ABSTRACT
Making the study of the human anatomy and physiology authentic and clinically relevant poses many challenges. Described herein is a program that, through the use of medical school cadavers, provides high school students a unique experience to enhance their clinically based study of human anatomy and physiology. The program incorporates many learning modalities as well as problem-based team learning and can be a feasible addition to many high school anatomy programs.

Key Words: cadaver; anatomy; physiology; clinical correlation.

Introduction
Oftentimes, human anatomy and physiology courses focus on rote memorization of structures with little clinical application and only minimal exposure to either small mammal or single organ dissection. Over the past several years, we have developed a program that allows high school students to experience human cadaver dissection accompanied by clinical correlation. Our efforts have shown that an overwhelming majority of students feel this cadaver component has substantially increased their understanding and appreciation of the function of the human body. The importance of cadaver use in an anatomy course is supported by the Human Anatomy & Physiology Society. They state:

Mindful of the constraints imposed by cadaver availability, limited facilities and underfunding, HAPS endorses the use of cadavers as consistent with the origins and nature of scientific inquiry and views the proper use of cadavers as an ideal laboratory experience in human anatomy and physiology. While animal dissection may approach the ideal, cadavers provide opportunities that cannot be duplicated by animal dissection, supplemental media or anatomical models. (HA&PS, 2014)

Although not every high school is in close proximity to a teaching hospital, there are still approximately 130 accredited medical schools in the United States (ABMS, 2012). If a high school teacher forms a rapport with the anatomy instructors at a nearby medical school, the activities described herein can serve as a framework for curriculum development.

Program Overview
Approximately one hundred students are enrolled in the honors level of Human Anatomy and Physiology in our high school. Because of a relationship with a local osteopathic medical school and its gross anatomy lab, our program is rather unique in that it requires multiple visits to the medical school lab as part of the lab component of this course, and that each visit is accompanied by a rigorous assessment. Some schools across the country have single visits to cadaver sites (Anderson, 2013). Most do not require a specifically matched assessment, or they provide the opportunity as a non-credited experience (Swiech, 2014). If only single visits are feasible for some districts, the exposure to cadavers, along with an assignment similar to those discussed below, will still add depth to the curriculum.

Prior to the first lab, each student and their parent must sign a permission slip agreeing to provide transportation as well as to adhere to safety guidelines while in the lab. First-year medical student volunteers are recruited by the co-course director of the gross anatomy lab to provide instruction and guidance to the high school students.

We have developed a program that allows high school students to experience human cadaver dissection accompanied by clinical correlation.
The Assignment

The assignments are designed specifically for each session, and they are vetted for feasibility and coordination with the stage of the medical dissection. Furthermore, they are provided to the medical student volunteers well in advance of the visit to allow adequate preparation time. The assignment questions correlate with the structures that have been exposed according to the medical dissection schedule. This may mean that the cadaver assignment does not parallel the unit being covered in our high school class. For example, the high school students may be learning about the skeletal system, but the cadaver assignment examines the thoracic and abdominal cavities exposed. We do not see this as a drawback; rather, this asynchronous exposure increases the level of independent research as students investigate topics about which they have yet to be instructed.

In general, the assignments must be a balancing act between gathering specific information (e.g., muscle origin, insertion, and innervation) and the development and honing of observational skills. We found that if the assignments were too fact-oriented, the high school students were more interested in getting the right answer instead of focusing on the entire cadaver experience.

At each visit, approximately 15 to 20 medical students are stationed in pairs at individual cadavers. The high school students are arranged in small teams of three to four, but there can be several teams at a cadaver at the same time. The lab session runs for approximately 75 minutes, and groups are instructed when to rotate (approximately every 15 minutes) to another cadaver. Thus, during a visit to the dissection lab, they will observe three to four different cadavers.

The initial visit to the lab in the fall can be an intense experience for the students. It is their first time viewing a cadaver—the sights, sounds, and smells are unlike anything they have experienced. As a result, the first assignment is the least demanding of anatomical information, and focuses more on encouraging detailed observations (Figure 1).

Subsequent visits reflect an increase in rigor and detail of anatomical information (Figure 2). In addition, the assignments include questions that help the students explore clinical correlations related to the exposed organs and structures.

Completing the Assignment

During their time in the cadaver lab, students are making notes and observations. The assignments are finalized in their small groups outside of class time. The report takes the form of detailed responses to each question in the exercise. The responses can vary

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<tr>
<th>Cadaver Lab Introduction</th>
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<tr>
<td>Participants must follow these guidelines during this introductory lab:</td>
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<tr>
<td>• No more than two groups at a time at each cadaver.</td>
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<td>• You will spend approximately 15 minutes at each cadaver.</td>
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<td>• Switch cadavers when given instruction to do so.</td>
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<td>• At least four cadavers must be viewed.</td>
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<td>In your groups of 3-4, answer the following questions:</td>
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1. In correct anatomical terminology, describe the area of the cadaver that is being dissected.
2. List the structures that are exposed in your first cadaver. Discuss the function of each.
3. Describe, in detail, the appearance of each structure listed in #2. Use enough detail so that someone who is not in the lab could picture clearly what you are seeing.
4. How does the appearance of the skin tissue differ from the appearance of a living person’s? What are the reasons for these differences?
5. Compare the general appearance of cadaver #1 with cadaver #2.
6. Compare the appearance of the exposed organs (the ones listed in #2) of cadaver #1 with cadaver #2.
7. Compare the general appearance of cadaver #2 with cadaver #3.
8. Compare the appearance of the exposed organs of cadaver #2 with cadaver #3.
9. Do you think you can tell anything about the overall health of an individual by observing their cadaver? Explain.
10. What do you think is the most difficult part of dissecting and using a cadaver to study human anatomy?
11. Explain two things that surprised you about your visit today.

Figure 1. Example of introductory cadaver lab assignment. The majority of the questions focus on honing observational skills.
in length from several sentences to short paragraphs. Within their teams, students must collaborate and use their peer-editing skills to create a final report. Students have approximately one week to complete their work and submit one final product per group. The use of this type of team-based learning has been shown to enhance student learning as well as their attitudes toward teamwork (Huitt et al., 2015).

To increase the academic rigor of the assignment, students are not allowed to research using typical internet sites; instead, they are required to use on-line reference collections and research databases to which our school district subscribes. For example, they have access to a virtual library of reference textbooks. In addition, they can read peer-reviewed journal articles specific to the search topics they enter into the database’s search engine. This encourages them to utilize scholarly articles and scientific reference collections instead of the unreliable information found on public websites.

**Cadaver Lab Assessment—Back & Limbs Dissection (45 points)**

1. Identify 5 muscles of the BACK. Give origin, insertion, innervations & function. (5pts)
2. Identify 5 muscles of the UPPER EXTREMITY. Give origin, insertion, innervation & function. (5pts)
3. Identify 5 muscles of the LOWER EXTREMITY. Give origin, insertion, innervation & function. (5pts)
4. How does the appearance of the muscles identified in #2 & #3 differ between cadavers you observed? (2pts)
5. Explore the motion of the hand. Describe how individual digit movement is produced. What motions result from contraction of the anterior forearm muscles? Posterior muscles? (2pts)
6. What artery supplies blood to the shoulder and arm? How does the right and left artery differ in terms of their origin from the aortic arch? (2pts)
7. What artery supplies blood to the lower limb? Describe its branching pattern and name 4 major arteries and the region of the lower limb each supplies. (2pts)
8. Observe the sciatic nerve. Describe its relationship to the muscles of the gluteal region. From what spinal nerve segments does it form and what are its 2 main branches? (2pts)
9. If possible and if time permits, locate a cadaver with a joint replaced. Describe the location and appearance of that joint. (2 pts)

**Self-Directed Study and Research**

10. Research two common conditions that lead to that type of joint surgery you observed in the dissection lab. If none were observed, describe in general the kinds of conditions or diseases that would require total knee replacement or total hip replacement. (4 pts)
11. Research a vascular disease that commonly occurs upper or lower limb. Distinguish between signs and symptoms. What is the recommended treatment for this disease? (3pts)
12. Recall your observations in #8. There is a disorder commonly referred to as “sciatica.” Research this condition giving spinal as well as muscular causes. Distinguish between signs and symptoms. What is the recommended treatment for this condition? (3pts)
13. Research a skeletal disease that commonly occurs in the upper or lower limb. Distinguish between signs and symptoms. What is the recommended treatment for this disease? (3pts)
14. Research a disorder that would result from compression of one (or more) of the nerves in the upper extremity. Specify the nerve, cause of compression, signs & symptoms as well as treatment. (5pts)

**Figure 2.** Example of a subsequent assignment reflecting more required rigor and detail.
Assessing the Assignment

When grading the report, the goal of the cadaver lab visit should be kept in mind. For example, Figure 3 presents a rubric for the first visit to the lab where observational skills are the focal point. This rubric allows the instructor to assess students’ work more holistically. With subsequent visits, when content is the focus, specific point values can be assigned to each question as in Figure 2. Overall, the cadaver lab portion of the course accounts for 12–15 percent of the students’ final grade.

Benefits

The benefits of this program are numerous. For the high school students, it offers the opportunity to learn using many modalities: visual, verbal, tactile, as well as deductive reasoning (Felder, 1988). Visually, the cadaver experience is second to none. Students can look at two-dimensional diagrams of the abdominal cavity and its contents, but nothing compares to seeing and verifying by touch the relationships of the actual organs—their position, color, and orientation. As students explore a particular body region, they are questioning the

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<tr>
<td><strong>Specificity of terminology</strong></td>
</tr>
<tr>
<td>Few structures &amp; locations were described with precise detail &amp; correct anatomical terms.</td>
</tr>
<tr>
<td>The group is developing observation skills, but only a brief list of structures &amp; observations were made.</td>
</tr>
<tr>
<td>The group was developing observation skills, but only a brief list of structures &amp; observations were made.</td>
</tr>
<tr>
<td>Clear indication that the group was highly observant: comprehensive list of structures was provided; several astute observations were made regarding the process of dissection.</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
</tr>
<tr>
<td>No evidence that the group worked well together—it appears as though one member took responsibility for the assignment.</td>
</tr>
<tr>
<td>Little evidence that the group worked well together with few members sharing responsibility for completion of the assignment.</td>
</tr>
<tr>
<td>Clear evidence that the group worked well together with all members sharing responsibility for completion of the assignment.</td>
</tr>
<tr>
<td><strong>Content/Presentation</strong></td>
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<tr>
<td>The report is incomplete with many spelling/formatting errors.</td>
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<tr>
<td>The report is not presented in a professional manner: some parts are answered, some functions are listed, but spelling/formatting errors are present.</td>
</tr>
<tr>
<td>The report is thorough &amp; presented in a professional manner: All parts are answered, All functions are listed, no spelling/formatting errors are present.</td>
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Total ______ / 32

Figure 3. Example of a rubric that can be used to score the cadaver lab assessments holistically.
medical students and listening to their explanations. Students who choose to do so may put on gloves and have an immersive experience with the organs of the body, whether they hold a human heart or explore the movement of the digits by tugging on the muscles and tendons of the forearm (Figure 4).

The written assignments, as stated earlier, require deductive reasoning and a careful search of reputable, scientific databases. Students must gather information from many sources and formulate conclusions specific to the cadavers viewed. For many students, this is their first exposure to formal research and scientific writing. By setting clear expectations, they are challenged to perform at an academically high level. The benefits are seen short-term as well as long-term, as many of them prepare to enter colleges where this type of scholarly research will be required.

In addition to these academic benefits, we have observed an even greater increase in enjoyment of the curriculum after the cadaver experience. As educators know, student engagement is often the first step in acquiring new knowledge.

Perhaps the benefits extend beyond the individual student to the medical school as a whole. Multiple studies have shown that the physician shortage—particularly of primary care specialists—may reach the tens of thousands by 2035 (Peterson et al., 2015). This cadaver lab experience has piqued many students’ interest in attending medical school. Part of the reason may be that during the high school students’ time in lab, they are not only learning anatomy and physiology, but they are also questioning the medical students about their experiences preparing for and entering medical school. These side conversations have proved invaluable in allowing high school students to see that entering the health care field is an attainable goal. One student’s comment sums up the importance of the cadaver experience:

The cadaver component allowed me to experience something that most high school students cannot. This program really helped me understand what it was like to be in an anatomy lab and become comfortable with how dissection works. As well, this program helped me realize I want to pursue a medical career.

In addition, the author is fortunate enough to have seen several students graduate and go on to pursue medicine—many of them have served as tutors for our current high school students. As one of these students states:

At age 18 I remember standing at one of the tables and thinking, “this could be me in four years.” Not only did my dream come true, but four years later—I got assigned to the exact same table during my first year of med school.

\section*{Conclusion}

Although the gulf between high school and medical school can seem large, the activity described herein can be used as a framework for schools to establish a relationship with a nearby medical facility. The experience not only enhances students’ understanding of anatomical structure and function, but it may have long lasting effects by helping them appreciate the intricacies of the human body and inspiring them to pursue a career in medicine.

\section*{Acknowledgments}

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\section*{References}


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