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The HAPS Educator is published in April, August and December. The deadlines for submission are March 1, July 1 and November 1.

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A Few Words about the Spring Issue of the HAPS Educator

In the face of this ongoing pandemic, I know that all of us, as educators, are working hard to engage with our students in a variety of ways given that much of their learning must presently occur either online or under very controlled small-group settings. I am so pleased that, despite the extra workload associated with maintaining an enriched learning and valid assessment environment during these challenging days, a number of instructors have also found the time to compose and submit manuscripts to the HAPS Educator in order to share their experiences and educational successes with you.

In this edition, you will find articles exploring the incorporation of mindfulness into student learning experiences, either as a direct way to foster short-term retention or as a benefit associated with student creation of their own handwritten notes while learning. Analogies are explored as a means of promoting in-depth understanding of anatomical and physiological concepts and a detailed exploration of a case of bilateral ureteral duplication has some important advice, from a medical perspective, for teachers of anatomy. The importance of diversity, equity, and inclusion as critical features of a welcoming and supportive learning environment is featured in an article summarizing historical, cultural and religious influences on anatomical and physiological instruction through the ages. Finally, our spring edition finishes with describing some variations on the use of the human diving reflex as a laboratory exercise to promote student understanding of autonomic cardiovascular responses.

The HAPS Educator provides an excellent platform for college and university professors to share their ideas and research pertaining to education. At no time is that needed more than right now. Our classrooms are often virtual, rather than bricks and mortar, and we are striving to find ways for students to interact not only with their instructors, but even more importantly with one another, as they explore concepts pertaining to body structure and function. I look forward to receiving more of your shared experiences and ideas in the months to come.

All the best,

Jackie Carnegie,
Editor-in Chief
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Can Mindfulness Practice Improve Short-term Retention in a Science Course?

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Abstract
Brief periods of wakeful resting have a positive effect on memory consolidation. To test the impact of mindful breathing exercises on the retention of new knowledge in a science class, we assigned lab sessions of Anatomy and Physiology I and II randomly to the intervention group or control group. During teaching periods, the intervention group lab sessions integrated mindfulness breaks by having students participate in guided breathing exercises every 25-30 minutes. With one exception, the average scores on the weekly retention quizzes taken at the end of the lab sessions were higher for the intervention group compared with the control group for all quizzes in both Anatomy and Physiology I and II. However, there was no significant difference in the average score between the intervention and control groups on formal quizzes and exams. Future studies should evaluate whether mindfulness techniques, such as mindful breathing exercises, used before exams lead to improved exam scores. https://doi.org/10.21692/haps.2021.001

Key words: wakeful resting, memory formation, mindfulness, mindful breathing exercises, Anatomy & Physiology

Introduction
In 1900, one of the founding fathers of experimental psychology, Georg Müller and his student Alfons Pilzecker, published their seminal work Experimental Contributions to the Science of Memory (Experimentelle Beiträge zur Lehre vom Gedächtnis)(Lechner et al. 1999). They proposed that memory formation is not an instantaneous process, but requires time to consolidate. Therefore, interruptions may negatively affect memory formation. Although this concept of memory consolidation was soon accepted, its importance and implications for teaching and learning were not fully recognized. Most research in this area focused on the benefits of sleep and its influence on forming memories. It was not until early in the twenty-first century, when studies were published that looked at factors affecting memory formation in patients with amnesia. For example, Dewar et al. (2009) reported that some of the severe forgetting observed in amnesia is actually the product of a disruption of memory consolidation by immediate post-learning interference.

Wakeful resting, which is a brief period of minimal mental stimulation after new learning, allows for novel memory traces to be consolidated better and therefore retained for much longer (Dewar et al. 2012). Craig et al. (2016) showed that wakeful rest can improve the integration of new spatial memories. A recently published review article by van Kesteren and Meeter (2020) stressed that offline periods, in which learners are allowed to let their mind wander, have a positive effect on memory consolidation. Analogously, Martini et al. (2020) found that, similar to sleeping after learning, a brief period of wakeful resting after encoding new information supports memory retention.

One way to achieve wakeful resting is by drawing the mind away from a mental or physical task to focus on ourselves, thus becoming mindfully aware of our body and emotions. Mindfulness can be defined as nonjudgmentally paying attention to the present moment (Kabat-Zinn 1994). The two main components of mindfulness are: present-moment awareness and acceptance (Ahmed et al. 2017). While mindfulness practices are often considered in conjunction with Eastern spiritual practices, they are gaining popularity in the classroom for young children through adolescents and college students (Franco et al. 2011; Joy et al. 2019; Leland 2015).

The positive effects of mindfulness on overall well-being, including the emotional and mental health of students, have been well documented (Szpunar et al. 2013; Warnecke et al. 2011). However, most studies involving undergraduate students focus on the beneficial effects of mindfulness on mental health and sleep, as opposed to learning and academic performance (Rosenzweig et al. 2003; Shapiro et al. 1998; Sohrabi et al. 2013).

For example, Gray et al. (2018) found significant decreases in stress levels and heightened sleep quality for undergraduate students who participated in a brief mindfulness-based intervention. Firth-Clark et al. (2019) explored the use of cognitive behavioral techniques to improve academic performance of student-athletes. Both researchers concluded that mindfulness on its own is not the most effective intervention, and thus should be used as an adjunct to other psychological methods.
To evaluate the effect of mindfulness on the performance of college students, this study addressed the following two questions:

1) Does integration of mindfulness practices into formal teaching increase retention of newly learned material?
2) If there is a positive effect on knowledge retention, does this lead to better performance on formal assessments and better grades?

Additionally, we were curious about student reactions to the integration of mindfulness practices into the classroom and whether they would see benefits beyond improved knowledge retention.

**Methods**

*Ethical research statement*

The research protocol and its amendment were approved by the Institutional Review Board of Florida Gulf Coast University (FGCU) prior to data collection (FGCU IRB 2018-57). All researchers involved in the study were trained in ethical data collection through the Collaborative Institutional Training Initiative (CITI). Data collection followed all laws relevant to the survey of university student populations.

*Data collection*

During academic year 2018/19, lab sections in both Human Anatomy with lab I (Anatomy and Physiology I) and II (Anatomy and Physiology II) were randomly assigned to either the intervention group or the control group. Both groups used the same course materials, followed the same syllabus, and used the same written tests to assess student progress. The only difference was that, during teaching periods, the intervention group lab sessions integrated mindfulness breaks by having students participate in guided breathing exercises every 25-30 minutes. The lab sessions lasted two and a half hours with an initial teaching period of 45 minutes to one hour, which meant there were usually two breaks for guided mindfulness. During the guided breathing meditation, the students sat up straight, closed their eyes, and listened to a five-minute recorded breathing exercise. Students were encouraged, but not required, to actively engage in the guided breathing exercise.

Students in both groups completed short quizzes of ten multiple choice questions at the end of each weekly lab session to assess their retention of the material covered during the session. Additionally, students in both Anatomy and Physiology I and II took nine weekly quizzes and four written exams during the term. The number of questions on these quizzes and exams ranged from 15 to 125 depending on how many chapters in the textbook were covered.

Students in the intervention group were invited to participate in three anonymous online surveys to assess their perceptions of the mindfulness breaks at the start of the semester, midway through the semester, and at the end of the semester.

**Data analysis**

Statistical analyses were performed using the SPSS, version 26.0, statistical software package from IBM. All data were analyzed using a confidence interval of 95% and a significance level of 0.05. The data were analyzed for normal distribution using the Shapiro-Wilk test of normality. All data were normally distributed with P>0.05 so that the assumption for parametric statistics was satisfied. To identify if a significant difference between groups existed, the paired sample t test was used to compare the difference between both groups each week. Where a significant difference between intervention group and control group was identified, the Cohen’s d effect size was determined.

**Results**

*Study population*

The number of students in our Anatomy and Physiology classes dropped over the course of both semesters and not all students attended all lab sessions or took all weekly quizzes and exams. In Fall 2018, 214 students started the semester in seven lab sections; four lab sections were assigned to the intervention group and three lab sections to the control group. There were 349 students in 12 Anatomy and Physiology I lab sections in Spring 2019; half of the lab sections were assigned to either the intervention or control group. Anatomy and Physiology II had 225 students in eight sections in Fall 2018 and 177 students in six sections in Spring 2019. At the beginning of each semester, the lab sections were randomly assigned to either the intervention or control group.

*Weekly retention quizzes*

The thirteen weekly quizzes administered at the end of each lab session consisted of ten multiple choice questions. The questions were designed to assess how much of the material covered during the lab sessions students actually remembered. The quizzes did not factor into the students’ overall course grades.

In Anatomy and Physiology I, the average scores on all quizzes were higher for the intervention group compared to the control group (Table 1). However, the difference between the scores of the intervention and control group was only significant for quizzes 4, 5, 7, 8, and 10-13. There was no significant difference for the average scores between the two groups for quizzes 1, 2, 3, 6, and 9. The Cohen’s d effect size for quizzes 4, 5, 7, 8, and 10-13 ranged between 0.257 and 0.500, indicating a small to moderate effect size as a result of the intervention.

For Anatomy and Physiology II, the average score on weekly retention quizzes was higher for the intervention group compared to the control group for all quizzes, except for quiz 4 when the control group had a higher average score (Table 1). There was no significant difference between the average scores...
of the intervention and control groups for quizzes 1, 2, 4, and 6-9. Significant differences in average scores between the two groups were, nonetheless, found for quizzes 3, 5, and 10-13. The Cohen's d effect size for these quizzes ranged from 0.258 to 0.407, i.e., showing a small to moderate effect size for the intervention.

<table>
<thead>
<tr>
<th></th>
<th>Anatomy &amp; Physiology I</th>
<th></th>
<th>Anatomy &amp; Physiology II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention group</td>
<td>Control group</td>
<td>p-value</td>
<td>Effect size</td>
</tr>
<tr>
<td>Quiz 1</td>
<td>7.5</td>
<td>7.3</td>
<td>0.198</td>
<td></td>
</tr>
<tr>
<td>Quiz 2</td>
<td>7.5</td>
<td>7.4</td>
<td>0.542</td>
<td></td>
</tr>
<tr>
<td>Quiz 3</td>
<td>7.3</td>
<td>7.3</td>
<td>0.683</td>
<td></td>
</tr>
<tr>
<td>Quiz 4</td>
<td>6.3</td>
<td>5.7</td>
<td>0.007* 0.257</td>
<td></td>
</tr>
<tr>
<td>Quiz 5</td>
<td>6.7</td>
<td>5.9</td>
<td>&lt;0.001* 0.373</td>
<td></td>
</tr>
<tr>
<td>Quiz 6</td>
<td>7.9</td>
<td>6.5</td>
<td>0.067</td>
<td></td>
</tr>
<tr>
<td>Quiz 7</td>
<td>7.0</td>
<td>6.1</td>
<td>&lt;0.001* 0.410</td>
<td></td>
</tr>
<tr>
<td>Quiz 8</td>
<td>6.9</td>
<td>6.3</td>
<td>0.013* 0.247</td>
<td></td>
</tr>
<tr>
<td>Quiz 9</td>
<td>6.1</td>
<td>5.9</td>
<td>0.329</td>
<td></td>
</tr>
<tr>
<td>Quiz 10</td>
<td>8.8</td>
<td>5.9</td>
<td>&lt;0.001* 0.376</td>
<td></td>
</tr>
<tr>
<td>Quiz 11</td>
<td>7.3</td>
<td>6.1</td>
<td>&lt;0.001* 0.500</td>
<td></td>
</tr>
<tr>
<td>Quiz 12</td>
<td>6.2</td>
<td>5.2</td>
<td>&lt;0.001* 0.443</td>
<td></td>
</tr>
<tr>
<td>Quiz 13</td>
<td>6.6</td>
<td>5.3</td>
<td>0.013* 0.541</td>
<td></td>
</tr>
</tbody>
</table>

*denotes significance

Cohen's d effect size: small effect size = 0.2; moderate effect size = 0.5; large effect size = 0.8.

**Table 1.** Average scores (out of 10) on weekly retention quizzes for the intervention and control group for Anatomy & Physiology I and II and p-values and Cohen’s d effect size for significant p-values.
Can Mindfulness Practice Improve Short-term Retention in a Science Course?

Quizzes and exams
Students in both Anatomy and Physiology I and II took nine weekly quizzes (multiple choice and open questions including labeling exercises) and four exams (multiple choice questions only). The quizzes covered one or two chapters in the textbook. Exams 1-3 covered between four and five chapters each. The last exam for both courses was cumulative and covered all chapters studied during the semester. As opposed to the weekly retention quizzes, the more formal quizzes and exams tested the students’ knowledge from material covered the week(s) before. These assessments contributed 95% of the overall course grade at the end of the semester.

There was no significant difference in the average score between the intervention and control groups on any of the quizzes or exams. For example, the p-values for the four exams in Anatomy and Physiology II were 0.46 (exam 1), 0.10 (exam 2), 0.28 (exam 3), and 0.74 (exam 4), respectively. In general, the average scores for students in the intervention group were slightly higher, but there were also instances where students in the control group had higher averages.

Feedback surveys
The number of students completing the feedback surveys was rather low and declined from survey 1 to 3 (Table 2). At the beginning of the term, students in both Anatomy and Physiology I and Anatomy and Physiology II reported a generally positive attitude toward mindfulness practices. Six out of ten Anatomy and Physiology I (61.3%) and Anatomy and Physiology II students (62.5%) reported having practiced mindfulness, such as mindful breathing exercises or meditation, prior to taking this course. These students also reported a more positive attitude toward mindfulness practices than students who did not indicate prior exposure (7.4 vs. 5.6 for Anatomy and Physiology I; 7.3 vs. 5.0 for Anatomy and Physiology II).

<table>
<thead>
<tr>
<th>Survey 1 (week 1)</th>
<th>Survey 2 (week 7)</th>
<th>Survey 3 (week 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy and Physiology I</td>
<td>Anatomy and Physiology II</td>
<td>Anatomy and Physiology I</td>
</tr>
<tr>
<td>Number of respondents</td>
<td>n = 64</td>
<td>n = 56</td>
</tr>
<tr>
<td>Attitude toward mindfulness practices</td>
<td>6.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Has your attitude toward mindfulness changed during the semester?</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Opinion of mindfulness breaks in labs</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Have mindfulness breaks been helpful?</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Student uses mindfulness breaks on their own</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Student plans on using mindfulness techniques in future</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

1How would you describe your overall attitude toward mindfulness practices such as meditation? Scale 1 (‘I just don’t care for it’) to 10 (‘I love it’)
2What do you think about the mindfulness breaks in labs? Scale 1 (‘I hate them’) to 10 (‘I love them’)
3Do you think the mindfulness breaks in labs have helped you remember things you learned in lab better? Yes/No
4Have you started to use mindfulness breaks/techniques on your own while studying for this or other classes? Yes/No
5Do you think you will continue to use mindfulness breaks/techniques on your own while studying after this course has ended? Yes/No

Table 2. Results of feedback surveys 1-3 for Anatomy and Physiology I and II
The average score for the attitude toward mindfulness practices was basically unchanged at 6.7 for Anatomy and Physiology I and 6.6 for Anatomy and Physiology II on survey 2. One-third (32.7%) of Anatomy and Physiology I students felt their attitude toward mindfulness had changed during the term. These students had a score of 7.6 for their attitude toward mindfulness. Only 18.8% of participating Anatomy and Physiology II students reported a changed attitude toward mindfulness, however their average score for attitude toward mindfulness was fairly high at 8.4.

Anatomy and Physiology I and Anatomy and Physiology II students had similar scores (Anatomy and Physiology I 6.7; Anatomy and Physiology II 6.5) when asked to rate the mindfulness breaks used in lab on a scale from 1 to 10. Almost one-third (32.6%) of Anatomy and Physiology I students and 36.5% of Anatomy and Physiology II students felt that the mindfulness breaks had helped them remember content that they had learned in lab better. However, only 26.9% of Anatomy and Physiology I students and 28.6% of Anatomy and Physiology II students reported using mindfulness breaks/techniques on their own while studying for this or other classes at this stage of the semester.

On survey 3, Anatomy and Physiology I students reported a lower score for attitude toward mindfulness practices at 5.8 compared with 6.7 in surveys 1 and 2. The score for Anatomy and Physiology II students was more or less unchanged at 6.3. Only one-fifth (19.0%) of Anatomy and Physiology I students indicated a change in attitude toward mindfulness compared with one-third (33.3%) of Anatomy and Physiology II students who reported a change. The scores for 'What do you think about the mindfulness breaks in labs?' were more or less unchanged for both student groups compared to survey 2.

The percentage of students who thought that the mindfulness breaks in labs had helped them remember things better was lower compared to survey 2 as well for both groups. On the other hand, more students had started to use mindfulness breaks/techniques on their own while studying for this or other classes since survey 2. The vast majority of these students indicated that they planned to use mindfulness breaks/techniques on their own while studying for future courses (Anatomy and Physiology I 92.3%; Anatomy and Physiology II 100%).

**Discussion**

The results of our study confirm the findings of previously published studies that integration of mindfulness breaks into the teaching/learning process improves short-term retention of studied material. With the exception of quiz 4 in Anatomy and Physiology II, the average scores on the weekly retention quizzes were higher for the intervention group compared with the control group for all quizzes in both Anatomy and Physiology I and II. Nonetheless, this is not an immediate effect but takes time and practice. The first quizzes with a significant difference in the average scores between intervention and control group were quiz 4 in Anatomy and Physiology I and quiz 3 in Anatomy and Physiology II. During the last part of the semester (week 10-13), the differences between the averages were statistically significant for all quizzes in Anatomy and Physiology I and II courses.

However, this increased retention of newly learned material did not carry over to quizzes and exams taken a week or more after the initial lab session in which the content was taught. For example, the average scores on the final exam of the term were only marginally different between the intervention group and the control group in Anatomy and Physiology I (62.2% for the intervention group vs. 59.8% for the control group) and almost identical in Anatomy and Physiology II (60.0% for the intervention group vs. 60.3% for the control group). This comes as no surprise as there many factors that influence student performance on formal exams. Students will have studied material repeated before taking an exam, thereby erasing any difference in immediate retention due to an integration of mindfulness practices.

Although almost one-third of students in the intervention group indicated in the feedback surveys that their attitude toward mindfulness practices had changed, the average rating on a scale from 1-10 did not reflect this change. The average score for the attitude toward mindfulness practices remained more or less unchanged over all three surveys. Students in both Anatomy and Physiology I and II who thought that the mindfulness breaks had helped them remember content better reported slightly better grades in survey 3. On the other hand, students who had started to practice mindfulness breaks/techniques on their own while studying for this or other classes did not earn better grades than those who did not.

Overall, four out of ten (39.5%) participating Anatomy and Physiology I students indicated that they planned on using mindfulness breaks/techniques on their own while studying for future courses; that percentage was even higher for Anatomy and Physiology II (50.0%). These participants had noticeably higher average scores for their attitude toward mindfulness (Anatomy and Physiology 7.2; Anatomy and Physiology II 7.7) than students who did not plan on using mindfulness techniques in future (Anatomy and Physiology 4.8; Anatomy and Physiology II 4.9).

Because the feedback surveys were anonymous and the number of responses very low, we were not able to analyze our data in more depth. Having more responses and being able to link them to student performance on quizzes and exams may have been able to yield more insight.
Can Mindfulness Practice Improve Short-term Retention in a Science Course?

Our next step will be to look at the impact of guided mindfulness on exam scores. Students regularly complain about being unable to perform well due to test anxiety. Having them engage in mindful breathing exercises before taking exams may help reduce their anxiety and improve their test performance.

Conclusions
Integrating mindfulness practices into teaching sessions/lectures increases the immediate recall of the learned material, especially if the students are new to the subject matter taught. However, doing so does not lead to better scores on formal exams nor does it help students earn better overall course grades. There are other factors that affect the preparation for and/or performance in exams more. Future studies should evaluate if mindfulness techniques, such as mindful breathing exercises, used before exams lead to improved exam scores.

About the Authors
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Rob Sillevis is an Assistant Professor and teaches in the doctor of physical therapy program research, movement sciences, and physical therapy courses. He has had a long standing interest in mindfulness and mediation.

Valerie Weiss is an Assistant Professor and teaches undergraduate anatomy and physiology to students in the pre-health professions. She is also a medical illustrator, contributing to the course companion and lab workbook used in the course.

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The Power of Analogy-Based Learning in Science

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Abstract
Analogies are useful pedagogical tools to introduce new and difficult concepts to students by building connections to familiar things from our daily life. Research has shown that applying analogies during the learning process facilitates the development of higher order thinking. In this article, we present a number of analogies that have been included in several science courses, including anatomy and physiology and clinical chemistry, in undergraduate nursing science education. We also evaluated student perspectives on the ability of these analogies to enhance student understanding of difficult concepts. A total of 53 analogies were organized into structural and functional categories and a survey explored student feedback on them. A total of 131 first-year and second-year students completed the survey. More than 70% of the students indicated that these analogies were useful in understanding the anatomical structures and physiological functions. Over 60% of students applied these analogies while studying. Eighty-eight percent of students found that analogies were engaging and made the lecture more enjoyable. We conclude that well-structured and purposeful analogies have positive impact on students' learning of science courses during undergraduate nursing studies. https://doi.org/10.21692/haps.2021.003

Key words: analogies, metaphors, pedagogical, undergraduate science education, anatomy and physiology, educational research

Introduction
Analogy has been defined as a comparison based on some form of similarity between an unfamiliar and a familiar domain. Traditionally this relationship is expressed with “a is to b is like c is to d” (Richland and Simms 2015; Seiler and Huggins 2018). Other definitions emphasize the role of analogies in learning and the cognitive process in the transfer of information from a source (familiar) to a target (unfamiliar) domain to achieve a better understanding (Brown and Salter 2010; Dagher 1995; Gentner 1983; Gentner 1989; Gentner and Markman 1997; Orgill 2006). Hofstadter (2001) defines analogies as the perception of commonalities between the target and source domains and sees analogies as the link between the familiar and the unfamiliar. The author adds that our brain is continuously building analogies during the learning process to facilitate comprehension. To understand a new concept, whether it is scientific in nature or for everyday life, the human brain finds a familiar concept and links that to the unfamiliar (Hofstadter 2001). Metaphors are similar to analogies in referring to the similarity between two things, however metaphors implicitly state the comparison, such as the heart is a pump and vessels are the pipes (Brown and Salter 2010; Niebert et al. 2011). Furthermore, analogies are more complex in their nature than metaphors. When used as pedagogical tools, analogies often need an explanation to make sure student construction of the similarities is what the teacher intended (Dagher 1995; Brown and Salter 2010).

Gentner's structure mapping theory has been foundational in understanding analogies as scientific concepts. Brown and Salter (2010) explain that based on Gentner’s theory, an analogy is well-developed and aids learning if the two domains share relations rather than attributes.

Figure 1. The extent of relation and attribute sharing between the two domains. Analogies have greater extent of relation sharing. [Adapted from: Gentner (1989) and Brown and Salter (2010)]
Although literal or superficial similarities have low explanatory power, they can serve as precursors for developing analytical thinking which suggests pedagogical value (Dagher 1995).

Heywood (2010) suggested a paradigm shift related to the role of analogies in education, in which research about analogies should focus on their role in engagement in the learning process rather than emphasizing the cognitive transfer between the unfamiliar and familiar domains. When reasoning occurs through analogies, the educator and the student are mutually engaged, and deeper understanding of complex concepts can be achieved. Understanding and utilizing analogies represents a higher order thinking compared to straight memorization (Castillo 2018; Heywood 2010; Richland and Simms 2015). Therefore, it is not surprising that educators have naturally incorporated the use of analogies and metaphors on an everyday basis (Brown and Salter 2010; Dagher 1995; Orgill 2006). However, analogies can also be consciously incorporated into lectures to make students fully aware of the purpose and the limitations of comparisons (Brown and Salter 2010; Castillo 2018; Mastrilli 1997). According to Brown and Salter (2010), students need to be taught about analogies by comparing the similarities but also by explaining the differences between the two domains.

To stress the importance of health-science for first-year nursing students, we used an analogy about a house. Anatomy and physiology can be compared to the foundations of the house. In the way that the foundation supports the walls of the house, anatomy and physiology provides basic but strong background knowledge for later science courses such as pathology, pharmacology, and for clinical courses, such as medicine and surgery.

Previous studies provided analyses on how analogies are used in classrooms and aid in science teaching (Dagher 1995; Mastrilli 1997; Niebert et al. 2012; Sellier and Huggins 2018). However, few of them examined how students received the analogies. In this study, our goal was to develop a well-structured and organized way to use analogies. Beside collecting the analogies that have been included in the science courses for first-year and second-year undergraduate nursing students, we conducted a survey-based study to obtain feedback from students on analogies. Our study aims specifically to evaluate students’ perspectives on how these analogies enhance their understanding of difficult science concepts.

**Methods**

**Participants**

This project was approved by the St. Lawrence College Research Ethics Board (SLC-REB #: 2019-208HE) and informed consent was obtained from all participants. Students from first-year and second-year undergraduate Bachelor of Science in Nursing program were recruited and invited to fill out a survey on a voluntary basis. First-year students were taking a university level Human Anatomy and Physiology course which is taught for two semesters encompassing 24 three-hour lectures and 24 three-hour laboratory sessions. Second-year nursing students enrolled in a Clinical Chemistry course were also recruited. This course builds on the knowledge of anatomy and physiology and adds the basics of pathophysiology, laboratory science, and diagnostics; related analogies are presented. Clinical Chemistry is taught for two semesters and includes 24 three-hour lectures.

Analogies were presented by the same instructor during lectures using the same protocol. When the lecture arrived at a concept to be explained, the instructor told students that this concept can be explained by an analogy. After the analogy was presented, the instructor explained the aspects of the analogy similar to the concept. The presentation was finished by explaining the boundaries that limit the similarities between the analogy and the concept.

Survey data was collected over two years. We received a total of 131 responses from students who participated in the study. Students who took the same course twice in consecutive years did not fill out the survey in the second year. Sixty-seven first-year and 64 second-year students (out of the total class size of 88 and 73 respectively) completed the survey after their last lecture of the semester. In the first year of the study, paper-based surveys were filled out in the classroom. In the second year, the surveys were converted to electronic format, and participants filled them out online due to mandatory physical distancing during the COVID-19 pandemic.

*The survey, the analogies, and data analysis*

The survey consisted of 12 questions and included two sets. The first set consisted of nine five-point Likert scale questions with answer choices from “strongly disagree” to “strongly agree”. The other set of three questions were open-ended questions soliciting student perception through free text answers.

In addition to conducting the survey, a total of 16 structural and 37 functional analogies were collected during the lectures for two years. The analogies were developed over fifteen years by the instructor of the two courses, and they were presented using the language and illustrations of the instructor to avoid potential copyright issues. The comprehensive list of analogies is provided in Table 1.

The analogies were organized by topic and grouped into structural and functional categories for better understanding. Structural analogies compare unfamiliar anatomical concepts to commonplace ideas by the similarity of their appearance or structures. An example of a structural analogy is lasagna as it resembles the endoplasmic reticulum by its layered organization. Functional analogies, however, show similarities in a process, such as playing musical chairs to explain the concept of competitive enzyme inhibition.

*continued on next page*
### LIST OF SELECTED ANALOGIES PRESENTED IN CLASS

<table>
<thead>
<tr>
<th>Analogy</th>
<th>Represented concept</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cellular Structure and Function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fenced swimming pool with swimmers</td>
<td>The cell. The fence represents the cell membrane, the pool water represents the cytoplasm, and the swimmers represent the organelles</td>
<td>S</td>
</tr>
<tr>
<td>A fence of a military base guarded by soldiers, watching cameras, and controlled gates</td>
<td>Cell membrane</td>
<td>F</td>
</tr>
<tr>
<td>Lasagna with cheese in-between the layers</td>
<td>Smooth endoplasmic reticulum. Cheese represents the stored calcium in the cisternae</td>
<td>S</td>
</tr>
<tr>
<td>Ground meat lasagna</td>
<td>Rough endoplasmic reticulum. The ground meat represents the fixed ribosomes</td>
<td></td>
</tr>
<tr>
<td>Stack of pancakes with blueberries within and in between the pancake layers</td>
<td>Golgi apparatus and their vesicle. Blueberries within the pancakes are comparable to vesicles being developed, and blueberries in between the layers represent the vesicles that were packaged and released by the Golgi apparatus</td>
<td>S</td>
</tr>
<tr>
<td>Children holding a rope when out for a walk</td>
<td>A single strand of DNA, children represent the nucleotides</td>
<td>S</td>
</tr>
<tr>
<td>Subway workers in some busy subway stations squeeze people into the train against the crowd</td>
<td>Na+/K+ pump transports sodium and potassium ions against their concentration gradient.</td>
<td>F</td>
</tr>
<tr>
<td>The doors between two adjacent hotel rooms can be open or closed depending on the need of the guests</td>
<td>Gap junctions</td>
<td>F</td>
</tr>
<tr>
<td>Dying peacefully at an old age versus dying in an accident at a young age</td>
<td>Apoptosis versus necrosis</td>
<td>F</td>
</tr>
<tr>
<td>All desks in a classroom are occupied by students, so no more students can sit down</td>
<td>Saturation</td>
<td>F</td>
</tr>
<tr>
<td>Musical chairs game</td>
<td>Competitive inhibition</td>
<td>F</td>
</tr>
<tr>
<td>A student cannot use a desk although can sit down if the desk is occupied by the belongings of another student such as books and a laptop</td>
<td>Non-competitive inhibition</td>
<td>F</td>
</tr>
<tr>
<td><strong>Bones and Joints</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hockey puck</td>
<td>Intervertebral disc</td>
<td>S</td>
</tr>
<tr>
<td>Horseshoe</td>
<td>Acetabular labrum</td>
<td>S</td>
</tr>
<tr>
<td>Wrench</td>
<td>Proximal end of the ulna</td>
<td>S</td>
</tr>
<tr>
<td><strong>Muscle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interdigitating fingers</td>
<td>Sliding filaments of a sarcomere</td>
<td>S</td>
</tr>
<tr>
<td>Direction of fingers when you put your hands in your pocket</td>
<td>Direction of the external oblique muscle fibers</td>
<td>S</td>
</tr>
<tr>
<td>Direction of fingers when you put your hands on your heart during the national anthem</td>
<td>Direction of the internal oblique muscle fibers</td>
<td>S</td>
</tr>
<tr>
<td>Direction of fingers when you put your hands on the abdomen during abdominal pain</td>
<td>Direction of the transversus abdominis muscle fibers</td>
<td>S</td>
</tr>
<tr>
<td>A swipe card opening a door</td>
<td>Acetylcholine when connecting with its receptor, it opens Na+ channels at the neuromuscular junction</td>
<td>F</td>
</tr>
<tr>
<td>Pushing a wall with your hands does not move the wall</td>
<td>Isometric contraction</td>
<td>F</td>
</tr>
<tr>
<td><strong>Nervous system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security guards</td>
<td>Neuroglia cells particularly astrocytes which contribute to the blood brain barrier</td>
<td>F</td>
</tr>
<tr>
<td>Cat analogy of neuron activation:</td>
<td>Different phases of neuron activation:</td>
<td>F</td>
</tr>
<tr>
<td>- Sleeping</td>
<td>- Resting membrane potential</td>
<td></td>
</tr>
<tr>
<td>- Slowly waking up when gently patting the back</td>
<td>- Graded potential</td>
<td></td>
</tr>
<tr>
<td>- Suddenly jumps when harshly poked</td>
<td>- Action potential</td>
<td></td>
</tr>
<tr>
<td>- When a child calls for their mother, she is expected to respond</td>
<td>- Normal response to a stimulus which generates action potential</td>
<td>F</td>
</tr>
<tr>
<td>- Sometimes the mother is busy working on an important task.</td>
<td>- During refractory period</td>
<td>F</td>
</tr>
<tr>
<td>- If the child keeps calling, the mother might not be able to answer until she has finished her task.</td>
<td>- Absolute refractory period</td>
<td>F</td>
</tr>
<tr>
<td>- Other times she has to answer these repeated calls.</td>
<td>- Relative refractory period</td>
<td>F</td>
</tr>
<tr>
<td>A wide/narrow corridor can let a large number of/only a few people through at the same time</td>
<td>Type A/C nerve fibers</td>
<td>F</td>
</tr>
<tr>
<td>A receptionist who receives a package then delivers it to another person</td>
<td>Association neuron</td>
<td>F</td>
</tr>
<tr>
<td>A company manager processes information, comes up with decisions, and gives commands</td>
<td>Central nervous system</td>
<td>F</td>
</tr>
</tbody>
</table>
### LIST OF SELECTED ANALOGIES PRESENTED IN CLASS (continued)

<table>
<thead>
<tr>
<th>Analogy</th>
<th>Represented concept</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A central airport such as Atlanta, Heathrow, or Cairo airports</td>
<td>The thalamus. The landing planes represent the signals from the ascending tracts while the departing aircrafts represent the signals sent to the cerebral cortex</td>
<td>F</td>
</tr>
<tr>
<td>A person learning how to drive and is aware of all his acts trying to consciously coordinate movements</td>
<td>Actions conducted by the pyramidal tract</td>
<td>F</td>
</tr>
<tr>
<td>An experienced driver is not always conscious of every movement when driving</td>
<td>Actions conducted by the extrapyramidal tract</td>
<td>F</td>
</tr>
<tr>
<td><strong>Endocrine system and Metabolic regulation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication between family members living within the same house</td>
<td>Autocrine communication where the rooms of the house represent different cell compartments</td>
<td>F</td>
</tr>
<tr>
<td>Neighbours communicating with each other</td>
<td>Paracrine communication where houses in the neighbourhood represent cells within the tissue</td>
<td>F</td>
</tr>
<tr>
<td>Sending a message or a parcel through the mail to another person living in a different city, country, or even continent</td>
<td>Endocrine signaling and communication</td>
<td>F</td>
</tr>
<tr>
<td>A mischievous child carried by the mother</td>
<td>An inactive hormone bound to a binding protein</td>
<td>F</td>
</tr>
<tr>
<td>A child running freely in a park</td>
<td>Free hormone which is the active form</td>
<td>F</td>
</tr>
<tr>
<td>Members of the same family share many characteristics, but they are not identical</td>
<td>Isoenzymes catalyze the same reaction; however, they have different structure and tissue distribution</td>
<td>F</td>
</tr>
<tr>
<td>In a battlefield, if a soldier were killed they could not be brought back to life, while injured soldiers might recover and resume fighting</td>
<td>Irreversible vs reversible enzyme inhibition</td>
<td>F</td>
</tr>
<tr>
<td>Same number of dogs playing fetch with increasing number of tennis balls</td>
<td>Maximum velocity of enzyme reaction</td>
<td>F</td>
</tr>
<tr>
<td>Building a house from bricks needs a lot of work and money</td>
<td>Anabolic reactions require ATP</td>
<td>F</td>
</tr>
<tr>
<td>A fire consumes oxygen and releases heat</td>
<td>Catabolic reactions producing ATP</td>
<td>F</td>
</tr>
<tr>
<td>A scenario when it is quite cold, and the only source of heat is fire. When there is no more firewood available, you would need to look for alternatives such as paper sheets then any old pieces of wood blocks. When you ran out of all of this and it became a matter of life or death, you would have to burn pieces of your furniture, but you would burn the expensive ones last.</td>
<td>Metabolism during starvation: after you ran out of carbohydrates, you will use fat. Structural proteins (the expensive pieces of furniture) are the last resort the body catabolizes for energy.</td>
<td>F</td>
</tr>
<tr>
<td>Extra furniture could be stored in storage units then when needed they could be moved in trucks back to your house</td>
<td>Excess iron is stored in storage proteins such as ferritin then when needed, it is transported via transport proteins such as transferrin</td>
<td>F</td>
</tr>
<tr>
<td><strong>Cardiovascular system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A stack of potato chips</td>
<td>RBCs and rouleaux formation</td>
<td>S</td>
</tr>
<tr>
<td>Parachute</td>
<td>AV valves. The canopy represents the cusps, the suspension lines represent the chordae tendineae, and the harness represents the papillary muscles</td>
<td>S</td>
</tr>
<tr>
<td>Loading a truck with goods</td>
<td>Preload</td>
<td>F</td>
</tr>
<tr>
<td>Biking against the wind</td>
<td>Afterload</td>
<td>F</td>
</tr>
<tr>
<td>Stretching and overstretching an elastic band</td>
<td>Stretching of the myocytes and Starling law</td>
<td>F</td>
</tr>
<tr>
<td>Water tap connected to a garden hose</td>
<td>Circulation physiology. The tap is the heart, the garden hose represents the blood vessels, and water is the blood</td>
<td>F</td>
</tr>
<tr>
<td>Rolling a ball on a bumpy field as opposed to a smooth surface</td>
<td>Resistance increases in arteriosclerosis</td>
<td>F</td>
</tr>
<tr>
<td><strong>Gastrointestinal system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A camel is a very patient and hard-working animal, but if it is not treated kindly, suddenly can get aggressive and even attack the owner</td>
<td>The liver is resistant to toxins and can recover from disease, but the symptoms of an end-stage liver disease can appear very suddenly and are irreversible</td>
<td>F</td>
</tr>
<tr>
<td><strong>Urinary system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving money notes between two pockets. The amount keeps changing in each pocket however, the total amount stays the same</td>
<td>Buffer system provides only temporary solution to acid--base imbalance but does not eliminate hydrogen ions</td>
<td>F</td>
</tr>
<tr>
<td>Funnel</td>
<td>Shape of the trigone of the urinary bladder with the urethra</td>
<td>S</td>
</tr>
<tr>
<td>Sandwich</td>
<td>The three layers of the detrusor muscle. The two toast slices represent the outer and inner longitudinal layers while the filling represents the middle circular layer in between</td>
<td>S</td>
</tr>
</tbody>
</table>

**Table 1.** Analogies presented during class, organized by organ system and categories. F: functional, S: structural analogies.
The Power of Analogy-Based Learning in Science

Likert scale answers were evaluated by descriptive statistics using Microsoft Excel. The dispersion of scores given to questions was measured using interquartile range (IQR) by calculating the difference between the 25th and the 75th percentile. To determine consensus among student opinion, a threshold of IQR ≤ 1 was used. Free text survey responses were evaluated by free text analysis. The first author reviewed student answers to the open-ended questions and general comments and looked for common themes about their perceptions of the presented analogies.

Results

Analysis of the survey responses showed that 92.5% (121 of 131) of the students were able to recall hearing analogies in class, however only 50% (65 of 131) remembered reading analogies in textbooks. Over 85% of the students found that the analogies that they heard were helpful in understanding anatomical structures and physiological functions. Over 60% of the students reported that they were able to remember these analogies while preparing for tests. The majority of the students (77.5%) agreed that the analogies were engaging and fun during the lecture time (Table 2).

<table>
<thead>
<tr>
<th>Survey questions</th>
<th>Strongly disagree (%)</th>
<th>Disagree (%)</th>
<th>Neutral (%)</th>
<th>Agree (%)</th>
<th>Strongly agree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1: The analogies helped me understand new concepts</td>
<td>3.8</td>
<td>3.1</td>
<td>7.6</td>
<td>50.4</td>
<td>35.1</td>
</tr>
<tr>
<td>Q2: The analogies made the lecture more engaging</td>
<td>4.6</td>
<td>3.1</td>
<td>14.5</td>
<td>42.7</td>
<td>35.1</td>
</tr>
<tr>
<td>Q3: The analogies incorporated humour and fun in the lecture</td>
<td>6.2</td>
<td>1.5</td>
<td>13.8</td>
<td>37.7</td>
<td>40.8</td>
</tr>
<tr>
<td>Q4: The analogies helped to shift my attention back to the lecture</td>
<td>4.6</td>
<td>6.2</td>
<td>23.8</td>
<td>35.4</td>
<td>30.0</td>
</tr>
<tr>
<td>Q5: I recalled the analogies heard in class while studying</td>
<td>2.3</td>
<td>7.7</td>
<td>28.5</td>
<td>30.0</td>
<td>31.5</td>
</tr>
<tr>
<td>Q6: I used the analogies heard in class to prepare for the tests</td>
<td>2.3</td>
<td>10.1</td>
<td>32.6</td>
<td>24.8</td>
<td>30.2</td>
</tr>
<tr>
<td>Q7: Remembering an analogy helped me find the correct answer for test questions</td>
<td>2.4</td>
<td>7.9</td>
<td>26.0</td>
<td>35.4</td>
<td>28.3</td>
</tr>
</tbody>
</table>

*Table 2. Percentage of students’ answers on each survey question (n=131). Highest percentage is in bold font.*
Consensus among students was measured by calculating the interquartile range. If the difference between the 25th and the 75th percentile of answers was no more than one grade on the Likert scale, we considered that the class had a consensus on that question. Our results showed that students had a consensus of agreement on questions 1, 2 and 3 (IQR ≤ 1). For questions 4, 5, 6 and 7, they did not have a consensus (IQR = 2). However, the majority of students either strongly agreed or agreed to all questions. The sum of disagreement was low in all questions (see Figure 2).

**Figure 2.** The number of students who agreed (selected strongly agree and agree) or disagreed (selected strongly disagree and disagree) to the asked questions (n=131, neutral answers are not shown). IQR: Interquartile range, IQR ≤ 1 means consensus.

Q1: The analogies helped me understand new concepts.
Q2: The analogies made the lecture more engaging.
Q3: The analogies incorporated humor and fun in the lecture.
Q4: The analogies helped to shift my attention back to the lecture.
Q5: I recalled the analogies heard in class while studying.
Q6: I used the analogies heard in class to prepare for the tests.
Q7: Remembering a particular analogy helped me find the correct answer for test questions.
Free text analysis revealed three themes in the content of student responses. First, students often commented on the usefulness of the presented analogies. Some examples of student comments about analogies as being beneficial were the following: “I like analogies because they explain things simply”. “Analogies help me understand and memorize things better”.

Second, several students described analogies as fun. Students also expressed that they enjoyed hearing analogies, especially during a long lecture. Examples included: “The analogies made the class engaging and more interesting”. “The analogies helped me focus to the material during the lecture”.

Lastly, some students requested to organize and incorporate analogies into lecture notes. Some of the comments were about the desire to have analogies as learning tools, such as: “Would be nice if they were provided as notes”. “Please keep doing them as they are memorable and help with understanding concepts”.

**Discussion**

Analogies have been historically used in many fields such as biology, philosophy, and literature. They remain an important part of high-level perception and require high cognitive functioning (Castillo 2018; Heywood 2010; Orgill and Bodner 2006; Richland and Simms 2015). In our study, we have introduced 53 newly developed analogies to support two science courses.

We evaluated student perspectives on how these analogies, which were consistently used throughout basic science lectures, have enhanced their learning and facilitated understanding of difficult concepts.

While analogies are often used naturally when educators teach new or unfamiliar concepts, it is reported that using analogies purposefully would benefit students more (Brown and Salter 2010; Richland and Simms 2015). Orgill and Bodner (2006) analyzed the use of analogies in college-level biochemistry textbooks. They concluded that, although textbooks contain a significant number of analogies, the explanations accompanying the analogies are often insufficient. Our study found that only 50% of the students were able to recall analogies read in textbooks, although the analogies in the textbook were comparable to the in-class analogies. Two examples from the course textbook are: “thyroid follicle is similar to a gel capsule with viscous content inside” and “the aorta resembles a walking cane” (Martini et al. 2018). A possible explanation for this is that students used textbooks as secondary resources. Students were keen on attending the in-class lectures where analogies were presented and explained, and they utilized lecture notes as their primary resource for studying.

When analogies are incorporated into lectures, they can be used to draw student attention to key or important parts of a scientific concept by comparing the new concept to a well-known model. This has been shown to facilitate deeper understanding (Richland and Simms 2015; Seiler and Huggins 2018) and this is what we adopted and aimed for in our practice. As it has been shown by cognitive scientists, it is easier to find similarities based on object properties for novice learners, for example, comparing the shapes of two objects. Recognising similarities and differences based on relationships, however, requires deeper understanding of the domains (Castillo et al. 2018; Heywood 2010; Richland and Simms 2015).

In our work, we found that analogies sharing similarities of appearance are as beneficial as functional analogies when explaining difficult anatomical and physiological concepts respectively. Students mentioned their favorite analogies in the free text comments at the end of the survey. The most mentioned functional analogy was the one that explains the difference between autocrine, paracrine, and endocrine signaling by comparing them to communication within the same house, in the neighborhood, and through the mail. The most popular structural analogy was lasagna for the endoplasmic reticulum. The cheese-filled pockets are like the calcium-full cisternae. Ground meat are like the fixed ribosomes that stud the rough endoplasmic reticulum, while the smooth endoplasmic reticulum, which lacks ribosomes, is like plain cheese lasagna.

It is important to add that analogies, in general, cannot perfectly describe physiological functions; therefore it is crucial to explain the boundaries related to the commonalities between the two domains. It is worth noting that similar analogies were also used in other courses taught by the last author to different student cohorts from various science disciplines in a different educational institute. They were also very well-received by the students as indicated in their comments in the students’ feedback forms (data not shown).

Students did not have consensus on whether they used the presented analogies while studying or recalled them during the tests. This indicates that while analogies are very well-received during the lecture time, they might be less utilized to prepare for exams. Organizing the presented analogies in a table format might be helpful for students reviewing course material in the future. Although we did not investigate whether analogies were used more as an engagement tool or a learning tool based on student responses, Figure 2 suggests that more students found analogies useful as an engagement tool.

Our study has a few limitations. The study was conducted in first-year and second-year science courses in undergraduate nursing education. Students from other areas of sciences may...
have different reception for analogies from our students. We have not objectively measured student performance after using analogies as learning tools. Future studies could explore possible correlations between the grades achieved in the courses with the analogies that students could recall. Another limitation of our methods is due to pooling of responses from both first-year and second-year students. Second year students were exposed to the analogies in their first year of studies, which may contribute to different perception of the analogies. This may have introduced bias in the responses of this group.

**Conclusion**

Overall, our results demonstrate that using analogies in an organized and purposeful way is helpful in teaching Anatomy and Physiology as well as Clinical Chemistry. As indicated by students, the analogies were useful when learning new concepts and made the lectures more engaging. We believe those analogies can be easily incorporated into lectures or lecture notes when teaching undergraduate science courses. We invite educators from other institutions to use and study the effect of these analogies or to collaborate on an expanded multicenter study to objectively evaluate the impact of these analogies on learning.

**About the Authors**

Zsuzsanna Keri received her medical degree in Hungary in 2001. She graduated as Academic Award Recipient from the Health Information Management Program at St. Lawrence College in 2012, and she has worked as a post-doctoral fellow in biomedical computing at Queen's University. She is currently a 3rd-year student at Laurentian University/St. Lawrence College BScN Program in Kingston, ON, Canada. She is the recipient of the Helen Van Dusen Prize for excellence in practice of nursing and she works as a peer mentor and tutor in anatomy and physiology, and clinical chemistry courses. Her area of interest includes biomedical computing, and educational research.

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Historical, Cultural, and Religious Influences in Anatomy and Physiology and Their Relevance to Diversity and Inclusion

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Abstract
There have been many cultural and religious influences on the studies of anatomy and physiology throughout history. This article provides a brief survey of historical and cultural influences on medicine and anatomy and physiology specifically. These historical and cultural influences include the lifetime and strategic contributions of early physicians, scientists, and scholars as well as the contributions of entire cultures through the social sciences and the religious and non-religious humanities. Discussion of these historical, cultural, and religious topics can be integrated into anatomy and physiology classrooms as lessons that promote diversity and inclusion and cultural humility among faculty and students. Examples of such lessons are described in this article in alignment with the diversity and inclusion goals that were incorporated into the revised Human Anatomy and Physiology Society (HAPS) Learning Goals for Students. These learning goals showcase the increasing emphasis that HAPS has been ascribing to diversity, equity, and inclusion. https://doi.org/10.21692/haps.2021.005

Key words: diversity, inclusion, human anatomy and physiology, historical influences, cultural influences, religious influences

Introduction
Historical events, culture, and religion can have transformative effects on human beings, their interactions in their daily lives, and their professional disciplines. This fact is certainly true for the fields of anatomy and physiology. This article discusses the impact of several historical events and influences as well as that of several religious and cultural influences on anatomy and physiology. In addition, this article highlights specific examples of how these influences can improve faculty and student cultural humility, appreciation for diversity, and acceptance of inclusive views via their incorporation into anatomy and physiology classrooms. This article also discusses the revision of the 2010 HAPS Learning Goals to the new 2020 HAPS Learning Goals to which these example lessons are aligned. And finally, this article places the importance of these learning goals in the greater context of the increasing significance with which other professional societies, like HAPS, are regarding diversity, equity, and inclusion.

The Importance of History, Culture, and Religion
One of the primary reasons for studying history is for human beings to learn from their mistakes. However, by learning about their history in whatever age, field, or discipline, humans learn much about the power of human resolve and resiliency in the pursuit of goals without giving up. Through reflections on their history as well as enrichment studies of the various cultural influences that have punctuated that history, people can also learn more about, from, and with one another. Even students and teachers of anatomy and physiology can experience role reversals in the laboratory or the classroom when different perspectives are shared with the group to instigate a remodeling in former, narrower ways of thinking. In such sharing, oftentimes, the instructor can become the learner and the student the instructor.

These cultural learning experiences can also include religious influences. In fact, a document published by the United Nations Office of the High Commissioner for Human Rights states that “measures required to improve participation of minorities in social, cultural and political life are to take into account the historical, cultural and religious contexts of a given country” (OHCHR 2014). These considerations are certainly critical for the United States, especially when one study reveals varying definitions of what constitutes an underrepresented minority among 78 academic health centers (Page et al. 2013). Nearly 17% of these institutions consider individuals whose personal characteristics are underrepresented in the medical profession relative to their numbers in the general population as comprising underrepresented minorities, and while these institutions do not explicitly mention religion as a personal characteristic, they certainly do not explicitly exclude it (Page et al. 2013). Similarly, religion can be considered a characteristic of minority status within anatomy and/or physiology professional societies, and respect for religious diversity within these organizations is important.

While the American Physiological Society (APS) does not explicitly mention religion in the purpose statement of its Diversity, Equity, and Inclusion Committee, it does argue the importance of respecting the religion of all members in its Conference Code of Conduct (APS 2019). The Liaison
Committee on Medical Education (LCME) also advocates the inclusion of cultural competence in belief systems in medical curricula (LCME 2016). Although gender diversity (Carter et al. 2018, Carter et al. 2021) and racial and ethnic diversity (Carter et al. 2021) are especially important topics of conversation in anatomy education, religion is regarded with equal inclusivity (AAA 2017, Carter et al. 2021). And even more generally, religion is a hot topic of diversity and inclusion within other organizations like the Association of Employee Resource Groups (ERGS) and Councils (AEC 2021).

There is no denying that racial and gender diversity are just as important topics of discussion as religious diversity, but this article primarily focuses on religious influences in anatomy and physiology among other historical and cultural influences and examples of incorporating them into the classroom. A previous paper mentioned some examples of incorporating racial and gender diversity as well as religious, spiritual, or secular diversity into anatomy and physiology classrooms (Meyer and Cui 2019). This paper, in focusing more intently on religious influences, aims to convey how an important personal characteristic like religious affiliation can be easily overlooked, as one study reports (Bowman and Smedley 2017). It also aims to convey its importance to the overall concept of cultural humility.

Cultural Humility

As the diversity and inclusion literature has evolved, there has been a transition from emphasizing cultural competence to adopting cultural humility (Chang et al. 2012, Isaacson 2014, Fisher-Borne et al. 2015, Foronda et al. 2016, Stubbe 2020, Tervalon and Murray-Garcia 1998). Cultural competence is regarded “as a skill that can be taught, trained, and achieved and is often described as necessary and sufficient [...] for working effectively with diverse [people]” (Stubbe 2020, pp. 49-50). In turn, cultural humility involves “a lifelong commitment to self-evaluation and self-critique [in order to foster] mutually beneficial [...] partnerships” (Tervalon and Murray-Garcia 1998, p. 117) in which the values, customs, and beliefs of those included are respected (Stubbe 2020).

One article advocates the incorporation of cultural humility into the training of healthcare professionals as an addition to the cultural competence curricula that already exist in many medical curricula globally (Chang et al. 2012). In fact, even the most recently updated Liaison Committee on Medical Education (LCME) Standards (2016) include standards for cultural competence but lack standards for cultural humility. Consideration of diversity and inclusion goals and standards allows professionals worldwide to discuss the changing language and ideas associated with diversity, equity and inclusion in order to increase awareness and application of cross-cultural concepts such as cultural humility in all scholarly enterprises. By embracing an acceptance of cultural humility, educators and researchers in anatomy and physiology, for example, can grow to acknowledge their limitations in understanding cultures different from their own while also valuing the impact of diverse cultures on their respective disciplines.

Historical Events and Influences on Anatomy and Physiology

Historical events and occurrences in various cultures have certainly influenced advances in anatomy and physiology as scientific disciplines. In fact, historical and cultural influences are intertwined as many cultural influences are punctuated by historical landmarks significant to progress in both the fields of anatomy and physiology. This section is dedicated to categorizing some of these key historical landmarks according to the types of contributions made toward anatomy and physiology. These contributions include those made by early and modern anatomists, physiologists, physicians, and/or other scientists and scholars. In turn, these contributions can be categorized as the overall lifework and studies made by these renowned people and as strategic discoveries, inventions, and developments, such as surgical or other clinical procedures introduced by these individuals.

Lifework Contributions

Many of the well-known lifework contributions made by individuals to anatomy and physiology were made by ancient Greek scholars or physicians such as Alcmaeon of Croton, whose work pre-dated even that of Hippocrates who has been given the epithet “the father of medicine”, Diocles, Herophilus, and Galen (Ghosh 2015, Hajar 2015, Magee 2001). Historically, the Greek philosopher Aristotle and the later Greek physician Galen have been viewed as the fathers of anatomy (Leroi 2014, Russell 1916, Singer 1957) though many of their understandings of anatomy have been proven to be inaccurate (Alghamdi et al. 2017).

The works of Andreas Vesalius, especially with cadaveric dissection, during the Renaissance have earned him his attribution as the father of modern anatomy and a pioneer in neuroscience (Splavski et al. 2019). Around this same time period, French physician Jean Fernel devised the term physiology (Tubbs 2015). Later, contributions of Swiss biologist Albrecht von Haller in the 1700's and French physician Claude Bernard in the 1800's earned these individuals the designations as the father of experimental physiology (Augustyn et al. 1999) and the father of modern physiology (Conti 2001, Greenen 2009), respectively.

Strategic Contributions

Numerous critical, isolated contributions to anatomy and physiology have also been made by individuals throughout history. In the late 1620's, the English physician William Harvey published his work titled An Anatomical Study (Dissertation) of the Motion of the Heart and of the Blood in Animals, which laid the foundation for future research regarding blood vessels

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and the heart; this strategic moment also made him the first to describe the movement of blood through the body in systemic circulation (Hajar 2015, Newman 2017, Westerhof 2011). Around 1840, Matthias Schleiden, Theodor Schwann, and Rudolf Virchow proposed what has come to be known as the cell theory (Newman 2017, Westerhof 2011), spurring in the field of physiology rapid progress by other scientists and practitioners that has continued into modern and contemporary times.

This progress has included from the late 1890’s to the early years of the twenty-first century the discovery of disease mechanisms of transmission; the development of many drugs, including antiseptics, antibiotics, and vaccines; the mechanism of nerve impulse transmission; the sliding-filament theory of muscle contraction; and anatomical and physiological imaging technologies that are still widely used today, such as X-rays, electrocardiography, ultrasound, and computed tomography (CT) (Hajar 2015, Newman 2017). As technology continues to expand, advances in clinical anatomy, anatomical sciences education, and physiological research continue to abound.

Integration of Historical Contributions into the Classroom

Despite advances in these disciplines, educators, practitioners, and scientists are beginning to learn that some content presumed to be attributed solely to the Western world, in fact, can be traced to other cultures besides the Greeks between the fifth century BCE and the second century CE and the Europeans during the Renaissance. This news can be a culturally humbling experience for many students and teachers, but through the investigative pursuit of knowledge, scholars can rely on evidence to help them admit when they are misinformed. Thus, instructors can incorporate opportunities for learning about enlightening historical discoveries that have changed commonly held views in anatomy and/or physiology.

One idea for a lesson anatomy and physiology instructors can incorporate into their classrooms might be an exploration of instances of non-Western cultures’ historical influences on anatomy and/or physiology. First, instructors could divide students into diverse groups based on whatever diverse characteristics exist in their classrooms, especially since diverse groups have been shown to foster inclusive interactions (Enberg and Hurtado 2011, Tienda 2013). Instructors can gauge the diversity of their classes by administering surveys to collect demographic information about their student population. In cases of extreme homogeneity in which there is very little diversity in the classroom, instructors can simply rely on the diverse content of reading assignments to forge diverse conversations.

These assignments could include articles or other readings about the contributions of various cultures to anatomy, and each group could receive a different culture and/or article. Some example articles to consider assigning to student groups would be those exploring historically significant Indian (Wujastyk 2009), Persian (Alghamdi et al. 2017), and Chinese (Shaw et al. 2020) contributions to anatomy. The first article explores the concepts of classical Indian anatomy and medicine known as Ayurveda recorded in the fifth century BCE (Wujastyk, 2009) during the same time period in which Alcmaeon and Hippocrates made their discoveries in ancient Greece. The second article accounts contributions of Persian scholars during the Golden Age of Islam (Alghamdi et al. 2017) which actually precedes the Renaissance during which time Vesalius lived. The third article describes ancient Chinese medical texts that have been considered the oldest surviving anatomical atlas in the world (Shaw et al. 2020), dated to a time period before Galen.

Students could be encouraged to research the differences and similarities between these ancient understandings of anatomy and physiology or medicine and modern understandings of the same or similar topics. Students could also be prompted to analyze those instances in which the Western scholars were incorrect and the non-Western scholars were correct in their assumptions and discoveries and vice versa. Upon the completion of their research outside of class time, students could present their findings in the format of formal presentations to the rest of the class followed by question-and-answer and discussion sessions to invoke further inquiry and learning.

Given the online learning format that most institutions have adopted in response to the COVID-19 pandemic, these activities can easily be converted into virtual learning experiences through the use of Zoom or another similar virtual meeting platform that allows breakout sessions. The instructor could schedule separate meeting times with associated links that are appropriate for each group, or the instructor could poll all students to schedule one meeting that fits every student’s schedule and then divide the students into their respective breakout rooms for them to discuss their assignments. In this way, the instructor can provide an opportunity for students to meet virtually without having them meet in person.

Moreover, since some personal accounts with meeting platforms do not allow meetings to last longer than an hour, the use of a licensed or paid account would allow students a longer, continuous timeframe for completing their work together. Any additional time that students might need could be spent finalizing their presentations using Google slides which allow students to work either simultaneously or separately on their presentation. On the day that presentations are due, the instructor could have one student
from each group share their screen while, as a group, they present the content of the slides. The instructor could then moderate a question-and-answer session after each virtual presentation, receiving questions anonymously through chat or orally.

The instructor also might even consider reassigning group members to different breakout groups and providing them with discussion questions to foster interactions whereby students can learn more about their other classmates’ projects while also sharing more information about their own with their other classmates. Presentations, readings, and discussion groups are a few of the best educational practices for increasing cultural competency (Brottman et al. 2020). In the event that students are challenged to learn something new, perhaps something that contradicts their former views or modes of thinking, these practices can also potentially foster cultural humility. This activity can also encourage engaging student connections and interactions which are especially important in an online class format.

Although this series of activities does not align with any specific HAPS Learning Outcomes, it does align with the newly revised diversity-and-inclusion-specific HAPS Learning Goals 13 and 14 (HAPS 2020) (Figure 1). The reason these learning goals do not have associated learning outcomes is because the outcomes are aligned with the standardized HAPS Exam which currently has no testable items pertaining to diversity and inclusion content. Nevertheless, the articles mentioned as examples in these activities contain anatomical content relevant to multiple organ systems and, thus, multiple learning outcomes. Therefore, instructors might consider including these reading, presentation, and discussion activities either at the end of the semester or year as a cumulative appreciation of multiple content areas or at the beginning of the year as a kind of exciting introduction to content areas to be visited throughout the semester or year.

**Figure 1.** Cognitive Skill Development Goals from the 2020 HAPS Learning Goals for Students. Goals 13 and 14 especially provide motivation to anatomy and physiology instructors to incorporate diversity and inclusion concepts into their course learning objectives while giving them the freedom and flexibility to integrate those concepts in creative ways.
Cultural and Religious Influences on Anatomy and Physiology

Many of the historical contributions to the fields of anatomy and physiology could also be considered cultural ones, given the fact that the culture of early anatomy and physiology contributors motivated and guided their efforts. Well before the ancient Greeks, the ancient Egyptians studied the human body in detail. A host of ancient papyrus scrolls and other literature have revealed ancient Egyptian embalmers’ knowledge of human organs and ancient Egyptian physicians’ diagnoses and treatments of medical conditions (Loukas et al. 2011). As much as the work of the embalmers was motivated by religious mummification rituals, the work of Egyptian physicians inspired Greek physicians like Herophilus and Erasistratus.

Herophilus and Erasistratus began a school of anatomy, including anatomical dissection, in Alexandria (Loukas et al. 2011), and their work has contributed greatly to anatomy and physiology. In fact, the adoption and furthering of Egyptian medical knowledge and practices by the Greeks provided the groundwork for the establishment of the anatomical sciences (Loukas et al. 2011, Standring 2016). Observations made by these ancient scholars about the functions of anatomical structures must have also informed rudimentary understandings of what would later come to be known as physiology.

The categories within this section are not quite as delineated given the fact that religious beliefs and practices are often deeply rooted in the cultures from which they arise just as in the case with the ancient Egyptian civilization. Conversely, diverse cultures also have unique influences on religions even if those religious traditions are introduced to various cultures. Profound examples of cultural influences on religions can be seen in Western Christianity, for instance, with the application of Christian meaning or symbolism to originally pagan holy days. Therefore, the remainder of this section is dedicated to discussing the contributions of the cultural humanities to anatomy and physiology with a distinction between those that are non-religious and those that are religious or spiritual. However, there are some instances in which there are mutual religious and non-religious influences on anatomy and physiology.

Non-Religious Humanities and Social Sciences

The average person who ponders the ways in which non-religious humanities have influenced anatomy and physiology might think of classical languages such as ancient Greek and Latin since most clinical and medical terms are derived from either of these languages (Smith et al. 2007). In fact, formal lists of anatomical terminologies have existed since 1895 with the publication of Basale Nomina Anatomica, but additional lists in other cultures or languages emerged (Tubbs 2020, Whitmore 2020). These varying lists raised awareness of a need for an international, standardized list of anatomical terminology, and at the meeting of the International Federation of Associations of Anatomists (IFAA) in 1910, leadership present agreed that the IFAA should oversee such a terminology list (Whitmore 2020).

In 1955, a nomenclature committee of the IFAA published a terminology list called Nomina Anatomica which was subsequently followed over the next two decades by three more editions as well as two additional lists specifically relevant to histological and embryological terms (Tubbs 2020, Whitmore 2020). Over the next several decades, oversight of the terminology list was transferred to a different committee which changed names twice, and during this time, Terminologia Anatomica was published; the second edition of which was recently published in 2019 by the current nomenclature committee called the Federative International Programme for Anatomical Terminology (FIPAT) (Gest 2020, Tubbs 2020, Whitmore 2020). The second edition provides the names of anatomical structures and their associated features in Latin with Latin synonyms and in British and American English with English synonyms as well as other names by which they are known, though eponyms are excluded (Gest 2020). Terminologia Histologica and Terminologia Embryologica were published in 2004 and 2009, respectively (Whitmore 2020). Although there is no formal list of terminology for physiology, most of the terms used in the field are derived from ancient Greek and Latin words as well.

Other non-religious humanities or social sciences such as the arts, ethics, and psychology, to name a few, have also influenced anatomy and physiology. Influences from Renaissance artists like Leonardo da Vinci who also dissected cadavers (Zucker and Harris 2016) and Michelangelo whose sculptures had his own identifiable, artistic, anatomical attributes (Abrahams 2019) provided both an anatomical understanding and an aesthetic appreciation of the human form. Ethical considerations have governed the proper care and treatment of human bodies used in anatomy education (Brenner and Pais 2014, Magee 2001), especially given the misuse and abuse of human remains committed by grave robbers in the early days of using human cadavers in medical education (Ghosh 2015, Magee 2001).

As discussions surrounding gender equity abound, the psychology of gender dysphoria becomes extremely relevant to anatomy and physiology in regard to transgender or non-binary-gender individuals who make decisions to alter their anatomy and physiology through feminizing or masculinizing surgeries (Carter et al. 2018) and/or hormonal therapies. This issue also becomes an ethical one as considerations of diversity, equity, and inclusion prompt the incorporation of feminizing and masculinizing treatments and procedures into health professional education curricula.

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Religious Humanities
Aside from Egyptian religious practices and their contributions to the understanding of the form and function of the human body, a number of other religious traditions have influenced anatomy and physiology. These influences have been made through the overall influence of the religious culture as well as through the work of scholars who ascribe to those religious traditions. For instance, the practice of dissecting humans emerged predominantly in Western Christian culture since many Greeks and Romans associated acts of handling the deceased with impurity (Park 2006). This fact probably explains the incorrect assumptions made by early physicians and anatomists like Galen until further anatomical studies were performed.

Although Vesalius has been acknowledged as the father of modern anatomy, a considerable number of contributions of Islamic scholars preceded his work. Throughout the Islamic Golden Age from the seventh to fifteenth or sixteenth century AD, at least nine Islamic scholars made novel discoveries and advancements in the field of anatomy, including osteology, the heart and pulmonary circulation, the circle of Willis, the eye, the relationships between the ureters and the urinary bladder, and several others (Alghamdi et al. 2017). The contributions of Islamic scholars to the preservation of scientific and medical texts during the high Middle Ages between the time of Galen and Vesalius have been well known (Muazzam and Muazzam 1989, Persaud 1984), but their anatomical feats have not been widely known (Alghamdi et al. 2017).

In addition to their contributions to the anatomical sciences, Islamic scholars have also contributed to medicine and physiology. The work of Ibn Al-Nafis earned him the designation as the father of circulatory physiology and anatomy (deVries and Price 2012, Greydanus et al. 2012, Moore and Casper 2014). Furthermore, the work of Abu al-Qasim al-Zahrawi earned him the designation as the father of operative surgery (Wijesinha 1983) and as the father of modern surgery (Martín-Araguz et al. 2002). Another Abrahamic religious tradition, Christianity, has also had a profound influence on the medical sciences and education in general.

The university as it is known today has its earliest beginnings, according to some, in the European Christian tradition of the Middle Ages (Rüegg 1992, Verger 1999), its precursor being education conducted by monks and nuns in cathedral or monastic schools as early as the sixth century AD (Riché 1978). These early schools helped set the foundation for what the later university would entail. Thus, the first universities were established under the direction of the Roman Catholic Church by public decree of the pope, the patriarchal head of the Church (Oestreich 1913). This same formal university education system is still used today, boasting disciplines in the arts and sciences such as anatomy and physiology.

Other formal institutions such as hospitals, at least for non-military personnel, also have their roots in the Christian Church with the first Christian hospital being established in the Byzantine Empire toward the end of the fourth century AD at the time of the second medical revolution (Jonson 2000, Nutton 2012). Religiously affiliated hospitals continued to spread throughout the Byzantine, medieval European, and Islamic world until the early modern era when caring for the sick, injured, and infirm became more secularized (Cunningham and Grell 2002). The nature of the hospital in the treatment of patients has endured through the centuries in much the same way as the nature of the university in educating students. As a result, the global community owes a debt to the religious men and women who were so influential in the emergence and evolution of formalized education and medical care.

Integration of Religious and Non-Religious Influences into the Classroom
As previously mentioned, there is quite a bit of overlap between historical and cultural influences on anatomy and physiology, and some of the cultural influences are also religious in nature. One historical classroom activity already discussed regarding the presentation of the contributions of Persian scholars during the Golden Age of Islam is both cultural and religious since the Persian scholars were also Muslim by faith (Alghamdi et al. 2017). In fact, Muslims comprise the second most racially diverse religious group in the United States (Lipka 2015).

Other activities that can allow instructors to incorporate Islamic and similar religious content into their courses involves immersion experiences which are yet another best educational practice for increasing cultural competency (Brottman et al. 2020) and, with the revision of previously accepted misconceptions, cultural humility. Anatomy and physiology instructors can take advantage of these immersion experiences through the resources provided by libraries and museums either in their local areas or through virtual learning experiences online, given the widespread physically distanced policies for COVID-19 still practiced by most institutions of higher learning.

If visiting libraries and museums in person is not feasible, instructors could potentially design activities that allow students to virtually navigate Islamic culture pertaining to anatomy and/or the medical arts online through such resources as the U.S. National Library of Medicine and the International Museum of Muslim Cultures (NLM 1994, IMMC 2021). The curator of the IMMC could potentially be contacted to arrange for a virtual guest lecture on such content in an anatomy and physiology course.

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Similar immersion experiences with experts regarding such content as the influences of Egyptian cultural and religious practices or any other civilization’s cultural or religious influences on the study of anatomy and physiology or medicine could also be provided. These immersion experiences could feature a virtual presentation by the expert that incorporated guided questions for the students throughout the presentation in order foster their engagement. These questions could be administered through the polling option in a platform like Zoom or using Turning Point since students could respond remotely with their phones or other smart devices, and the instructor could decide whether or not to grade these submitted responses. Students could then be divided into breakout rooms following the presentation and provided discussion questions that motivated them to consider how they might create works of art with only the knowledge from a given culture and time period.

Students could even be encouraged to render drawings or sketches with or without color of anatomical regions that they may not have covered yet as a way of simulating how early speculative anatomists in Egyptian or other cultures might have thought in time periods and cultures when dissection may not have been an option or when ancient philosophies pervaded anatomical understanding. In the latter scenario, students could be creative in the way they represent body organs or other anatomical structures for which they might have minimal understanding. These types of activities could be conducted at the end of a semester before a second semester of continued learning in anatomy and physiology or anytime during the year prior to the actual content that the instructor aims to cover in full detail. In this latter case, the activities provide a way to pique student interest before exploring what is really currently known about that particular anatomy.

In addition to Islamic and Egyptian influences, Christian influences on anatomy and physiology can be explored in the classroom. A number of specific Christian influences can be as subtle as the usage of certain religiously influenced vocabulary for certain anatomical terminology. For instance, the left atrioventricular or bicuspid valve also known as the mitral valve is aptly named because the valve itself actually resembles the tall headdress, or mitre, worn by bishops, popes, and senior abbots as a symbol of their office.

In another example, a frontal plane is also known as a coronal plane because the way it separates the head into anterior and posterior parts, especially as viewed from a two-dimensional perspective, resembles a crown, or a corona in Latin terminology. These coronal planes can be best appreciated in the halos depicted in Christian paintings and stained-glass windows throughout the centuries. For students or teachers to appreciate these examples in person, they would merely have to visit a cathedral during a Mass celebration, tour a Catholic or an Orthodox church, or visit any art museum. Most art museums are bound to contain religious works.

Religious works of art, though, are not the only works of art that celebrate anatomy. There are numerous historical portraits and sculptures that not only convey artists’ expert skill but also convey their knowledge of the human form. Although the trip has been cancelled the past two years due to the COVID-19 pandemic, Dr. Kevin Petti, a HAPS member and anatomy and physiology instructor at San Diego Miramar College, has offered a summer course called Connecting Art and Anatomy through the HAPS Institute to allow instructors to earn professional development experiences (HAPS 2019). During the twelve-day trip, travelers have the opportunity to tour sites such as the Pathological Anatomy Museum of the University of Florence, the Galleria dell’Accademia, the Anatomy Theatre at the Archiginnasio Palace, and the Morgagni Museum of Pathological Anatomy. Instructors who complete the experience and take plenty of photographs can potentially share the experience with their students in the form of a lecture in the classroom or a discussion-based activity.

The discussion of non-religious humanities and social sciences and their influences on anatomy and physiology is also important because there may be some students in the anatomy and physiology classroom who do not affiliate with any particular religion (spiritual) or who do not consider themselves religious or spiritual at all (secular). Importantly, it should be noted that this paper has also not addressed any aspect of indigenous teaching of anatomy and physiology, an additional avenue worthy of exploration. In this respect, instructors must strive to provide an inclusive environment that supports spiritual and secular diversity as well as religious diversity.

In this way, religious, spiritual, and secular students can learn about, from, and with one another. In fact, data regarding the religious diversity of the United States suggest that the religiously unaffiliated comprise the second largest considerable percentage (16%) of the United States population (PRC 2014). A survey at the author’s current institution also exhibits this growing trend of secularism as agnostics and atheists were the most represented among the minority students in the medical class of 2023 (Meyer 2020). These growing numbers of religiously unaffiliated students necessitates the incorporation of class activities that not only include them in religious conversations but also include religious students in secular conversations.
Conclusions
Consideration of the diversity- and-inclusion-specific HAPS Learning Goals allows instructors to implement diverse lessons that integrate historical and other cultural, humanistic, and/or religious contexts, thus providing more enriched learning experiences for their students. The adoption of diversity and inclusion learning goals aligned with any instructor-authored learning objectives is critical for a more comprehensive, multi-perspective view of anatomy and physiology which are disciplines that not only complement one another but also forge connections with other disciplines. After all, history is littered with evidence of the contributions of physicians, scientists, and scholars to the medical sciences and to the field of science in general.

Many early physicians, anatomists, and scientists made significant impacts on the fields of anatomy and what would eventually be called physiology. Similarly, cultural aspects of religious traditions, the humanities, and the social sciences have greatly influenced both anatomy and physiology, challenging practitioners, scientists, and scholars to think about human form and function in new and sometimes controversial, yet beneficial, ways. While many enjoy the freedoms of living in countries in which a separation of religion and government exist, when contemplating the substantial contributions of religious traditions to anatomy and physiology especially, they cannot deny their valuable influence and the diverse perspective they offer to these disciplines.

About the Author
Edgar R. Meyer, MAT, PhD, is an Assistant Professor in the Division of Clinical Anatomy in the Department of Neurobiology and Developmental Sciences in the College of Medicine at the University of Arkansas for Medical Sciences. He currently serves as an instructor in medical gross anatomy and neuroanatomy, as well as in the physician assistant gross anatomy courses. His research interests include the validation of virtual 3D stereoscopic anatomical models and their impact on medical and graduate students' short- and long-term retention of 3D relationships. He also has interests in K-12 outreach and promotion of diversity, equity, and inclusion.

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Complete Bilateral Ureteral Duplication: A Case Study on Anatomic Variations

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Abstract
Developmental variation is frequently observed during anatomical study. Some variations remain asymptomatic and do not interfere with normal function but others may have significant clinical consequences. Developmental anomalies of the renal excretory system are not uncommon. Knowledge of the variation in ureteral development is essential in determining the management strategies of urogenital disorders. Partial or complete duplication of the ureter may result from early splitting of the ureteric bud or the presence of a second ureteric bud. Here we report a case of congenital anomaly in the ureterorenal system where complete bilateral ureteral duplication was found in a female cadaver donor. Both sets of ureters entered the urinary bladder enclosed in a common fascial sheath but opened separately into the trigone of the bladder. In this case, no evident renal pathology was observed. There was no sign of renal cysts, hydronephrosis or calculus in either kidney. This case highlights the importance of learning morphological variations to students of health science. https://doi.org/10.21692/haps.2021.004

Key Words: Ureter, Bilateral Duplication, Gross anatomy, Cadaver dissection, Anatomic variations

Introduction
Except for monozygotic twins, each person is different from every other person (Moore 1989). In the study of anatomy, a structure is considered normal if it follows the most common morphological pattern. Structures that are less frequent morphologically are referred to as variations but they are not abnormal. This understanding leads one to categorize these variations as part of the total fabric of the human body rather than as being mere anomalies or being unnatural (Bergman 2011).

The ideal method of introducing the concepts of normality and variation is by cadaveric dissection in the gross anatomy lab. For centuries, cadaver dissection was considered to be the only acceptable way of teaching medical gross anatomy and this traditional way of teaching anatomy still continues at most allopathic and osteopathic medical schools (Drake et al. 2009; Drake et al. 2014; Gabard et al. 2012). Cadaver dissection not only promotes an understanding of the intricate structure of the human body, but also allows students to discover structural variations and developmental anomalies during the course of dissecting. As students build up their own mental representation of human anatomy in a dissection lab, they will very quickly find out that their textbooks do not represent the reality of their dissected body (Brenner 2011).

Increased use of virtual dissectors, computer-generated images and models, and the lack of a morphological approach, deprive students of a learning experience where they can encounter structural variations. The current trend away from cadaver dissection may compromise the knowledge and understanding of anatomic variations that is required to practice medicine safely and competently (Willan and Humpherson 1999). Anatomical variations provide an embryological and comparative background for medicine and biology in order to understand the morphological aspect of the human body and its related structures (Sanudo et al. 2003). It has been reported that about 10% of clinical malpractice is due to ignorance of anatomical variations (Cahill and Leonard 1999).

Development of renal collecting system and common variations
The kidneys initially develop in the region of the pelvis from the metanephros that appears in the fifth week of intrauterine life (Sadler 2018). Through differential body growth they assume a more superior position in the posterior abdominal wall. The collecting system of the kidney develops from the ureteric bud which is an outgrowth of the mesonephric duct. The ureteric buds give rise to the ureters and other components of the collecting system. Cross talk between the ureteric bud and the metanephros is essential for the normal development of functional renal parenchyma and the collecting system. Failure of the reciprocal signaling between the ureteric bud and metanephros leads to urinary tract anomalies (Didier et al. 2017).
Proper formation of the urinary tract is dependent on the interaction of multiple genes and their sub-products. Identifying alterations in those genes can help us understand the different molecular expressions and different morphological anomalies (Nordmark 1948). Anomalies in the development of the urogenital system include variations in the kidney, ureters, bladder and urethra. Ureters are muscular conduits that transport urine from the kidneys to the urinary bladder. During embryonic development, partial or complete duplication of the ureter may result from early splitting of the ureteric bud (Roy et al. 2017) or the appearance of a second ureteric bud (Sadler 2018). Congenital variation in ureters includes variation in number. For example, there could be a single ureter with one absent or double, triple, quadruple, quintuple or sextuple on one side or on both sides (Tubbs et al. 2016). A duplex collecting system is the most common malformation of the urinary tract (Schultza and Todab 2016), with a prevalence of 0.1% to 4% (Bordei et al. 2004; Smith and Orkin 1945).

Ureteral duplication is described in approximately 1 in 125 (0.8%) people at autopsy (Nation 1944) and it occurs more frequently in females than in males [1.6:1] (Privett et al. 1976). Unilateral duplication is six times more common than bilateral duplication (Nation 1944). Duplication is believed to be an autosomal dominant trait with incomplete penetrance (Cohen and Berant 1976) with the highest prevalence occurring in Caucasian females (Siomou et al. 2006).

Duplication is a common variation in ureteral development. Incomplete duplication results when both ureters fuse at their termination with a common stalk opening in one ureteric orifice in the urinary bladder (Vasi 2014). Most of the incomplete duplication remains undetected and clinically silent. However, when complete, ureteral duplications may coexist with ectopic ureters or ureteroceles (Rodrigues et al. 2016). Complete ureteral duplication, where each ureter opens separately in the urinary bladder is less common (Karakose et al. 2013). An ectopic ureter may open in the urethra, vagina, vestibule or epididymal region (Tubbs et al. 2016). A ureterocele, another congenital anomaly of the ureter, is a cystic outpouching of the distal part of the ureter into the urinary bladder (Shokeir and Nijman 2002; Sozubir et al. 2005). It is commonly seen with ureteral duplication.

A higher occurrence of complications such as obstructive uropathy, stone formation, ureterocele and vesicoureteral reflux has been recorded with a duplex system (Unarini and Nike 2020). These types of findings underscore the importance of learning common variations/anomalies in anatomy. Recognition of the possible effects of abnormal ureteral development is essential in determining the management strategies of patients with urogenital disorders.

**Case Report**

We report on a case of a middle-aged Caucasian female donor with bilateral ureteral duplication found after routine dissection in a senior medical student elective at the University of Arkansas for Medical Sciences. Although the duplication anomaly in the renal excretory system is not uncommon, complete bilateral duplication is rarely seen (Aiken et al. 2015). Therefore, only a small minority of anatomy students will observe this developmental anomaly during the course of cadaver dissection. Hence, we felt the importance of reporting the case.

The area around both kidneys was cleaned to study renal blood supply and the relation of the ureters to the nearby structures (Fig 1). The ureter to the right upper moiety measured 25 cm in length and drained 3 major calices, while the ureter to the right lower moiety was 22 cm long and drained 2 major calices. On the left, both ureters drained 2 calices (Fig. 2) with the upper one measuring 27 cm and the lower one measuring 25 cm.

The size and parenchyma of both kidneys were within normal range from a gross anatomical perspective (Fig. 2). The left kidney (11.2 x 4.2 x 3 cm) was larger than the right kidney (9.5 x 3.8 x 1.8 cm). There was no sign of any renal cyst, hydronephrosis or calculus in either kidney. The renal blood vessels appeared normal.

The ureters were followed to the urinary bladder by blunt dissection (Fig.3). Ureteral catheters were used to examine the opening of the ureters in the bladder (Fig.4). Each set of ureters entered the urinary bladder enclosed in a common fascial sheath but the two ureters opened separately in the trigone of the urinary bladder (Fig. 3). The upper ureter opening was located approximately 5mm below and medial to the opening of the lower ureter. On the right side there was a prominent intravesical ureterocele associated with the upper ureter (Fig. 4).

The pattern of ureteric insertion into the urinary trigone followed the “Weigert-Meyer law”, which states that the lower renal pole drains into a laterocranial ureteral orifice (and may reflux), while the upper renal pole drains into a mediocaudal ureteral orifice (and may be obstructed) (Glassberg et al. 1984). No other significant anomaly was observed in the four ureters.
Complete Bilateral Ureteral Duplication: A Case Study on Anatomic Variations

Figure 1. Duplicate ureters from both sides shown to have normal anatomical relations with the other structures as they reach the urinary bladder. (RUU-right upper ureter, RLU-right lower ureter, LUU-left upper ureter, LLU-left lower ureter). They were crossed by uterine artery (UA) before their entry into the bladder.

Figure 2. Sliced left kidney showed normal appearance of the renal parenchyma. The upper ureter (uU) and the lower ureter (lU) both drained two major calices each.

Figure 3. Complete bilateral duplicate ureters entered the urinary bladder separately. The urinary bladder was sliced into two halves to show the openings of the ureters.

Figure 4. Separate opening of all four ureters in the urinary bladder were demonstrated with ureteral catheters. Opening of the upper ureters on both sides were marked with black striped catheters. Right side of the bladder had a prominent ureterocele (UC).
**Discussion and Conclusion**

Each human body is unique and variations among different individuals are common. Human anatomic variation can be defined as human form that is outside of the normal but the definition of normal is not very clear. One definition of normal is the gauge by which an anatomic trait is considered a variation or not (Tubbs et al. 2016).

Developmental variations may range from subtle to significant and may have important influences on predisposition to illness, symptomatology, clinical examination and patient management. Therefore, concepts of normality and variation should be introduced early in a medical course (Willan and Humpherson 1999) since 40% of pathologic conditions of the urinary system are due to variations (Bergman et al. 2015).

We are reporting one such variation in the formation of ureters. The clinical relevance of this finding is that in many cases, ureteric duplication can be asymptomatic, and in this case of bilateral ureteral duplication there was not any evident renal pathology. In some cases, however, it can be a source of urinary tract infection, hydronephrosis, or incontinence (Raja et al. 2016). Complete duplication is most often associated with vesicoureteral reflux, ectopic ureteroceles, or ectopic ureteral insertion, all of which are more common in girls than in boys (Fernbach et al. 1997). Urinary incontinence in females occurs as a result of the ectopic ureter entering the vagina, urethra and vestibule (Siomou et al. 2006). Duplicated ureters can be challenging if they harbor pathology such as a tumor, and urologists need to recognize this variant, especially if reconstruction is contemplated.

This case report aims to draw attention to a congenital anomaly of ureteric duplication found in a middle-aged patient with completely normal kidneys in gross appearance. Clinically, there should be a suspicion of duplication when there is a mismatch between a diagnostic finding and actual discovery during a procedure. For example, imaging may show a stone in the ureter, while it cannot be found when attempting an endoscopic retrieval. This can be explained by accessing an ipsilateral duplicated ureter that is free from stones.

In terms of learning anatomy, study of these types of cases will reinforce the understanding that structural variation is not something very uncommon. In some cases, the structural variation may have significant consequences, but at times people are able to lead a normal and healthy life without being aware that something that could be considered a significant structural disparity exists.

Morphological variation is an important topic in anatomical study that is better learned by case studies than typical textbooks. Textbooks are limited in that they typically describe a structure based on the most frequently occurring form. Thus, it is the responsibility of anatomy educators to introduce this concept with not only textbooks, but also with equally relevant case studies.

In teaching students the value of case studies, educators can use this case of a complete bilateral duplication of the ureter as an example to demonstrate that anatomical education does not only stop at the textbook. Cases such as the one highlighted in this paper serve a vital role in supplementing textbook anatomical education.

Education of morphological variation in ureters would be severely limited if students only learned that one ureter carries urine from each kidney; a fact we are showing may not be the case in many patients. This case showed that in spite of a major variability in the renal excretory system, the individual did not show any significant renal malfunction, which makes this a unique case study that anatomy educators may use in their classes to drive the point home of the importance of evidence-based case studies.

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Complete Bilateral Ureteral Duplication: A Case Study on Anatomic Variations


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The Benefits of Handwriting Class Notes: Neuroanatomy, Mindfulness, and Anecdotal Evidence Supporting Handwritten Notes

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Abstract
Students who take notes by hand are more likely to process the content by summarizing or paraphrasing the material to maximize understanding and recall compared to those who use a keyboard for note taking. The benefits of handwriting notes can be seen not only in student performance but also in the brain itself as measured by high density encephalograms (HD-EEG), which indicate that proficiency in handwriting is associated with advanced brain function. Proficient handwriting is strongly correlated with the quality of writing, the ability to read, the ability to spell, and the ability to compose written documents, all of which are beneficial to students at all grade levels. This article examines the benefits of taking notes in class, the computer versus handwriting for note taking, and the neuroanatomy of the regions of the brain that are triggered by the process of taking handwritten notes. Anecdotal evidence of the value of note taking in class is offered and the role that mindfulness can play in the process of handwriting and reviewing class notes is examined. https://doi.org/10.21692/haps.2021.002

Key words: note taking, handwriting, HD-EEG, neuroanatomy, mindfulness

Introduction

Why take notes in class?
Taking notes in class is an important success strategy in college. The active process of note taking helps students stay focused on the material being presented and contributes to their understanding of the concepts that are central to a discipline. Note taking can facilitate learning by helping students grasp and process the lecture content, make appropriate inferences, and put material into a form the student comprehends (Aiken 1975; DiVesta and Gray 1972.) Good notes are critical for studying class material outside of class time and preparing for exams. If notes are concise and efficient, they can save time and energy that can then be focused on the learning and retrieval of information that was presented in class. Good, systematic notes should help prevent class material from being overwhelming or confusing. Ideally students will take the time to go over their notes within 24 to 48 hours after class to check for clarity, fill in any missing material, and prioritize the material. This time frame is in keeping with the Ebbinghaus forgetting curve, which proposes that people start losing the memory of learned material very quickly, unless the material is reviewed (Murre and Dros 2015).

According to the curve theorized by Herman Ebbinghaus, a German psychologist whose work on the nature of memory was done in the late 19th century, approximately two-thirds of anything that has been memorized will be forgotten after 24 hours unless a conscious effort is made to retrieve and review it. The review process must take place consistently over time until the material is learned (Murre and Dros 2015).

The type of notes taken will likely vary with the course content. Students seeking conceptual information may focus primarily on the main topics of a lecture in preparation for possible essay questions on an exam, while students in high content courses such as anatomy and physiology may want their notes to track the lecture as closely as possible, enabling them to create a store of facts for short-answer test questions. Some students will want to take notes that will cover both eventualities.

What method of note taking is best?
The ubiquity of laptop computers on college campuses means that many students may be able to choose whether to take class notes on a laptop computer, by hand, or with some combination of these two options.
Taking notes on a computer is faster and easier for many students. The assembled volume of material on a computer is easy to edit, store, search, and share. However, a computer might not be the best choice for making diagrams, copying illustrations, or keeping track of chemical formulas, and computers can be a distraction when attention wanders during class and temptation causes students to stray to the internet for gratification (Mueller and Oppenheimer 2014).

Taking notes by hand makes it easier to copy diagrams and illustrations during a lecture and may better serve the needs of visual learners (Mueller and Oppenheimer 2014). Handwritten notes are not associated with computer-based distractions. Both types of note taking can help with comprehension and retention of material.

This article examines the benefits of taking handwritten notes in class including encoding and external storage, the computer versus hand writing for notetaking, and the neuroanatomy of the regions of the brain that are triggered by the process of taking handwritten notes. Additionally, we offer anecdotal evidence of the value of taking notes in class and the role that mindfulness can play in the process of handwriting and reviewing notes.

Encoding and External Storage
Recent research focusing on the ways in which note taking can benefit learning, suggests that two processes, encoding and external storage, may be enhanced by the process of handwriting notes (Mueller and Oppenheimer 2014). During encoding, the physical eye-hand process of actually taking the notes may serve to improve learning and retention of the material (van der Meer and van der Weel 2017), spelling accuracy (Cunningham and Stanovich 1990) and improved memory and the ability to recall (Longcamp et al. 2006; Mueller and Oppenheimer 2014). External storage refers to the ability to review material outside of a classroom environment. Students who take good notes and conscientiously review them can benefit from both processes (Kiewra 1985).

Note taking can be described as generative when it includes summarizing and paraphrasing material or mapping the main concepts of a lecture or class experience, and non-generative when the goal is verbatim transcription of a lecture (Mueller and Oppenheimer 2014). Generally, taking notes verbatim is associated with less cognitive processing than note taking involving the summarizing or paraphrasing of material (Craik and Lockhart 1972; Kiewra 1985). Encoding benefits are believed to be greater when there is deeper information processing, such as is characteristic of generative note taking (Kiewra 1985; Mueller and Oppenheimer 2014).

The use of a laptop computer for note taking facilitates verbatim transcription of notes because many students are able to type faster than they can write (May 2014). Typing may diminish the encoding benefits associated with handwriting while increasing the benefits of external storage (Kiewra 1985; Mueller and Oppenheimer 2014).

Note taking using a laptop compared to handwritten notes
Mueller and Oppenheimer (2014) investigated whether taking notes on a laptop computer or taking handwritten notes had an effect on the academic performance of 67 Princeton University students (33 male, 33 female, 1 unknown). They found that students who use laptop computers for note taking were more likely to take verbatim notes, even when they were instructed not to do so.

It is reasonable to assume that taking verbatim notes would result in more complete external storage records; therefore, generating a more complete study system leading to better performance on exams, but Mueller and Oppenheimer (2014) found the opposite to be true. Indeed, they reported that students who took notes using a laptop computer performed worse on fact-based tests and on tests targeting the understanding of concepts than students who took handwritten notes. They concluded that students who take handwritten notes may process information better than those who take computer notes, increasing their ability to select important information from the material being presented and ultimately being equipped to study more efficiently.

Mueller and Oppenheimer (2014) found the greatest advantage to those who take handwritten notes occurred when there was a delay between the presentation of the material and the time of the test. They reported that there was no difference in performance between computer note takers and handwriting note takers on fact-based questions when testing was immediate, although students who took handwritten notes performed better on conceptual questions across the board.

Differences in brain activity with different methods of note taking
Van der Meer and van der Weel (2017) designed an experiment to investigate differences in brain activity observed in those who wrote using a keyboard and those who wrote with pen and paper. They studied 20 students between the ages of 21 and 25 (12 female) from their local University in Norway. They made the assumption that handwriting and drawing with a pen would, in general, stimulate similar brain activity. They hypothesized that drawing and handwriting involve many of the same complex skills. Handwriting and drawing require acute visual processing skills and the integration of vision and touch capabilities combined with the fine motor skills and coordination of muscles used for hand movements (Askvik et al. 2020; van der Meer and van der Weel 2017).
The use of a keyboard and a pen and paper for drawing depend on different underlying neurological processes (van der Meer and van der Weel 2017). Handwriting and drawing are both complex tasks that require integration of unique sensory and motor movements in order to accomplish many separate skills such holding a pen, making coordinated fine motor adjustments, and reproducing visualized shapes on paper. Operating a keyboard requires only that a fingertip touch the correct key, which requires a very different skill set (Askvik et al. 2020; Longcamp et al. 2006; van der Meer and van der Weel 2017).

Two studies have used high-density electroencephalograms (HD-EEG) to investigate brain activity during handwriting. Van der Meer and van der Weel (2017) found direct electrophysiological evidence that drawing by hand activates larger brain networks in the parietal and occipital regions of the brain, in the theta (4-8 Hz) and alpha range, than using a keyboard for typing. Askvik et al. (2020) used HD-EEG to study the brain waves generated by 12 young adults and 12 children (12 years of age) while they were writing in cursive, typing, or drawing a series of visually presented words. During handwriting, increased brain wave activity was noted in the parietal regions of the brain in the theta range in the young adults. Activity in this area provides the brain with optimal conditions for learning and is important for memory and the encoding of new material. Theta band activity is observed in the parietal areas of the brain during the production of letters and when creating drawings by hand (Askvik et al. 2020).

Similar patterns of increased activity were observed in the parietal areas of the brain in the alpha range (8-10 Hz) and the beta range (12-20 Hz) when young adult subjects were drawing. This suggests that there is an increase in cognitive effort coupled with an increase in the processing of information during drawing (Askvik et al. 2020). During typing, brain wave activity in the theta band was increased and to a lesser extent, activity in the alpha range was also observed in the young adult subjects (Askvik et al. 2020). Askvik et al. (2020) concluded that the underlying electrical activity of the brain is different for handwriting, drawing, and typing, with the brain wave patterns for handwriting and drawing being more similar to each other than to typing.

The same brain wave patterns were generated in the 12-year-old children; however, they were manifested to a lesser degree. This possibly indicates that children must be exposed to handwriting and drawing activities over a number of years in order to establish the strongest possible correlations with learning (Askvik et al. 2020).

### Neuroanatomy of handwriting

Learning to write has consequences for early brain organization and acquiring complex skills such as reading (Longcamp et al. 2016). The slow process of mastering the skills required for handwriting starts in kindergarten for most children, where writing is most similar to drawing, and progresses over a period of several years until children are able to write legibly and competently on their own (Askvik et al. 2020; Semerano et al. 2018).

After a written sequence has been learned, there is a memory trace of the specific sequence of motor movements required to produce each letter in the primary motor area of the brain. Disruption of this memory by a stroke or some other trauma makes the shaping of letters problematic, a condition known as apraxic agraphia (Longcamp et al. 2016). Injury to a region anterior to the premotor cortex, close to the junction of the middle frontal and precentral gyri in the left hemisphere, most profoundly affects the ability to shape letters. This region is known as “Exner’s area” after Sigmund Exner (1846-1926), an Austrian physiologist who observed the brains of agraphic patients (Longcamp et al. 2016).

When handwriting occurs, an extensive area of the brain ranging over the primary sensory-motor cortex and several sensory and associative regions is activated in addition to Exner’s area. The extreme size of the area of the brain that is activated by the process of handwriting is attributed to the fact that writing is not just a series of finely tuned hand movements (van der Meer and van der Weel 2017; Askvik et al. 2020; Longcamp et al. 2016). It requires neural analysis of the stimulus; for example, analysis in the auditory region of the brain if the word is heard before being written, coupled with constant visual feedback in the occipital region if the writing can be viewed (Askvik et al. 2020; Longcamp et al. 2016).

Examples of brain areas that are known to contribute to handwriting include the left superior parietal cortex, the cerebellum, and the left fusiform gyrus. The fusiform gyrus contributes to spelling, orthographic word-form processing, and letter-form processing (Cohen and Dehaene 2004; Cohen et al. 2002; Joseph et al. 2003). The cerebellum helps to stabilize and regulate motor movements, and the superior parietal cortex has close links with the occipital lobe and is involved in visuospatial perception (Longcamp et al. 2016). The four cerebral brain regions that are activated most consistently in brain imaging studies of handwriting are the dorsal premotor cortex, the ventral premotor cortex, the superior parietal cortex, and the fusiform gyrus (Longcamp et al. 2016).
The patterns of brain activity associated with handwriting strongly predicts the ability to master other language skills such as recognition of individual letters, the ability to read, spelling, and the ability to compose written documents (Askvik 2020; Cunningham and Stanovich 1990; Longcamp et al. 2016).

How can mindfulness help?
Mindfulness is defined as the act of paying attention, on purpose and without judgement, to the present moment. Mindfulness is being explored in higher education as a way to enhance learning outcomes because of the way it allows the learner to minimize attention to distractions and attend more fully to the task at hand (Napora 2012).

Analysis of current research suggests that the act of writing notes by hand exemplifies student engagement in the learning process. Students create a deeper connection to academic material through the process of physically writing out notes, which encodes content in such a way as to enhance academic outcomes in testing situations (Clawson 2019). Because handwriting is a multi-sensory experience that engages multiple areas of the brain, it creates more opportunities or “hooks” for the brain to latch onto the material, which in turn leads to enhanced memorization (Bergland 2020). The same focused attention that is required to hand write notes is similar to the type of attention that is cultivated through a consistent mindfulness practice (Clawson 2019).

Attending to the present moment, which is fundamental to mindfulness, requires a certain amount of slowing down in order to absorb details of the moment. In other words, if people are moving, thinking or acting too quickly, they will miss the details that make up that moment (Olson 2020). The same is true of note taking and test review. If people are reviewing too quickly, or just skimming the material, the brain will not “hook” onto the material as it would if greater care and attention were paid to it. By bringing mindful attention to the experience of note taking, students may be able to enhance the process of memorization.

In addition to helping students stay focused during class while taking notes and encoding the content more deeply, the experience of handwriting may help reduce stress and anxiety in a way that is similar to mindfulness. Because handwriting activates the same region of the brain as drawing, it may have a comparable effect to meditative drawing activities or the ever-popular adult coloring books that are used to calm the mind and encourage a greater mind-body connection (Bash et al. 2018). This may also help to explain why some students report success when incorporating anatomy coloring books into their study regime. Rewriting notes made in class can also be a powerful tool to help students calm their mind and focus their attention on the course content that must be mastered.

Anecdotal evidence supporting handwritten notes
In order to get a sense of how successful students navigate the note taking process, one of the authors (LP) interviewed six students to learn about their strategies for taking notes. All of these students were Learning Resource Network (LRN) Tutors at Arcadia University. In order to be a peer tutor for the LRN, students must maintain a cumulative grade point average of 3.0 or above, have received a grade of “B” or better in the courses they tutor, and, most importantly, have a recommendation from a member of the faculty. These criteria formed the basis for their qualifications as “successful” students at Arcadia.

As tutors they had undergone the LRN’s basic tutor training, which involves learning questioning techniques and methods of communication. Two of the students were Psychology majors and four were Biology majors. They were upper class students who had successfully completed 200- and 300-level courses both within and outside of their majors. Most of them were advanced tutors, known as Peer Study Assistants. LRN Peer Study Assistants undergo additional training, which involves examining a range of learning and study strategies for the content areas they tutor, as well as strategies for imparting these skills to the students they tutor. The training also includes a module on learning styles designed to help tutors understand that their way of learning may not always match up with how their students learn.

All but one of these students have completed either Human Anatomy or Comparative Anatomy and Physiology. For the most part, they spoke from the context of these two classes, which are very focused on detailed, factual information, but also require a mastery of concepts and processes.

Each of these tutors has developed their own personal strategies for taking notes both in class and before class, and for processing notes after class. The following information was elicited directly from the students during private, informal personal interviews. Each student gave permission for their thoughts to appear in this summary.

Haley is a senior Biology major, with a cumulative GPA of 3.79. She reported that she takes detailed notes in class, reviews her notes after every class, and studies by rewriting her class notes. She does not do a word-for-word rewrite. Instead, she integrates content from PowerPoint slides and handwritten class notes into what she calls “summary sheets.” She evaluates the information, then prioritizes what she decides is most important and relevant. The process she describes for studying includes self-testing which is an important step in test preparation that novice students often leave out (Karpicke 2009). After rewriting her notes, Haley takes out a blank piece of paper and writes headings of the specific concepts she

continued on next page
wants to learn. She handwrites everything she remembers from her notes and summary sheets, adds additional details that she might have missed, and makes any necessary corrections. She does the same with diagrams, drawing them from memory and then going back to insert what she may have left out.

Olivia is a senior Psychology major, with a cumulative GPA of 3.70. A Peer Study Assistant, Olivia plans to pursue graduate studies in neuroscience. She reported that when she initially began as a Psychology major in college, she took notes on her computer. However, as she became more deeply interested in the biological basis of psychology, she moved toward taking notes by hand and has found that to be more effective than typing notes. As a Psychology major, she is familiar with encoding for learning and memory. She feels that handwriting supports the encoding process for her.

Jill is a senior Psychology major with a Cumulative GPA of 3.62, who plans to pursue forensic psychology at the graduate level. She is a Peer Study Assistant. She calls herself a “huge proponent” of handwriting notes. Jill has created her own “shorthand” which, she says, forces her to think about what she is writing while taking notes in class. After some “trial and error” she began developing her shorthand as she realized she needed to become more accurate in real-time. When professors post their notes or lectures online, she compares her handwritten notes with the posted notes, cross-referencing to see if she missed anything.

Brady is a senior Biology major in the Pre-Physical Therapy program, who will matriculate into Arcadia University’s Doctorate of Physical Therapy in the Fall 2021. He noted that “there’s going to be different ways of note taking depending on which class you’re doing it for.” He feels that the student has to be completely engaged while in the class in order to take the most accurate notes. Brady is also an athlete who relates what he is learning about the body to the ways he and his teammates use the body in motion, while working out, practicing, and on the field. Brady remarked that “For people who have a familiarity with the body” drawing a picture of doing a bicep curl helps to understand what is involved in that activity. He explained how and why this works for him: “As an athlete I have spent many hours in the gym and looking at exercises online, so I know what movements each muscle can make. For example, if a particular muscle inserts in a particular place it is going to pull in a certain direction and it is going to cause a predictable motion. So, when I am taking notes in class, the drawings are the most important thing because they allow me to relate it to myself.”

Sarah is in her senior year as a Biology major in the Pre-Physician’s Assistant program with a 3.67 Cumulative GPA. She will be starting in a PA program in Fall 2021. She was the only student out of the group interviewed who said she often looks at notes or PowerPoint slides if they are provided before the class. She makes notes on the print-outs of what she thinks will be important in class or takes the time to paraphrase something she thinks is important. Her before class notes do not have to be perfect, so long as she can read and understand what she has written. Subsequently, she feels more relaxed in class, so that she can “actually listen to what the teachers are saying instead of rushing to write everything down.” She feels that she has a “frame of reference of what the instructor is going to talk about in class.” Like Jill, she has her own abbreviations. After class she creates flashcards on her computer from her handwritten notes, adding emphasis if necessary. She also uses Quizlet. She rewrites the answers to questions she has difficulty with. Sarah noted that she learned cursive writing in school, but she mostly prints when she writes by hand. However, she has no difficulty understanding board notes that might be in cursive.

Ben is a junior Biology major in the Pre-Physical Therapy program with a 4.0 Cumulative GPA. He is a Peer Study Assistant. Ben writes his notes by hand and uses rewriting notes as a way of studying. Much of what he emphasized had to do with keeping his notes organized. He is currently enrolled in Human Anatomy, so he spoke from the experience of taking notes and studying for that class. The instructor writes on the board and draws detailed diagrams with labels and directional arrows. The method he has found that works best for him is to use one page for drawing the pictures and the other side of his notebook for writing notes. While he said he is “not artistic at all,” the act of drawing supports his learning because he can recall the visual later. He said that because he “struggled with the drawing” it required him to slow down and thoroughly process the material as he built up the drawing to be sure he was getting all of the necessary information and understood the significance of each part. Drawing and rewriting of notes has contributed to his ability to memorize the material. He usually starts studying about a week before an exam by going through his notes, deciding what he needs to know better, and rewriting those details. He quizzes himself, then goes back to rewriting and redrawing, repeating the process up to three or four more times. When taking the test, he says he can visualize his notes on each page.

The single common thread across each of these students’ strategic approaches to note taking is that they make handwritten notes. Whether those notes are made in cursive or printed or written in their own personal shorthand did not seem to make a difference. The students also incorporated principles of mindfulness into their studying in that they planned ahead to set aside ample time for rewriting their notes, redrawing diagrams, and repetitively processing the information in their notes and they tried to be fully engaged with the learning process during class time.
From this series of interviews, we conclude that successful students are autonomously motivated to find the learning process that works best for them. They take responsibility for their actions and outcomes and they are willing to put forth whatever effort is required to achieve their goals. They handwrite their notes to support the encoding process and practice mindfulness principles as they plan to set aside quiet time for reviewing and processing the information they are given in class.

Application
Information found in this article can be used to encourage students to take concise and accurate handwritten notes in class, perhaps by referencing some of the many pamphlets and handouts about note taking that are widely available online and in university tutoring centers, which will help them focus on the main concepts and make it easier for them to block out distractions. Material presented in this article can be used as a window through which students can better understand the organization and coordinated workings of the nervous system with respect to:

HAPS Human Anatomy Learning Outcomes
MODULE H: Nervous System
1. General functions of the nervous system
2. Organization of the nervous system
8. Specific anatomical organization of the brain

The meditative principles of mindfulness can be applied by all individuals of all age groups in order to attain a type of relaxation that is alert and focused, and therefore helpful in the learning process. Ultimately, mindfulness leads people to focus on the present moment while paying attention to emotions, sensations, and thoughts. It can be a dynamic mechanism that facilitates the management of stress in daily life and fosters learning.

Conclusion
It is generally accepted that the act of note taking is beneficial to students whether or not it is accompanied by later review, although later review of notes adds another dimension and additional benefits to the process. Students who take notes in class generally achieve more academically than students who simply listen in class (Kiewra 1985).

The pattern of neural involvement that is triggered by handwriting has been observed and recorded on HD-EEG and described anecdotally. This pattern suggests that handwriting involves large regions of the sensory cortex accompanied by the recruitment of fine motor skills required for the precisely controlled hand movements that are characteristic of handwriting. During the process of handwriting the brain is creating new circuitry to facilitate the required movements, optimize the speed of what is seen and evaluated, and coordinate the extent and timing of muscle responses (James and Engelhardt 2012). The new circuitry becomes part of the brain’s reservoir of information and can be recruited for use in other eye-hand intensive tasks. This suggests that handwriting activities have a place in the learning environment and should be considered as a viable option for note taking in the classroom to facilitate and optimize the overall learning experience.

Successful students who told us about their study strategies for this article reported that they take handwritten notes and practice some of the principles of mindfulness as they set aside quiet time to review, rewrite, and process the material in their notes. They also make an effort to be fully engaged in learning during class time.

More research into the study strategies employed by successful students is needed to further characterize the information processing methods employed by high achieving students. Based on the evidence that handwriting notes is helpful to students, it is recommended that instructors make students aware of the benefits of handwriting notes and encourage students to take the time to listen carefully to what the lecturer says, extract the appropriate information, and attempt to integrate the new information with previously learned knowledge.

About the Authors
Sarah Cooper, MEd, is an Associate Professor of Biology at Arcadia University and Managing Editor of the HAPS Educator. She teaches Human Anatomy, Comparative Anatomy and Physiology and General Biology. She is the pre-nursing adviser and serves on the Judicial Board.

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The Benefits of Handwriting Class Notes: Neuroanatomy, Mindfulness, and Anecdotal Evidence Supporting Handwritten Notes


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Cardiovascular Changes in Human Diving Reflex Based on Student-Collected Data in a Physiology Lab Course

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Abstract
In this study, we analyzed data of heart rate and pulse amplitude collected by undergraduate students in a physiology lab course during and after the diving reflex. On average, heart rate was reduced 21% at 15 seconds and 29% at 30 seconds during diving. Pulse amplitude generally decreased but with greater individual variation. There is no difference in the heart rate decrease seen between male and female subjects. Athletes started with slightly lower heart rate but showed the same response as non-athletes during diving. This study provides some variations on the typical diving reflex laboratory activity that could be used with students studying the physiological regulation of cardiac function. https://doi.org/10.21692/haps.2021.006

Key words: diving reflex, heart rate, pulse amplitude, athlete, laboratory activity

Introduction
The diving reflex, characterized by bradycardia, peripheral vasoconstriction, a reduction in cardiac output, and a rise in mean arterial blood pressure, is an innate physiological response present in all air-breathing vertebrates to conserve oxygen and heat. It is sometimes referred to as the mammalian diving reflex. In humans, the reflex may be elicited by face immersion into cold water. Knowledge of the diving reflex has been well established since it was first described in 1786 by Edmund Goodwyn (Godek and Freeman 2020). In recent years, the diving reflex has been used clinically to treat paroxysmal supraventricular tachycardia (PSVT) (Smith et al. 2012).

The mechanism of the diving reflex in humans has been well studied (Foster and Sheel 2005). Diving in cold water (< 21°C/70°F) stimulates facial thermoreceptors, carotid chemoreceptors, baroreceptors, pulmonary stretch receptors, and atrial receptors. The nucleus tractus solitarius (NTS) branch collects these inputs through the trigeminal nerve and projects them to central nervous system centers responsible for respiration and cardiovascular functions, which in turn activates the vagus nerve and other nerves in the autonomic nervous system to produce the cardiovascular responses (the diving reflex) that adapt to the new environment.

Individual variation has been observed in previous studies. The decrease in heart rate generally ranges from 12% to 40% (Alboni et al. 2011; Sterba and Lundgren 1988). Recent studies also suggest the polymorphisms in certain genes like the ACE, REN, and ADBR2 gene may contribute to the variation in the diving response (Baranova et al. 2017). For example, individuals with a polymorphism in the gene ACE and ADBR2 showed the strongest peripheral vasoconstriction in response to diving.

In Physiology teaching, the human diving reflex is widely used as a lab activity for its simplicity and reliable results. Students learn both reflex and cardiovascular functions by observation of the changes in heart rate and pulse amplitude. It is also an activity suitable for the start of the course due to the straightforward experimental setup and data recording process. In this study, we asked two questions: 1) How much individual variation is observed in a typical group of young undergraduates, particularly in a lab course setting? 2) Are common factors such as sex and athletic background correlated with the cardiovascular changes? Overall, our analysis showed that the student-collected data is consistent with the established conclusions, however with greater variation. We hope our results provide insights and a reference for physiology lab instructors to guide students to compare and interpret their experimental data.

Materials and Methods
Data were collected by students enrolled in an undergraduate Human Physiology Lab in 2019. Forty-two student volunteers, 24 males and 18 females, 18-22 years of age, participated in the diving response experiment. This project was approved by the Institutional Review Board of Gannon University (GUIRB-2019-2-200), and all subjects gave their informed consent and filled out a survey about their age, physical condition, and athletic status. A finger pulse transducer (AD Instruments) connected with PowerLab (AD Instruments, containing an amplifier and a digitizer) was used to capture the subject’s pulse. While sitting and after a deep breath, the subjects immersed their face up to the cheeks in a washbasin filled with cold water at 10 – 14°C. Pulses were recorded for 30 seconds at rest, up to 30 seconds during diving, and 30 seconds when the subject came out of the water after diving. Breath-holding above water and after a
deep breath, was used as the control for comparison. Students measured the real-time heart rate and pulse amplitude using LabChart software and filled in the datasheet for this study. In their lab reports, they compared the heart rate and pulse amplitude observed under the diving reflex and breathholding conditions.

Experimental data were collected from subjects’ lab reports with the consent form and analyzed with ANOVA using a post-hoc Tukey HSD test (Figure 1) or pairwise t-test between two groups (Figure 2). Data are presented as mean ± SEM.

**Results**
The data showed the average heart rate was reduced from 81.0 ± 2.0 BPM at rest to 68.9 ± 2.8 BPM at 15 seconds into diving, and further to 56.5 ± 2.1 BPM at 30 seconds into diving (Figure 1A). Both reductions are statistically significant (p < 0.01). After 30 seconds of recovery, the heart rate returned to 76.0 ± 2.5 BPM, not significantly different from the resting heart rate. The percentage reduction was also examined to eliminate the baseline variation in heart rate. The average heart rate was reduced from 13.7 ± 3.7% at 15 seconds into diving, and further to 28.9 ± 2.5% at 30 seconds into diving. After 30 seconds of recovery, the heart rate recovered to 5.9 ± 2.3% below the resting heart rate (Figure 1C). Breath-holding also caused a decreasing trend in both heart rate and percentage change, but the changes were not statistically significant (Figure 1A and 1C). The percentage reduction at 30 seconds of diving was statistically significantly lower than 15 seconds and recovery (p < 0.001).

![Figure 1](image.png)

*Figure 1. Changes of heart rate and pulse amplitude during diving and breath-holding. Heart rate decreased in both BPM and percentage in diving and recovered after diving (A, C). Pulse amplitude showed a decreasing trend in diving (B, D).*
The changes in pulse amplitude showed much greater variation. Percentage-wise, the pulse amplitude decreased 16.3 ± 18.9% at 15 seconds into diving, then 46.8 ± 23.8% at 30 seconds. After 30 seconds of recovery, the pulse amplitude returned to 32.0 ± 14.5% below the resting level (Figure 1D). The pulse amplitude changes were much less in the breath-holding control. Due to the larger variation, these percentage changes in pulse amplitude were not statistically significant. Since finger pulse amplitude is an external measurement, as it may vary by the tightness of the pulse transducer on the subject's finger, the absolute values cannot be compared across individuals. Nevertheless, we still saw a decreasing trend in pulse amplitude values during diving, and not statistically significant either (Figure 1B).

To further investigate the individual variation, we summarized the data in Table 1. In all 42 subjects, reduction of heart rate was observed at 15 seconds and 30 seconds into diving with individual variation. At 15 seconds, 33 subjects showed a decrease in heart rate, two had no change, while seven subjects showed higher heart rate. At 30 seconds, all 40 subjects showed lower heart rates (two subjects could not hold breath under water for 30 seconds). The heart rate decrease showed a wide range, between 5% and 75%, but averaged 21% at 15 seconds and 29% at 30 seconds.

In comparison, data recorded from breath-holding are also summarized in Table 1. At 15 seconds, 28 subjects showed a decrease in heart rate while 11 subjects showed higher heart rates. At 30 seconds, 29 subjects had lower heart rates, while eight had higher heart rates. Throughout the breath-holding, the average percentage of heart rate reduction was only 9%.

We also examined factors that may possibly contribute to the variation of cardiovascular changes and listed the data in Table 2. Between males and females (Figure 2A), we observed no difference between the heart rate before (80.8 ± 2.3 BPM in males and 81.3 ± 3.5 BPM in females) and during diving (at 30 seconds, 55.8 ± 2.7 BPM in males and 57.3 ± 3.5 BPM in females). Both sexes also showed about the same amount of decrease in heart rate.

Interestingly, we observed a baseline lower heart rate in student-athletes (73.0 ± 3.7 BPM), compared to non-athletes (82.9 ± 2.2 BPM, p<0.05, Figure 2B). Though this difference diminished in diving (athletes 55.3 ± 4.0 BPM, non-athletes 56.8 ± 2.5 BPM), the percent change in heart rate in athletes was less (24.2%) compared to non-athletes (31.5%). Since the student group was randomly chosen by the enrollment of the lab course, the types of sports these athletes participated were not controlled, including lacrosse, volleyball, wrestling, soccer, dance, competitive cheer, and cross-country running.

<table>
<thead>
<tr>
<th></th>
<th>Change</th>
<th>Percentage Range</th>
<th>Average</th>
<th>Overall Average</th>
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<tr>
<td>Diving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diving at 15 secs</td>
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<td>0%</td>
<td></td>
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<td></td>
<td>Decrease (33/42)</td>
<td>-5% to -74%</td>
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<td>Diving at 30 secs*</td>
<td>Increase (0/42)</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
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<tr>
<td></td>
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<td>-29%</td>
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<tr>
<td>Recovery</td>
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<td></td>
<td>No change (6/42)</td>
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<td></td>
<td>Decrease (24/42)</td>
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<td>-16%</td>
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<tr>
<td>Breath-holding</td>
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<td></td>
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<tr>
<td>Breath-holding at 15 secs</td>
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<td>+14%</td>
<td></td>
</tr>
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<tr>
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<td>0%</td>
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<td></td>
<td>Decrease (29/42)</td>
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<tr>
<td>Recovery</td>
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<td>+9%</td>
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<td>Decrease (18/42)</td>
<td>-2% to -50%</td>
<td>-11%</td>
<td></td>
</tr>
</tbody>
</table>

* Two subjects were able to sustain 15 seconds but not 30 seconds in water.

Table 1. Percentage Heart Rate Changes during Diving and Breath-holding
Cardiovascular Changes in Human Diving Reflex Based on Student-collected Data in a Physiology Lab Course

Table 2. Comparison of Heart Rates by Sex and Athlete Status

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>Athlete Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>80.8 ± 2.3</td>
<td>81.3 ± 3.5</td>
</tr>
<tr>
<td>Diving at 30 secs</td>
<td>55.8 ± 2.7</td>
<td>57.3 ± 3.5</td>
</tr>
<tr>
<td>% Change in Diving</td>
<td>30.9%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Recovery</td>
<td>76.0 ± 3.1</td>
<td>76.0 ± 4.2</td>
</tr>
<tr>
<td></td>
<td>67.6 ± 5.1</td>
<td>78.0 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>82.9 ± 2.2</td>
<td>56.8 ± 2.5</td>
</tr>
<tr>
<td></td>
<td>55.3 ± 4.0</td>
<td>24.2%</td>
</tr>
<tr>
<td></td>
<td>29.5%</td>
<td>31.5%</td>
</tr>
</tbody>
</table>

Figure 2. Comparison of heart rate change between sexes and athletic statuses. Male and female subjects showed similar bradycardia during diving (A). Athletes showed slower heart rate at rest compared to non-athletes but similar responses and heart rates during diving (B).
Discussion
In this study, we analyzed student-collected data in a lab course. Overall, the cardiovascular changes we observed are consistent with the observations in published studies in past years (Alboni et al. 2011; Sterba and Lundgren 1988). The heart reduced on average 20% at 30 seconds into diving, and pulse amplitude showed a decreasing trend as well. We did observe greater variation in the sample, particularly with the pulse amplitude data. There might be two causes. First, pulse amplitude may change even without the subject doing diving or breath-holding, at least with our experimental setup. Occasionally, we observed pulse amplitude change at rest, although usually it was stable (Figure 3).

We also examined whether sex and athletic status affect the subject’s response in the diving reflex. Our data showed that both males and females responded in a similar magnitude. Although student-athletes started with a lower heart rate on average, the difference diminished in diving. We wonder if the type of sports a student participates in plays a role. We did not have enough racial diversity in the subjects, thus the contribution by any racial and genetic background remains a question. These questions may be answered by future studies with larger sample sizes.

It should be noted that the data analysis for this study was carried out by the investigators with the students being involved in only provision and collection of the experimental data. However, this study could lay the groundwork for laboratory exercises involving both data collection and its analysis by students studying cardiac physiology in the laboratory as they evaluate the influence of various parameters on individual responses during the diving reflex. This in-class activity addresses HAPS Learning Objectives:

11.10: Describe the influence of positive and negative chronotropic agents on HR
11.12: Describe the role of the autonomic nervous system in the regulation of cardiac output.

Figure 3. Variation in pulse amplitude recordings. Both stable (A) and unstable (B) pulse amplitudes were recorded from the same subject at rest.
Conclusions
On average, heart rate was reduced from 81.0 ± 2.0 BPM at rest to 68.9 ± 2.8 BPM (-21%) at 15 seconds into diving, and further to 56.5 ± 2.1 BPM (-29%) at 30 seconds into diving. Pulse amplitude generally decreased but with greater individual variation. Male and female subjects showed no difference in their diving reflexes. With a limited sample, athletes started with slightly lower heart rates but showed similar heart rates as non-athletes during diving. We hope our results provide insights and a reference for physiology lab instructors to guide students to compare and interpret their experimental data.

Acknowledgments
The authors would like to thank the students enrolled in the Human Physiology Lab course in 2019 spring and fall semesters for participation and contribution of the data. Two undergraduate students, Britani Wike and Mitchell Cashmer assisted with data collection and recording.

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Both authors are faculty members at Gannon University, Erie, PA. He Liu, PhD, is an Associate Professor and the Chairperson of the Biology Department. Mary Vagula, PhD, is a Professor of Biology. The authors teach multiple sections of Human Physiology and Human Physiology Lab, as well as other courses.

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