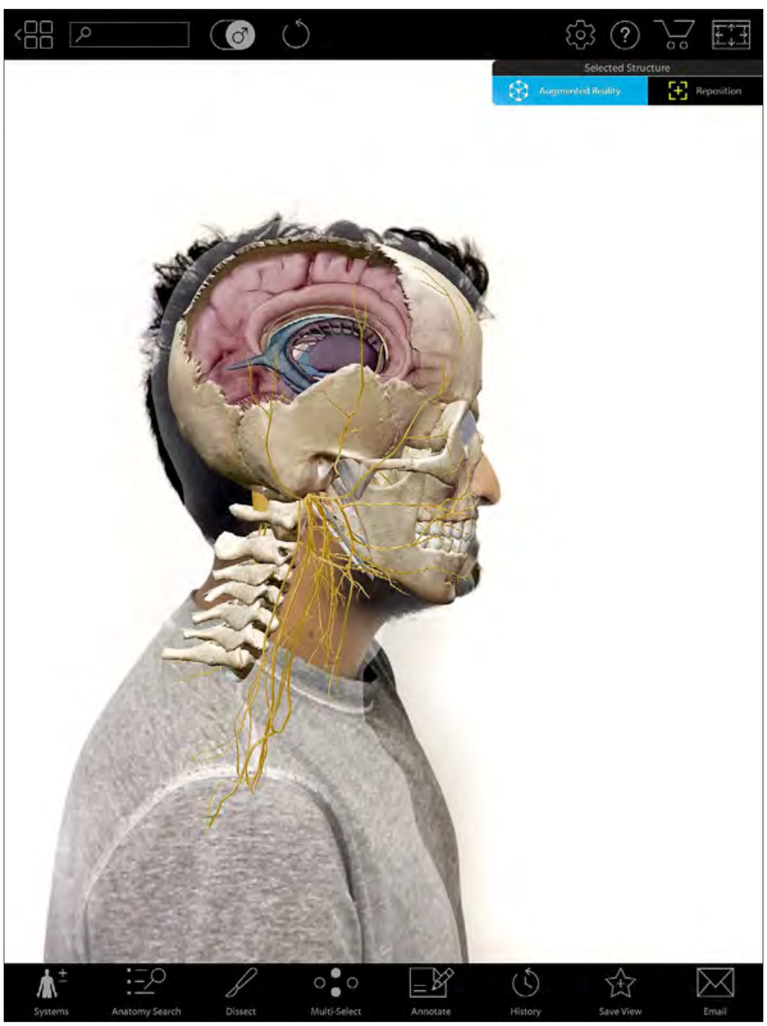

Figure 2. *Approach used by Visible Body to illustrate some brain and skull structures as well as some cranial nerves*

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Step 3. Gathering Images

Finding replacement images for the publisher's copyrighted images proved to be challenging, but not impossible. The amount of open-source or creative commons content grows daily. Image libraries, like Adobe Stock (stock.adobe.com), offer licenses to educators that allow for the use of their images in content like what we put together. We found their prices to be very reasonable and were pleased to learn that our university already had agreements set up to facilitate image selection and use. Overall, we were able to find more than ninety five percent of the image replacements we needed in open-source formats. The remaining five percent were adopted from Adobe Stock image collections. Our license with Adobe allows for royalty-free, extensive use of their images in our resources.

Most images that are openly available online have what are known as Creative Commons Attribution Licenses instead of copyrights. These kinds of licenses typically only require image attribution when they are used by others. As we gathered images and incorporated them into the content, we meticulously kept a log of image details like author, source, creative commons license and whether the image was modified or not. This image attribution list is an appendix to our study guide. We used the online file management system, Box (box.com), to add our images and documents so they could be shared and reviewed by the rest of the department during development.

Step 4: Recording Lectures

The Department of Health Sciences has always made recorded video lectures available to campus, online and concurrent enrollment students. We recorded new video lectures for each of the newly redesigned learning units, breaking each recording into shorter videos covering one objective at a time. This approach makes future edits easier by allowing for changes or replacements of only one objective at a time compared to the longer video formats from our previous course design that had to be rerecorded in their entirety.

Recorded video lectures proved to be extremely valuable with the way COVID-19 disrupted our ability to hold face-to-face lectures. We were able to record quality video lectures for each learning unit using a do-it-yourself studio put together by members of Weber State's audiovisual team. The videos were recorded, stored, organized and delivered using Kaltura (corp.kaltura.com). One extremely useful feature of the Kaltura system is the ability to create playlists that can be embedded within learning management systems like Canvas (Figure 3). Any changes we make to videos in the playlist are automatically updated in our learning management system.

Step 5: Study Guide Creation and LMS Course Construction

After collecting new images, reorganizing and rewriting content, and building lab activities, what was left to be done was to compile the study guide and build the course within our learning management system. Most standard word processing programs have limited design functionality, but Adobe InDesign (adobe.com) allowed us to create a new study guide that was visually appealing and facilitated the creation of pages with written content, tables, graphs, and images. We were fortunate to have a skilled colleague who was able to

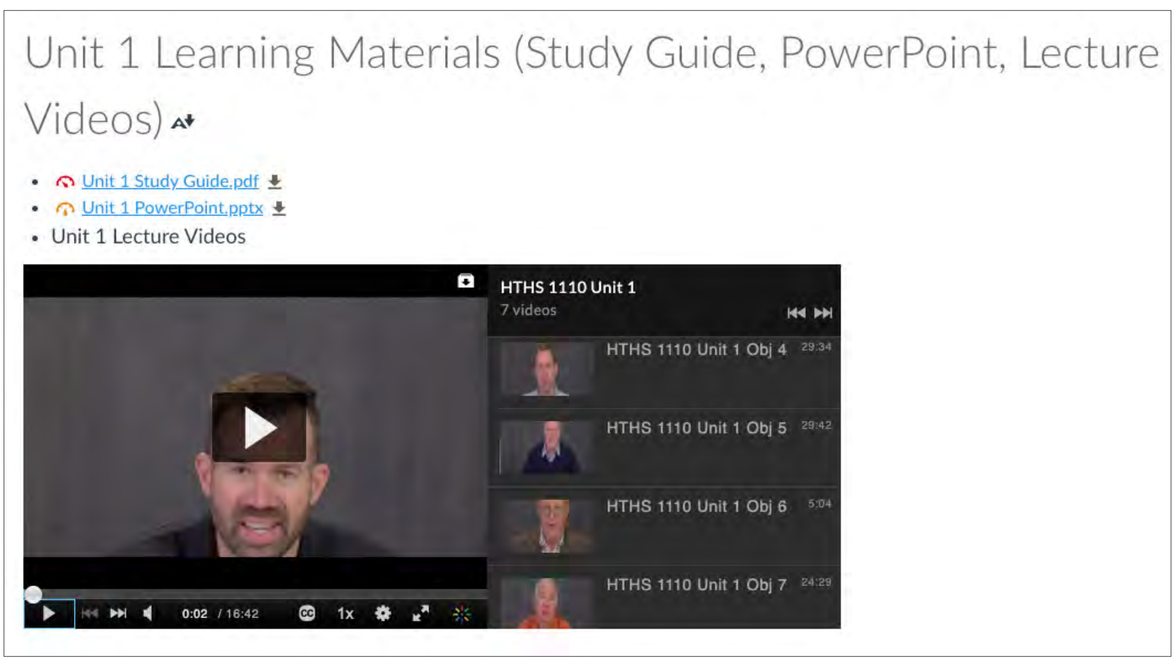

Figure 3. *Example of embedment of Kaltura instructional videos plus supportive study materials within Canvas.*

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take our documents which contained mostly written content and references to the images we had uploaded to our Box folder and turn it all into print-quality pages (Appendix).

In 2010, Utah adopted Instructure Canvas (instructure.com) as the learning management system for all levels of education delivery, including higher education. We were able to make all of our content available and easy to navigate within Canvas. The Kaltura system, used to manage our video lectures, integrates well with Canvas and allows for video play directly within Canvas as well as options to download and save the videos. As soon as students are given access to their Canvas-based courses, typically on the first day of the semester, they gain instant access to the study guide, PowerPoint presentations, recorded lectures and other learning activities. All learning materials are copyright free, so students can download, share, and print the content however they choose. PDF versions of course content are available for easy printing. Students who choose to print the study guide with campus-based printing services report spending about $15 for a black and white, spiral bound version of the study guide for each semester.

Step 6: Assessing Learning

One appeal of most publishing companies today is online, interactive learning activities. Our exploration of these revealed an abundance of quiz-based activities, but a somewhat limited catalog of activities that encourage a wide variety of learning strategies. Once again, we determined these kinds of activities, which we refer to simply as "formatives", were something we could create ourselves given the extensive number of resources available online. The product of these endeavors is more than 230 short, formative learning activities incorporated into our courses. These activities were designed to enhance learning and provide unique opportunities to explore topics by taking students away from the standard methods of content presentation. The value of such approaches has been widely discussed in the literature (Shute 2008). We designed each activity to be worth only a few points to encourage students to do them but to not dilute the weighted value of the summative assessments already in place.

The range of activities and learning strategies these "formatives" incorporate is extensive. Some examples include the following: opportunities for the students to practice taking notes in a new format, short video clips with accompanying quizzes, exploration of online databases, online games, experiments they can do in their kitchens, short papers encouraging students to explain things in their own words and drawings and diagrams they create and upload. Our goal with the creation of so many formative activities was to push students out of the learning model of "cramming" content and then "dumping" it on a summative exam to an explorative process that might yield better long-term learning and retention. The formative activities enhance learning beyond the cram and dump paradigm by requiring students to conceptualize content, engage in repeat and retrieve practices, teach challenging concepts to others as well as promoting learning through a variety of audio and visual resources. These kinds of active learning strategies have proven to be effective ways to improve learning of anatomy and physiology concepts. (Zimanyi et al. 2019)

These formative activities allow students as well as faculty to assess understanding and make corrections during the learning process for each objective within a unit. For example, one formative for the renal system asks students to draw and upload a picture of the nephron of the kidney and label important structures, giving one key function of each structure. Instructors can then look at the pictures and provide feedback to the students before their end-of-unit summative quiz. The combination of these formative activities with our summative assessments for each learning unit and comprehensive midterm and final exams create a system that we believe better assesses learning than the previous model which only used unit exams and a single final comprehensive exam. The literature on science education pedagogy support a range of learning activities for better integration of learning and retention (Barber 2012; Weurlander et al. 2012).

Step 7: Reviewing, Correcting, and Revising

Any content revision process will unavoidably yield errors. The old model we worked under allowed very little opportunity for corrections on a regular basis. We often would have to wait years to make adjustments or changes as the materials we used followed textbook editions and were professionally published. One of the most significant advantages of the model being presented is the ability to make changes at any time. In most cases, the changes involve simply pulling the section of the study guide, assignment, activity or other resource from Canvas, making the changes and then re-uploading it. In most cases, we are able to make these changes before students even reach that point in the course, leaving them unaware that edits were made. This model also allows for the addition of new content at any time. If there is a particular topic students appear to be struggling with, we can add content or a formative activity to enhance or supplement the learning.

We piloted the new content (Table 1) during the Summer 2020 semester. As a part of our pilot run, we hired one of our lab instructors to go through the entire course, ahead of the cohort of students, as if they were a student enrolled in the course. In this way, they acted like the "rail sweep" or "cowcatcher" on the front of a locomotive that sweeps obstacles off the track that might otherwise derail the train. As they encountered potential issues, they alerted the unit reviser, who was then able to quickly fix the problem. The final result was a semester with only minimal issues related to

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course content, all of which were easily and quickly remedied. Implementation of the revised content for both HTHS 1110 and HTHS 1111 is currently underway in all sections of the course. Future studies will include an exploration of students' perceptions of the new content design, the efficacy of the learning materials, and a comparison of grades prior to and following the implementation of the new course content.

Previous Course Design	Current Course Design
Course Reference Materials	
Students purchased a commercially published textbook and custom study guide. Students were not allowed access to digital copies of the content due to copyright restrictions. Total cost varied from $270 to $330, depending on the textbook format. Students reported relying almost entirely on the study guide for personal studying	Students can view, download, print and share the study guide, PowerPoint presentations, and all images and diagrams used in the course. There is no cost associated with any of these materials. The study guide remains the principal resource for personal studying
Laboratory Resources	
Students purchased an access code to online learning materials as part of their course materials bundle. Students who had the study guide and textbook already from a previous semester could purchase the access code alone for $140. Student in campus-based labs experienced interactive learning activities using cadavers and other models in addition to the publisher's online resources. The publisher's online learning activities were the only lab activities online students completed.	Students purchase an access code to the Visible Body suite of applications and programs The cost of the bundle, which includes 4 downloadable mobile apps, is less than $30 for Weber State students. A significant price reduction was negotiated due to our high enrollment. Campus-based and online students alike experience a higher level of interactive learning using 3D models, dynamic videos and augmented reality. Do it yourself laboratory activities designed to mirror campus-based activities have been developed and incorporated for online students.
Learning Strategies	
Students attended lecture or watched recorded lectures online. Students would study on their own from the study guide, textbook or lab materials and would take a unit exam after each learning unit.	Students attend lecture or watch recorded lectures online. Students study on their own from the study guide and other content available online. Students are guided through a series of formative assignments associated with each learning objective for each learning unit. Formative activities incorporate a variety of different learning strategies.
Assessment	
Course grades were based on 10 unit quizzes (100 points each), 15 weekly labs (10 points each) and a final exam (100 points). All points were of equal weight.	The 120+ formative assignments are worth 1-5 points each depending on the time required to complete them. The lowest 30 scores from the formatives are automatically dropped. Students complete an open-book, unit quiz (50 points each) at the end of each learning unit. A midterm and final exam (120 points each) serve as summative assessments. The assignment groups are weighted in the grade book to give highest value to the midterm and final exam.

Table 1. *Previous Course Design Compared to Current Course Design*

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Other Considerations

Funding

This project involved a significant amount of work on the part of department faculty, much of which occurred during off-contract time. Compensation for this time came through department funding as well as grant monies we were able to obtain. Weber State University has an affordable course materials committee that encourages this kind of work and is able to secure donor-funded grants. The university provost as well as the dean of the college of health professions were supportive of the work and contributed to the funding. In total, approximately $50,000 was spent to fund the project. Assuming flat enrollment (although enrollment in Health Sciences courses continue to rise) 1300 students spending $250 less than they used to for course materials generates a yearly savings of about $325,000 and a ten-year savings of more than $3,250,000. Using these figures as a return on investment made acquiring grant money much easier.

As initiatives to reduce course materials costs gain traction, the number of funding opportunities increase. Many universities are creating affordable materials committees, often staffed by librarians with special responsibilities to seek out and assist those interested in finding ways to reduce textbook and other materials costs. In 2018 the U.S. Department of Education initiated the Open Textbooks Pilot Grant Program, funded through the Fund for the Improvement of Postsecondary Education (FIPSE). To date, this program has awarded approximately $10 million to projects that aim to reduce course materials costs (US Department of Education 2020b).

A simple mention of our project to our college's librarian put us on track to meet with various individuals and groups, including members of university administration, who were interested in what we were doing. Affordable textbook projects address a variety of institutional goals. These include reduced costs and increased accessibility to education for the general student body, and especially underrepresented students. With regard to traditionally disadvantaged students, one study referred to affordable and open access learning resources as an "equity strategy for higher education that helps to mitigate a variety of socioeconomic factors that can impact students' ability to succeed in higher education" (Todorinova and Wilkinson 2019).

Additional Resources

Other schools that have undertaken similar projects are often eager to help and assist in the process. We learned a lot from looking at Rice University's OpenStax textbooks. In fact, we even used several pictures from their Anatomy and Physiology text, a practice that is not only acceptable but encouraged. A program looking to get away from a publisher, but not able to develop their own materials, could benefit from the OpenStax library (openstax.org) of free materials. Other such textbooks and even complete courses are available in completely open-source formats. Lumen and their collaboration with Boundless have an extensive library of courses and titles. OER Commons, textbookequity.org, BCcampus OpenED, and the Open Textbook Library all contain texts for Anatomy and Physiology that could be easily adapted to suit the needs of a program. Organizations such the Scholarly Publishing and Academic Resources Coalition (SPARC), have been founded to promote open, affordable access to learning materials across disciplines and in all areas of education and research.

A variety of programs and departments from across one's own campus can be included in this kind of endeavor. Collaboration with student writers, artists, graphic designers and researchers creates interdisciplinary experiences that can be rewarding and valuable to all involved. Student workers as well as graduate students can be very helpful in many phases of a project involving the creation or adoption of low cost learning materials.

Conclusion

The catalog of open educational resources (OER) seems to grow daily. We hope to eventually add our newly redesigned anatomy and physiology materials to that collection, but have felt the need to vet our learning materials with our own students before making them more widely available. We also hope to hire illustrators who can help us replace the images we needed to pull from stock image banks as these images carry some limitations that prevent them from being used in a truly open-access resource. All who contributed to the development of the affordable resources described in this paper share the goal of one day making what we produced freely available to anyone who may be interested.

The Health Sciences Department at Weber State University is only in its second semester of course instruction using the new materials, making it challenging to assess their true efficacy. The changes forced upon us as a result of the global pandemic have further complicated the process of evaluating the new content and course design. Anecdotal evidence and informal statistical analysis give us reason to believe the content is being well received. Unit scores have not deviated significantly from what they have been in the past. Further analysis will be required to fully ascertain the impact of the new course materials on anatomy and physiology students at Weber State. We believe that the effects on student learning will mirror what has been seen at other institutions and in other programs that have adopted affordable or open educational resources.

What is clearly evident is the impact of the financial savings on students. The informal feedback we have received has been overwhelmingly positive, with respect to the cost of course materials and abundance of learning resources. During the current global pandemic, having a variety of free, easily

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accessible resources has been of monumental value. We have already begun the process of converting course materials for our other courses into affordable course materials with the hopes that we might continue to make all of our students' academic and career goals easier to achieve.

About the Author

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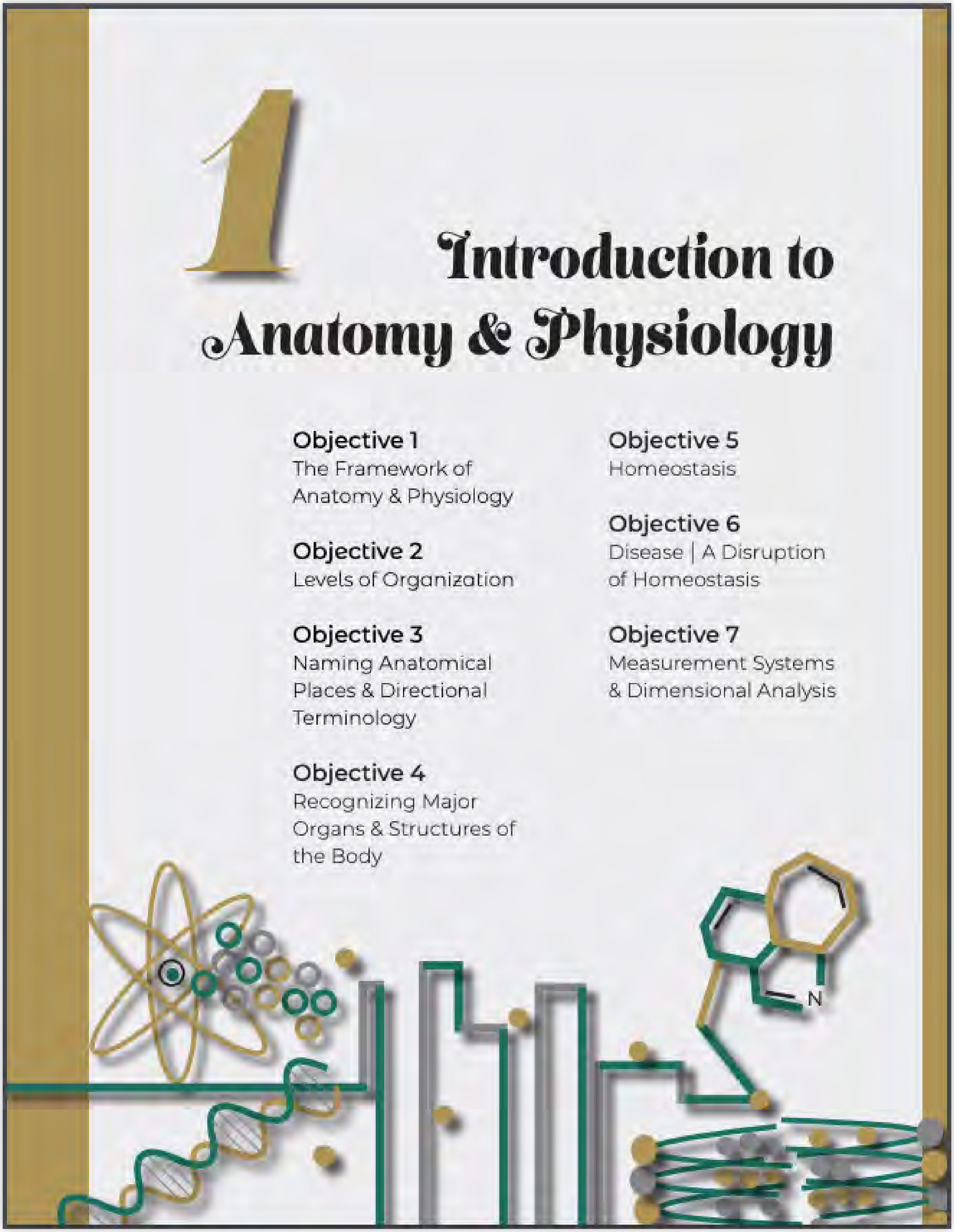
APPENDIX

Unit 1 Title Page



1

Introduction to Anatomy & Physiology

Objective 1
The Framework of Anatomy & Physiology

Objective 2
Levels of Organization

Objective 3
Naming Anatomical Places & Directional Terminology

Objective 4
Recognizing Major Organs & Structures of the Body

Objective 5
Homeostasis

Objective 6
Disease | A Disruption of Homeostasis

Objective 7
Measurement Systems & Dimensional Analysis

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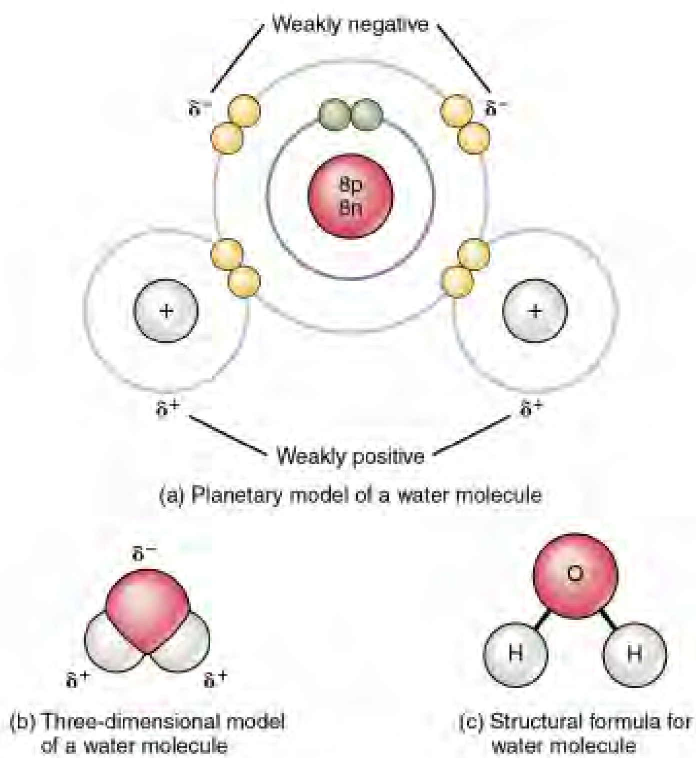
Objective Page Example 1

Objective 11: Special Properties of Water

11 **Describe the special properties of water: hydrogen bonding and surface tension.**

Water forms from a relationship between the highly electronegative atom oxygen and the more weakly electronegative and really kinda wimpy hydrogen atom. Since hydrogen only has one proton, it has a hard time holding onto its electrons. This results in the special properties of water. Water is 60% of the human body for a reason: these special properties make water the ideal substrate for chemical reactions.



Water has special hydrogen bonding properties.

Water is thought of as a near-universal solvent. A wide variety of substances dissolve in water.

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Objective Page Example 2

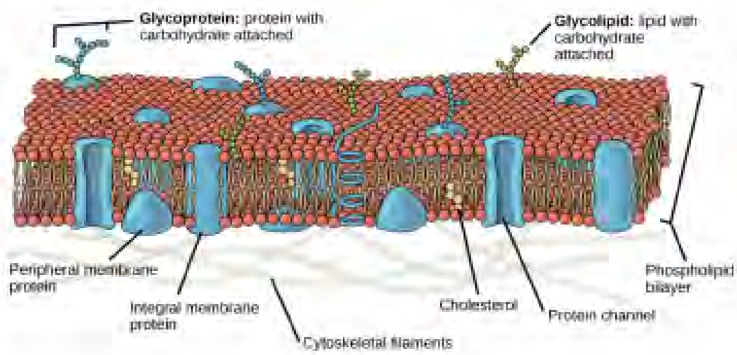
Objective 3: The Plasma Membrane

3

List and classify the components of the plasma membrane, as defined by the fluid- mosaic model. Classify membrane proteins as peripheral or integral. Define permeability. Classify substances according to permeability through the plasma membrane.

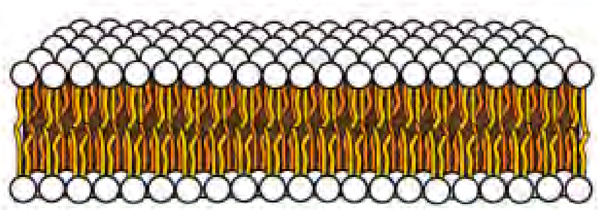
In this objective we'll look at the structure of the plasma membrane and how this creates a selectively permeable barrier. We'll describe substances that can freely pass through the membrane and those that cannot without assistance. Proteins in the membrane will be defined as peripheral or integral (transmembrane).

In 1973, Singer and Nicholson proposed a new model for the cell membrane, which came to be called the fluid-mosaic model. Among the features of the model are:



1. Lipids consist of polar (i.e. hydrophilic, water-soluble) head groups with non-polar (i.e. hydrophobic, fat-soluble) tails.
2. Lipids arrange themselves into two layers, with the head groups facing the extracellular and intracellular solutions (like the "bread" in a sandwich) and with the lipid tails forming a layer between (like the "peanut butter" of a sandwich).

Lipid-bilayer sheet



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Objective Page Example 3

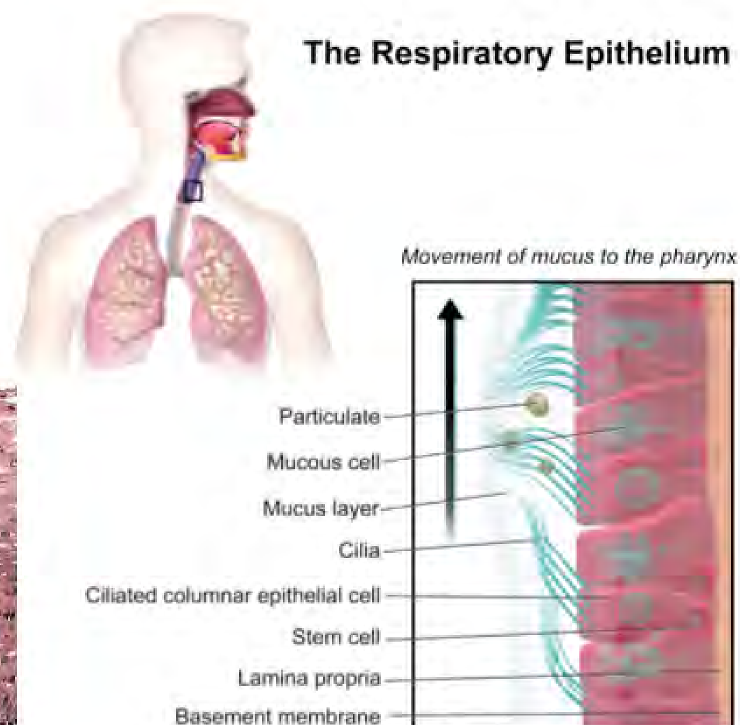
Objective 4: Respiratory System Histology

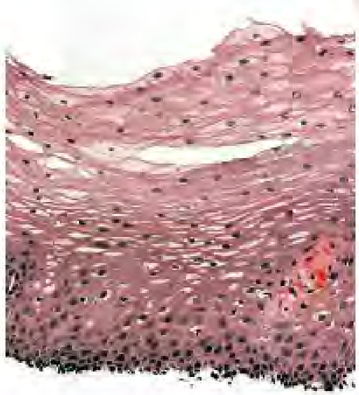
4 **Describe the histology of the respiratory system.**

This objective will focus on the histology of the respiratory system. You are familiar with the tissue types from previous units but we will describe how they play a role in the respiratory system. By the end, you should be able to describe the histology of the respiratory epithelium and state the function(s) for each kind of tissue.

Remember that function denotes structure. This is true of the tissues of the respiratory tract. Tissues vary throughout the respiratory tract to meet specific functions.

Parts of the pharynx and larynx are lined with stratified squamous epithelium for protection. Most of the conducting portion of the respiratory tract is lined with pseudostratified columnar ciliated cells, also called the respiratory epithelium. This epithelium also contains goblet cells which produce mucus. The mucus and the cilia form the mucocillary escalator which transports foreign particles out of the respiratory tract.





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