Educational Research

Factors Associated with A&P I Grades at a Community College
Predictors of Success for Nursing and Health Science Students in A&P
Achievement in A&P Associated with Learning and Studying Strategies

Current Topics in Anatomy and Physiology

Lactate: Toxic Villain or Metabolic Superhero?
How Much Sleep Do You Need?
Partial Thickness Keratoplasty In Corneal Transplantation

Perspectives on Teaching

Why all Professors Should Take Psychology
A&P Infograms: Abbreviations and Acronyms
The Uvula and the Story It Tells
Creative Writing as a Tool for the Review Physiological Content
Impact of Rapid Change in Educational Technology on Teaching
Use of Silicone Dielectric Gel for Preservation of the CNS
The Pedagogical Value of Mobile Devices
Sorting Activities to Engage A&P Undergraduates
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Edu-Snippets are now being organized into a data base that will be available on the HAPS website. Please share descriptions of classroom activities that have worked well for you at: https://form.jotform.com/62146240511948
Submission Guidelines for Authors

The HAPS-Educator aims to foster teaching excellence and pedagogical research in anatomy and physiology education. The journal publishes articles under three categories. Educational Research articles discuss pedagogical research projects supported by robust data. Perspectives on Teaching articles discuss a teaching philosophy or modality but do not require supporting data. Current Topics articles provide a state-of-the-art summary of a trending topic area relevant to A & P educators. Additionally, the Summer edition of the HAPS Educator provides extended summaries of selected oral and poster presentations as well as the abstracts from the HAPS Annual Conference. All submitted articles undergo peer-review. Educational Research articles will additionally be reviewed for the quality of the supporting data. All submissions are disseminated to non-HAPS members one year post-publication via the Life Sciences Teaching Resource Community database.

The HAPS-Educator publishes manuscripts consisting of original material that is not currently being considered for publication by another journal, website, or book and has not previously been published. Publication of the manuscript must be approved by all of the authors and have the approval of the appropriate institution(s). Manuscripts are to be submitted alphabetically by author’s last name. Example references are available at http://www.hapsweb.org/?page=hapsed_submissions. Materials for EDU-Snippets can be submitted at: http://bit.ly/HAPS_Snippet.

Formatting

Manuscripts are to be submitted in rich text format (rtf.) or .docx, in Arial (10) font with 1” margins on all sides. Accompanying the text, authors should submit an Author Submission Form consisting of a title page that lists the full name, associated institution and address, and email address of each author. A short Abstract of 150 to 200 words that explains the primary thesis of the manuscript should be included. Photos and illustrations should not be included in the body of the manuscript but they should be submitted, clearly labeled, with the manuscript. They should be submitted in JPEG form or in some other appropriate and usable form.

References

It is the responsibility of the author to make sure that the information on each reference is complete, accurate and properly formatted. References should be included in the body of the manuscript where appropriate using the following format: Author’s last name and date of publication, (Martini should be included in the body of the manuscript where appropriate using some other appropriate and usable form).


Deadlines for specific issues are:

- March 15 for the Spring Issue
- July 15 for the Conference Issue
- November 15 for the Winter Issue

You do not need to be a member of HAPS to publish in the Educator. For more information see the complete submission guidelines using the link above.

Human and animal research subjects

Research that includes dissection and manipulation of animal tissues and organs must adhere to the Human Anatomy and Physiology Society (HAPS) Position Statement on Animal Use (Adopted July 28, 1995, modified January 2001, Approved April 29, 2012), which states that the use of biological specimens must be in strict compliance with federal legislation and the guidelines of the National Institutes of Health and the United States Department of Agriculture. The use of humans or animals in research must fulfill clearly defined educational objectives.

Experimental animals must be handled in accordance with the author’s institutional guidelines and informed consent must be obtained for studies on humans. It is the responsibility of the author(s) to secure IRB approval for research on humans.

How your submission will be handled

The editor will assign the manuscript to a minimum of 2 and a maximum of 4 members of the HAPS-Educator editorial board for Educational Scholarship review. The reviewers will evaluate the manuscript for scientific accuracy, appropriateness to the audience, readability and grammar. The reviewers will submit their reports along with a recommendation that the manuscript be (a) published unaltered, (b) published with minor changes, (c) published with major changes or (d) not published at all. The editor will then decide what action will be taken with the manuscript and the author will be notified to prepare and submit a final copy of the manuscript with the changes suggested by the reviewers and agreed upon by the editor. Once the editor is satisfied with the final manuscript, the manuscript can be accepted for publication.

If the editor recommends rejection of the manuscript due to inappropriateness of its subject, lack of quality in its presentation or incorrectness of grammar or style, it will be rejected. If two reviewers recommend rejection of the manuscript made on the basis of inappropriateness of its subject, lack of quality in its presentation or incorrectness of grammar or style, it will be rejected.

The review process is single blinded which means that the reviewers know the identity of the authors of the manuscript but the authors do not have access to information regarding the identity of the reviewers.

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An Opportunity to Serve!

Ron Gerrits, President-Elect of HAPS and 2016-2017 Nominating Committee Chair
Professor of Biomedical Engineering, Milwaukee School of Engineering, Milwaukee, WI 53081

Reading the HAPS listserv and HAPS Educator, reviewing position statements, implementing HAPS learning outcomes and returning from an annual or regional conference with new ideas are all ways that I have benefitted from the volunteer efforts of the many engaged HAPS members. Hearing others similarly express their gratitude for the services offered by our organization provides some evidence that we are helping meet the professional needs of the A&P instructors we aim to represent. Yet there are always improvements to be made, fresh ideas to be considered, and management tasks that must be completed. A vibrant and dedicated leadership team helps guide the HAPS organization in these various areas. Please consider joining this team, or nominating others, for the Board positions that are open for elections in spring.

One of the responsibilities of the HAPS President-Elect office is to chair the annual Nominating Committee and solicit potential candidates for the leadership positions that are scheduled to be filled at the beginning of the next fiscal year (which starts July 1). Working with me this year on the Nominating Committee are Leslie Day, Membership Committee Chair; Kerry Hull, HAPS Educator Committee Chair; and Murray Jensen, previous Central Regional Director.

We are currently accepting nominations for candidates to fill the four HAPS offices with terms that will commence on July 1, 2017. These offices are: President-Elect, Secretary, Central Regional Director, and Southern Regional Director. Both self-nominations and nominations from colleagues are welcome and are due to the Nominating committee by January 15, 2017 in order to be considered. Questions or nominations should be submitted to me at rgerrits@hapsconnect.org, or directed to other members of the Nominating Committee.

All discussions of potential candidates will remain confidential within the Nominating Committee. The Nominating Committee will review all nominations and verify willingness to serve. A final slate of candidates will be recommended to the Board of Directors for approval in March, with a maximum of two candidates for President-Elect and maximum of three candidates for each of the other offices. The final candidates will be asked to provide a biography and position statement for the April ballot.

All of the elected officers serve on the Board of Directors during their term. The Board holds in-person meeting twice a year; during a weekend in October at the location of the next annual conference, and for two days prior to the annual conference.

The work of the Board is conducted the rest of the year through scheduled monthly e-meetings and synchronous conference calls, and other asynchronous communication as needed.

Descriptions of the roles and responsibilities of each office can be found in the HAPS Bylaws available on the HAPS website (http://www.hapsweb.org/page/GovernanceDocuments). Below is a short synopsis of each office that will be filled in the 2017 election:

President-Elect:
Election to this office involves a three-year commitment, one year each as President-Elect, President, and Past-President. The year as President-Elect provides a year to become accustomed to serving on the Board of Directors before transitioning into the role of President. The President, in consultation with the Board, provides direction and guidance by establishing and managing the policies and affairs of the Society. Following the President’s term, they become Past-President to provide leadership continuity.

Secretary:
The Secretary is responsible for maintaining the official records of the Society. This includes recording minutes of Board and general membership meetings, and maintaining bylaws and other corporate documents. The Secretary’s term of office is for two (2) years, and they may not serve more than two (2) consecutive terms.

Regional Directors (Central & Southern Regions – see website for boundaries http://www.hapsweb.org/?page=MapofHAPSRGions&hhSearchTerms=%22regions%22):
Although each Regional Director serves as a representative of one of the four HAPS regions to ensure diverse geographical representation on the Board of Directors, they are elected by the entire membership. They act as a liaison between the region’s constituency and the Board and promote increased involvement of the region’s membership in the activities of the Society, including regional conferences. Each Regional Director’s term of office is for two (2) years. Regional Directors may not serve more than two (2) consecutive terms.

Becoming part of the HAPS leadership team is a great way to give back to the organization and to enhance personal and professional development within a nationally respected educational organization. Whether you, or someone you know, would be interested in this opportunity, please let us know.

For those who are not comfortable participating at the Board level at this time, but who are still interested in becoming involved, please consider participating on one of the HAPS committees (see http://www.hapsweb.org/?page=SteeringCommittee for a list of committee and http://www.hapsweb.org/?page=abouthapscommittee&term s=%22committees%22 for additional information). We value the time and talent of all those who strive to improve the organization!
Distribution of and Factors Associated with Anatomy and Physiology I Grades at a Community College

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2Professor and Coordinator of The Learning Center, 229 HULT, Jamestown Community College, Jamestown, NY
3Associate Professor, Science, Technology, Engineering, and Math Division, Jamestown Community College, Jamestown, NY 112 SCCE

Abstract
Anatomy and physiology I (A & P I) grade distributions were quantified for a large, multi-year dataset from a community college. Students were predominantly white, young women who received Pell Grants and almost half of whom were first generation college students. 58.6% of students received a C or higher grade while 41.4% of students received a D+ or lower grade including student and administrative withdrawals. Binomial logistic regression was used to identify factors associated with C or higher grades. Statistically significantly associated factors included higher age; not taking a developmental reading, writing, or math class; taking any college credits prior to A & P I; not repeating any college course with or before A & P I; not being a first generation student; taking a freshman biology, chemistry, or physics class before A & P I; and taking a daytime class.

Key Words: Anatomy and Physiology I, grades, course attrition, at-risk students, community college

Introduction
Human Anatomy and Physiology (HAP) is a two semester or three quarter sequence of undergraduate courses which combine the study of human anatomy and physiology. The courses introduce basic concepts of biology followed by in depth exploration of the structure and function of all organ systems. The HAP courses, along with anatomy or physiology courses offered separately, are taught to about 450,000 students annually in the United States and Canada. The number of students who take these courses is large because their successful completion is a prerequisite or a core requirement for many two- and four-year allied health degree programs including registered nursing, occupational therapy assistant, dental hygiene, physical therapy assistant, radiation technology, physical education, exercise physiology, and athletic training. The content of the HAP courses is foundational: students learn about the normal structure and function of the human body so they can apply that knowledge to medical problems within their field (Human Anatomy & Physiology Society 2013).

Human anatomy and physiology courses serve as gatekeepers for the health programs that require them (Human Anatomy & Physiology Society 2013). Success in the first course in the human anatomy and physiology (HAP) sequence, in particular, determines whether or not a student can progress to the following HAP and vocation specific courses (Anderson and Chivers 2016, Griffiths et al. 1995, Hull et al. 2016, Kenny 2010, Langtree 2014, McKee 2002, Whyte et al. 2011). Poor grade performance in the first HAP course can be high (Harris et al. 2004, Gultice et al. 2015, Hopp 2009; Hopper 2011) and may be leading to degree changes and college drop-out (Hamilton 2011, McKee 2002). This is of concern not only because it significantly reduces the allied health workforce but also because it may prevent those seeking to better their lives through education from achieving career goals with under-represented groups especially impacted (Abdullahi and Gannon 2012, Atamturktur et al. 2015, Beeber and Biermann 2007, Langtree 2014, Witt-Rose 2003).

Given the critical importance of the first HAP course, many investigators have quantified grade data and researched factors associated with passing or failing grades (Brown 2010, Harris et al. 2004, Hamilton 2011, Hopp 2009), and the Human Anatomy & Physiology Society is conducting a national effort to analyze the association between prerequisite courses and other factors and grades (Hull et al. 2016). The purpose of this paper is to contribute to that body of knowledge by reviewing the literature, describing in detail grade data from a large, multi-year dataset, and identifying factors associated with passing and failing grades in that dataset. It is hoped this will help more explicitly define the problem, serve as a model for this type of approach, and lead to the design of evidence-based investigations to improve learning.

Literature Review
Distribution of Grades in the First HAP Course
A backward citation search was performed with the Education Source (EBSCO), ProQuest® Education Journals, and Google Scholar databases using all fields, years 1995 – present, and the following syntax: ((anatomy and physiology) or anatomy or...
physiology) and (grades or (grade performance) or (academic performance) or (academic achievement)). The titles of articles identified by that search were then used in a forward citation search conducted with the ProQuest® Education Journals and Google Scholar databases. The literature cited sections of articles located using the searches also were reviewed. The literature review below is limited to articles which addressed the first HAP course.

Grade data were found in two types of investigations: ones designed to identify factors associated with passing or failing grades (Table 1) and ones which presented control data in a learning intervention study (Table 2). As can be seen in Tables 1 and 2, the way grade data were described and calculated diverged widely across the following characteristics. Grading scales varied, the level of grade information ranged from broad estimates to detailed grade-by-grade breakdowns, cutoffs for grades often were not reported, and withdrawal, incomplete, and/or repeat categories may or may not have been included. The student population differed among studies, and demographic information provided spanned from none to detailed. Sample sizes extended from a single class in one year up to several thousand students over many years. Content sequencing, science prerequisites, grade cutoffs, and lecture/lab grade weight frequently were not presented even though those features can be quite different among institutions.

The variability in how grades are described and calculated is expected because the data were derived from real students, actual courses, and varying contexts. That variability, though, limits comparisons and makes it challenging to accurately determine the prevalence of poor grades in the first HAP course. However, out of the studies presented in Tables 1 and 2, only one reported strong grade performance. In that study (Witt-Rose 2003), the class average was a B. Withdrawals and incompletes were not included in estimates so the success rate might have been lower if those categories had been incorporated. Four studies used the same grading scale (A, B, C, D, F, and withdraw) and presented the combined percentage of students receiving a D, F, or withdraw. That percentage ranged from 29% (Griff and Matter 2008) to 43.6% (Hopp 2009) to 48.9% (Rosenzweig 2012) to 62% (Hopper 2011). Most studies reported about one-third or more students received grades the authors defined as unsuccessful or failing, something which is often called course attrition. Using the one-third or more estimate and assuming it can apply to the 450,000 students who take some version of anatomy and physiology annually in the United States and Canada (Human Anatomy & Physiology Society 2013), then, course attrition is very roughly 150,000 or more students each year in those two countries alone.

### Table 1 – Grade data from studies that examined factors associated with grades in the first HAP course.

<table>
<thead>
<tr>
<th>Study</th>
<th>College and Course</th>
<th>Demographics</th>
<th>n</th>
<th>Grading Scale</th>
<th>Grade Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Witt-Rose 2003</td>
<td>Chipewa Valley Technical College</td>
<td>• Female = 83.3% • Ages 18 to 24 = 55.6% and greater than age 24 = 44.4% • Non-Hispanic White = 96.3% with Asian, Hispanic, other, and not specified = 3.7%</td>
<td>158</td>
<td>• A, B, C, D, F including all + and - grades • Converted to numbers with A+ and A = 4, B+ = 3.3, B = 3, and B- = 2.7, etc. • Cutoffs not reported • Withdraws and incompletes not reported • Repeats = 17.1% of students</td>
<td>• 3.07 ± 0.87 (± SD)</td>
</tr>
<tr>
<td>Harris et al. 2004</td>
<td>Lewiston-Auburn College</td>
<td>• Female = 82% • Average age of 28 years with 31 years or older = 31%</td>
<td>91</td>
<td>• A, B, C, D, F • Minimum grade of 75% for a C • Rest of cutoffs not reported • Withdraws, incompletes, and repeats not reported</td>
<td>• A = 16% • B = 18% • C = 31% • D and F = 35%</td>
</tr>
<tr>
<td>Griff and Matter 2008</td>
<td>University of Cincinnati</td>
<td>• Not reported</td>
<td>222</td>
<td>• A, B, C, D, F, Withdraw • Curved with above mean given A or B • Cutoffs not reported • Incompletes and repeats not reported</td>
<td>• A = 27% • B = 24% • C = 21% • D = 8% • F = 8% • Withdraws = 13%</td>
</tr>
</tbody>
</table>

Continued on next page
Table 1 (Continued) – Grade data from studies that examined factors associated with grades in the first HAP course.

<table>
<thead>
<tr>
<th>Study</th>
<th>College and Course</th>
<th>Demographics</th>
<th>n(^1)</th>
<th>Grading Scale</th>
<th>Grade Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopp 2009</td>
<td>• Houston Baptist University</td>
<td>• Not reported</td>
<td>546</td>
<td>• A, B, C, D, F, Withdraw</td>
<td>• A, B, or C = 56.4%</td>
</tr>
<tr>
<td></td>
<td>• 2-semester sequence</td>
<td>• No science prerequisite</td>
<td></td>
<td>• Cutoffs not reported</td>
<td>• D, F, or Withdraw = 43.6%</td>
</tr>
<tr>
<td></td>
<td>• Content covered not reported</td>
<td>• Content covered not reported</td>
<td></td>
<td>• Repeats not included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No science prerequisite</td>
<td>• Science prerequisites not reported</td>
<td></td>
<td>• Incompletes not reported</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Content covered was integumentary, skeletal, muscular, and nervous systems</td>
<td></td>
<td>• Repeats not included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Special senses</td>
<td></td>
<td>• Incompletes not reported</td>
<td></td>
</tr>
<tr>
<td>Rosenzweig 2012</td>
<td>• Unknown southern community college</td>
<td>• Female = 82.9%</td>
<td>2236</td>
<td>• A, B, C, D, F, Withdraw</td>
<td>• A, B, or C = 51.1%</td>
</tr>
<tr>
<td></td>
<td>• 2-semester sequence</td>
<td>• Ethnicity = 44.2%</td>
<td></td>
<td>• Cutoffs not reported</td>
<td>• D or F = 26.1%</td>
</tr>
<tr>
<td></td>
<td>• Content covered</td>
<td>• White, 34.5%</td>
<td></td>
<td>• Rest of scale not reported</td>
<td>• Withdraw = 22.8%</td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Black, 7.2%</td>
<td></td>
<td>• Incompletes not included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• 5.3% Asian, 0.5% other, 8.2%</td>
<td></td>
<td>• Repeats not reported</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Average age = 26.5 years from 18 to 62 years</td>
<td></td>
<td>• Incompletes not included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Repeats not included</td>
<td></td>
<td>• Repeats not reported</td>
<td></td>
</tr>
<tr>
<td>Caplan 2015</td>
<td>• Kentucky Community and Technical College System</td>
<td>• Female = 90%</td>
<td>61</td>
<td>Failed plus withdraw</td>
<td>Failed plus withdraw = 33%</td>
</tr>
<tr>
<td></td>
<td>• 2-semester sequence</td>
<td>• Ethnicity not reported</td>
<td></td>
<td>Rest of scale not reported</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Content covered</td>
<td>• Female = 90%</td>
<td></td>
<td>• Cutoffs not reported</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No science prerequisites</td>
<td>• Ethnicity not reported</td>
<td></td>
<td>• Rest of scale not reported</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Science prerequisites not reported</td>
<td></td>
<td>• Incompletes not reported</td>
<td></td>
</tr>
<tr>
<td>Langtree 2014</td>
<td>• KwaZulu-Natal College of Nursing, South Africa</td>
<td>• Female = 70.2%</td>
<td>248</td>
<td>% correct on qualifying (final) examination for progression in a nursing program</td>
<td>≥90% = 0.4%</td>
</tr>
<tr>
<td></td>
<td>• 2-semester sequence</td>
<td>• 26 years or older = 30.4%</td>
<td></td>
<td>• 80 – 89% = 6.5%</td>
<td>80 – 89% = 6.5%</td>
</tr>
<tr>
<td></td>
<td>• Content covered</td>
<td>• Black = 86.7%, Indian = 8.9%, Colored’s = 4%, White = 0.4%</td>
<td></td>
<td>• 70 – 79% = 27.8%</td>
<td>70 – 79% = 27.8%</td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• English as a second language = 86.6%</td>
<td></td>
<td>• 60 – 69% = 31%</td>
<td>60 – 69% = 31%</td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Ethnicity = 44.2%</td>
<td></td>
<td>• 50 – 59% = 23.0%</td>
<td>50 – 59% = 23.0%</td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Ethnicity = 44.2%</td>
<td></td>
<td>• &lt;50% = 6.5%</td>
<td>&lt;50% = 6.5%</td>
</tr>
<tr>
<td></td>
<td>• Science prerequisites not reported</td>
<td>• Ethnicity = 44.2%</td>
<td></td>
<td>• No grade = 4.8%</td>
<td>No grade = 4.8%</td>
</tr>
<tr>
<td>Gultice et al. 2015</td>
<td>• University of Cincinnati Blue Ash College</td>
<td>• Not reported</td>
<td>2728(^2)</td>
<td>• C and above = passing, C, D, F, and withdraws = failing</td>
<td>Passing = 67.3%</td>
</tr>
<tr>
<td></td>
<td>• 2-semester sequence</td>
<td>• Ethnicity not reported</td>
<td></td>
<td>• Rest of scale not reported</td>
<td>Failing = 32.7%</td>
</tr>
</tbody>
</table>

\(^1\)Sample size. Since most studies had sample fall-out during the study, only final sample sizes are reported.

\(^2\)Content covered was integumentary, skeletal, muscular, and nervous systems and special senses.

\(^3\)Content covered was basic chemistry, cell structure, cell physiology, metabolism, tissues, and integumentary, skeletal, muscular, and nervous systems.

\(^4\)Content covered was cytology, histology, and the musculoskeletal, cardiovascular, respiratory, and digestive systems.

\(^5\)Reported a combined n for students in the HAP and another biology course but grades are only for the HAP course.
Table 2 – Grade data for the control group in studies that examined learning interventions in the first HAP course.

<table>
<thead>
<tr>
<th>Study</th>
<th>College and Course</th>
<th>Demographics</th>
<th>n1</th>
<th>Grading Scale</th>
<th>Grade Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beeber and Biemann 2007</td>
<td>• Kingsborough Community College</td>
<td>• Not reported but the college has a large number of at-risk students</td>
<td>• Not given</td>
<td>• Pass, Fail, Withdraw, Incomplete&lt;br&gt;• Rest of scale not reported&lt;br&gt;• Cutoffs not reported&lt;br&gt;• Repeats not reported</td>
<td>• Pass = 65.4%&lt;br&gt;• Fail = 6.1%&lt;br&gt;• Withdraw or Incomplete = 28.5%</td>
</tr>
<tr>
<td>Hopper 2011</td>
<td>• University of Southern Indiana</td>
<td>• Not reported</td>
<td>• 101</td>
<td>• A, B, C, D, F, Withdraw&lt;br&gt;• Cutoffs not reported&lt;br&gt;• Incompletes not reported&lt;br&gt;• Repeats not included</td>
<td>• C or better = 38%&lt;br&gt;• D and F = 26%&lt;br&gt;• Withdraw = 36%</td>
</tr>
<tr>
<td>Abdullahi and Gannon 2012</td>
<td>• Bronx Community College</td>
<td>• Not reported but the college has a large number of at-risk students</td>
<td>• 1429</td>
<td>• C+ or better&lt;br&gt;• Rest of scale not reported&lt;br&gt;• Cutoffs not reported&lt;br&gt;• Withdraws, incompletes, and repeats not reported</td>
<td>• C+ or better = 36%</td>
</tr>
<tr>
<td>Gannon and Abdullahi 2013</td>
<td>• Bronx Community College</td>
<td>• Not reported but the college has a large number of at-risk students</td>
<td>• 91</td>
<td>• A to F with all + and – grades, Withdraws plus debarments&lt;br&gt;• Cutoffs not reported&lt;br&gt;• Incompletes and repeats not reported</td>
<td>• A+ to C+ = 28.6%&lt;br&gt;• C to D = 25.3%&lt;br&gt;• F = 7.7%&lt;br&gt;• Withdraws plus debarments = 38.5%</td>
</tr>
<tr>
<td>Atamturktur et al. 2015</td>
<td>• Bronx Community College</td>
<td>• Not reported but the college has a large number of at-risk students</td>
<td>• 1042</td>
<td>• C and above, D to C&lt;br&gt;• Rest of scale not reported&lt;br&gt;• Cutoffs not reported&lt;br&gt;• Withdraws not included&lt;br&gt;• Incompletes not included&lt;br&gt;• Repeats not reported</td>
<td>• C and above = 59.0%&lt;br&gt;• D to C = 30.4%</td>
</tr>
<tr>
<td>Decicco et al. 2015</td>
<td>• Southern Vermont College</td>
<td>• Not reported</td>
<td>• 75</td>
<td>• &lt; 77%, Withdraws&lt;br&gt;• Rest of scale not reported&lt;br&gt;• Other cutoffs not reported&lt;br&gt;• Incompletes not reported&lt;br&gt;• Repeats not reported</td>
<td>• &lt; 77% = 41%&lt;br&gt;• Withdraws = 24%</td>
</tr>
</tbody>
</table>

1Sample size. Since most studies had sample fall-out during the study, only final sample sizes are reported.
2Calculated by averaging the four semesters of data provided in their Table 1.
Factors Associated with Grades in the First HAP Course

Studies that examined associations between a variety of factors and grades in the first HAP course are presented in Table 3. Except for one additional article (Good et al. 2013), those studies are the ones presented in Table 1. Thus, the same sources of variability are present, and as before, that variability limits comparisons. In addition, as many of the articles stated, the studies used convenience sampling and/or were quasi-experimental; none of the studies employed a double-blinded randomized control design. Because of the limited control, statistically significant associations with grades are correlative in nature, and it cannot be assumed any of the associations are causative. Given those cautions, some trends are apparent. In the two studies which examined it, gender was not related to grades (Harris et al. 2004, Witt-Rose 2003). The impact of age varied with two studies finding no impact of age on grades (Harris et al. 2004, Witt-Rose 2003) whereas two other studies found higher age was associated with increased grades (Caplan 2015, Gultice et al., 2015). A higher high school GPA (Gultice et al., 2015), a higher prior college GPA (Rosenzweig 2012), prior total college coursework (Gultice et al., 2015), and factors which measured prior science and math training all were linked to increased grades (Harris et al., 2004, Hopp 2009, Langtree 2014). Factors which measured aspects of personal responsibility towards learning additionally were connected to increased grades (Griff and Matter 2008, Witt-Rose 2003). Factors which measured aspects of demands external to the classroom (Harris et al. 2004, Gultice et al. 2015, Langtree 2014) as well as the course delivery method (Caplan 2015, Rosenzweig 2012) showed variable results.

Table 3 – Factors associated with grades in the first HAP course.

<table>
<thead>
<tr>
<th>Factors Not Associated with Grades</th>
<th>Factors Associated with Increased Grades&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Age (Harris et al. 2004, Witt-Rose 2003)</td>
<td>• English as a first language (Langtree 2014)</td>
</tr>
<tr>
<td>• Gender (Harris et al. 2004, Witt-Rose 2003)</td>
<td>• Higher age (Caplan 2015, Gultice et al. 2015)</td>
</tr>
<tr>
<td>• First generation student (Langtree 2014)</td>
<td>• Higher high school GPA (Gultice et al. 2015)</td>
</tr>
<tr>
<td>• Science attitude score (Harris et al. 2004)</td>
<td>• Higher cumulative college GPA prior to course (Rosenzweig 2012)</td>
</tr>
<tr>
<td>• Points in English, Mathematics, Mathematical Literacy, and Physical Science on nursing entrance exam (Langtree 2014)</td>
<td>• Higher number of quarter hours earned prior to course (Gultice et al. 2015)</td>
</tr>
<tr>
<td>• Orientation to and lack of knowledge of the course (Langtree 2014)</td>
<td>• Higher # of high school math and science courses (Harris et al. 2004)</td>
</tr>
<tr>
<td>• Course delivery method (face-to-face vs. online) for chemistry, tissues, joints, senses, disease/dysfunctions, and the integumentary and skeletal systems (Caplan 2015)</td>
<td>• Higher # of undergraduate math and science credits prior to course (Harris et al. 2004)</td>
</tr>
<tr>
<td>• Lab delivery method (face-to-face, kit, virtual) (Caplan 2015)</td>
<td>• Prior college science coursework (Hopp 2009)</td>
</tr>
<tr>
<td>• Type of degree desired (Harris et al. 2004)</td>
<td>• Prior college chemistry coursework (Hopp 2009)</td>
</tr>
<tr>
<td>• Read-write and kinesthetic VARK preferences (Good et al. 2013)</td>
<td>• Enrolled in a science major (Hopp 2009)</td>
</tr>
<tr>
<td>• # of children at home (Harris et al. 2004)</td>
<td>• Higher total points on nursing entrance exam (Langtree 2014)</td>
</tr>
<tr>
<td>• Stressors such as family pressure, sense of belonging, insufficient time and money (Langtree 2014)</td>
<td>• Higher points in biology on nursing entrance exam (Langtree 2014)</td>
</tr>
</tbody>
</table>

<sup>1</sup>To provide a consistent reporting format, the scales of the factors are described for a positive impact, i.e., for an increase in grades. The opposite portion of the scale decreased grades.
Methods

The dataset used in this study was derived from students who took the first HAP course, BIO 2510, Anatomy & Physiology (A & P) I, at Jamestown Community College (JCC, http://www.sunyjcc.edu), a two year college which is part of the State University of New York (SUNY, https://www.suny.edu/). JCC is a regional, open-access institution providing liberal arts transfer degree programs, career programs, community service, developmental education, and business and industry training. Two campuses (Jamestown and Olean, NY) and one center (North County in Dunkirk, NY) serve about 3500 students annually in southwestern New York and parts of northwestern Pennsylvania. The dataset was provided by JCC’s Department of Institutional Research and Planning, which uses Banner Student software (http://www.ellucian.com/Software/Banner-Student/) to track student information. The dataset included students who were matriculated and were taking A & P I for the first time from the fall 2003 to spring 2015 semesters. Grades from students who were repeating the course were not included in the dataset. The fall 2003 semester was chosen as the starting point as that was the first semester JCC used Banner Student software. Because of small sample sizes (see Results), the dataset did not include students who were non-matriculated, took the course during a summer semester, took the course while in high school, or transferred in their A & P I grade. Students who received grades of A, B+, B, C+, C, D+, D, F, and withdrawal (student on or after census, student before census, or administrative) were included in the dataset, and because of small sample sizes, students who received incomplete, pass/fail, or audit grades were not included. Characteristics of A & P I at JCC are presented in Table 4. All statistical analyses were conducted using SPSS® software according to methods described by Lund and Lund (2016). Specific statistical methods are described in Results.

Table 4. Characteristics of the first HAP course at Jamestown Community College.

<table>
<thead>
<tr>
<th>Course Number and Title</th>
<th>BIO 2510, Anatomy &amp; Physiology I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course Description</strong></td>
<td>This first of two sequential human anatomy and physiology courses is designed for students who have had little or no previous study of the body or the physical and chemical principles on which body structure and function is based. In this course, students will learn basic chemistry and physics, cytology, and histology. Students will study the following organ systems: integumentary, skeletal, muscular, cardiovascular, lymphatic, and respiratory. In the accompanying laboratory, students will learn basic terminology, microscopy, animal dissection, organ dissection, and experimental process and protocols.</td>
</tr>
<tr>
<td><strong>Requisites</strong></td>
<td>Prerequisite: High school chemistry, CHE 1500 (Introduction to Chemistry), or CHE 1530 (Allied Health Chemistry); Corequisite: ENG 1510 (English Composition I); must meet minimum college level reading score: Accuplacer 80+. It is strongly recommended that students have an appropriate biology course.</td>
</tr>
<tr>
<td><strong>Credits and Seat Time</strong></td>
<td>4 credits; Fall and Spring semesters: 15 weeks, 150 minutes/week each lecture and lab; Summer semester: 6 weeks, 375 minutes/week each lecture and lab</td>
</tr>
<tr>
<td><strong>Lecture Content Sequence</strong></td>
<td>Major Themes, Chemistry, Cells, Genetics, Histology, Organs and Organ Systems, Integumentary System, Skeletal System, Muscular System, Cardiovascular System, Lymphatic and Immune Systems, Respiratory System</td>
</tr>
<tr>
<td><strong>Lab Content Sequence</strong></td>
<td>Language of Anatomy, Organs and Organ Systems, Compound Light Microscope, Histology, Skeletal System, Muscular System, Cardiovascular System, Respiratory System</td>
</tr>
<tr>
<td><strong>Semesters and Sites Offered</strong></td>
<td>Fall, Spring, and Summer semesters at Jamestown campus, Fall and Spring semesters at Olean Campus, Fall semester at North County Center</td>
</tr>
<tr>
<td><strong>Instructional Delivery</strong></td>
<td>Face-to-face lecture and lab</td>
</tr>
<tr>
<td><strong>Textbook and Lab Book</strong></td>
<td>Varied among sites and across sampling years</td>
</tr>
<tr>
<td><strong>Lecture/Lab Grade Weight</strong></td>
<td>60% lecture/40% lab</td>
</tr>
<tr>
<td><strong>Grading Scale</strong></td>
<td>A, B+, B, C+, C, D+, D, F, Withdrawal (student or administrative), Incomplete, Pass/Fail, Audit</td>
</tr>
<tr>
<td><strong>Grading Cutoffs</strong></td>
<td>Varied among instructors; Most commonly used cutoffs were 90% = A, 85% or 87% = B+, etc.</td>
</tr>
<tr>
<td><strong>Core Requirement at JCC</strong></td>
<td>A.A.S. Nursing, A.A.S Occupational Therapy Assistant, State University of New York Transfer Pathways in Physical Education and Nutrition</td>
</tr>
</tbody>
</table>
Results

Distribution of A and P I Grades

The distribution of A & P I grades among years was not statistically significantly different (Independent Samples Kruskal-Wallis test, p = .16). Thus, grades from all years were combined into one dataset, and all further analyses were performed with that dataset (Table 5). Grades were not distributed normally (Kolmogorov-Smirnov test with the Lilliefors Significance Correction, p < 0.001) with the data tailing towards the lower grade and withdrawal categories. The highest percentage of grades fell into the B and C groupings. To meet the requirements of the binomial logistic regression analyses (see below) and to calculate annual course attrition, grades were combined into two groups: C and above and D+ and below including student and administrative withdrawals. The C and above cutoff was chosen because that grade is required in A & P I for admittance into JCC’s two health-related programs: registered nursing and occupational therapy assistant. Withdrawal categories were included in the D+ and below group because preliminary data showed college attrition in the withdrawal categories was similar to that of the lower grade categories. The D+ and below category represents course attrition. 58.4% of students received a C or higher and 41.6% of students received a D+ or lower grade in A & P I. On an annual basis, 165 students achieved a C or higher grade while yearly course attrition was 118 students.

Table 5. Distribution of A & P I grades.

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Individual Grade Categories</th>
<th>Combined Grades</th>
<th>Combined Grades</th>
<th>Number of students per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13.5 (497)</td>
<td>13.5 (497)</td>
<td>58.4 (2151)</td>
<td>165</td>
</tr>
<tr>
<td>B+</td>
<td>7.1 (261)</td>
<td>23.3 (859)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>16.2 (598)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C+</td>
<td>7.9 (290)</td>
<td>21.6 (795)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>13.7 (505)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D+</td>
<td>4.4 (164)</td>
<td>12.3 (457)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>7.9 (293)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>15.3 (566)</td>
<td>15.3 (566)</td>
<td>41.6 (1542)</td>
<td>118</td>
</tr>
<tr>
<td>W¹</td>
<td>10.5 (389)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WB¹</td>
<td>2.2 (81)</td>
<td>14.0 (519)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X¹</td>
<td>1.3 (49)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100% (3693)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

¹W = Student withdrawal on or after census. Census occurs at the time point when 20% of the course has been completed. WB = Student withdrawal before census. X = Administrative withdrawal.

²Percent of total (sample size).

³B and B+ categories combined, etc.

⁴C and above combined, and D+ and lower including withdrawal categories combined.

⁵Calculated from the sample size of the column to the left divided by 13, the number of years of the study. The rate for the D+ and lower including withdrawal categories is the annual A & P I course attrition rate at JCC.

Factors Associated with A & P I Grades

Because A & P I grades are nominal, binomial logistic regression analyses were used to identify associated factors. Binomial logistic regression models require the following structure:

- The dependent variable must be dichotomous. As explained above, the individual grade categories were combined into two groups: C and above and D+ and below including the withdrawal categories.
- Independent variables must be measured on a continuous or nominal scale. Twenty independent variables were analyzed for inclusion in the model, nineteen of which were nominal and one of which was continuous. Independent variables were selected based on these factors:
  - a) JCC tracks using Banner Student software
  - b) the literature review was associated with grades in the first HAP course

- The authors wanted to examine for associations.
- Because this was an initial exploration, factors were defined broadly. For example, taking any freshman biology class was selected rather than looking at specific freshman biology courses. In selecting independent variables, the goal was not to find a perfect fit model. Instead, the goal was to use the most rigorous statistical method possible to explore factors that might explain grade performance, and thus, could lead to next steps to improve learning. Independent variables used in the analyses are presented in Table 6.
- Observations must be independent of each other, and observations in the two categories for nominal variables must be mutually exclusive. Since the cases of this dataset are individual students, all observations are independent of each other. Because each student’s observations could fall into only one of each of the two possible nominal categories, the observations are mutually exclusive.

continued on next page
Sample size must be large enough with fifteen total cases required and fifty total cases generally recommended for each independent variable. The total sample size for the dataset was 3693, and high school GPA was the only independent variable that had missing data. High school GPA had 16.1% missing data. Because of that and for reasons outlined below related to outliers, high school GPA was not included in the model. As noted in Methods, several other variables were not included because of sample sizes that were too small. Sample sizes are presented in Table 6.

Table 6. Characteristics of independent variables used in the binomial logistic regression model.

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Categories of Independent Variables</th>
<th>Percent of Total (n)</th>
<th>Model Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Continuous2 – No categories</td>
<td>See Figure 1</td>
<td>---</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>20.2 (746)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>79.8 (2947)</td>
<td>1</td>
</tr>
<tr>
<td>Received a Federal Pell Grant at any time?</td>
<td>Yes</td>
<td>62.6 (2312)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>37.4 (1381)</td>
<td>1</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>All other ethnicities</td>
<td>7.6 (280)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>White/unknown</td>
<td>92.4 (3413)</td>
<td>1</td>
</tr>
<tr>
<td>First generation college student?</td>
<td>Yes</td>
<td>44.4 (1639)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>55.6 (2054)</td>
<td>1</td>
</tr>
<tr>
<td>Any college credits earned before A &amp; P I?</td>
<td>Yes</td>
<td>79.5 (2936)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>20.5 (757)</td>
<td>1</td>
</tr>
<tr>
<td>Repeat any course before or with A &amp; P I?</td>
<td>Yes</td>
<td>21.1 (780)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>78.9 (2913)</td>
<td>1</td>
</tr>
<tr>
<td>Took a developmental reading course before A &amp; P I?</td>
<td>Yes</td>
<td>11.6 (427)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>88.4 (3266)</td>
<td>1</td>
</tr>
<tr>
<td>Took a developmental math course before, with, or after A &amp; P I?</td>
<td>Yes</td>
<td>35.0 (1292)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>65.0 (2401)</td>
<td>1</td>
</tr>
<tr>
<td>Took a developmental writing course before A &amp; P I?</td>
<td>Yes</td>
<td>9.6 (356)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>90.4 (3337)</td>
<td>1</td>
</tr>
<tr>
<td>Took a freshman biology course before A &amp; P I?</td>
<td>No</td>
<td>52.9 (1954)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>47.1 (1739)</td>
<td>1</td>
</tr>
<tr>
<td>Took a freshman chemistry course before A &amp; P I?</td>
<td>No</td>
<td>62.7 (2314)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>37.3 (1379)</td>
<td>1</td>
</tr>
<tr>
<td>Took a freshman physics course before A &amp; P I?</td>
<td>No</td>
<td>97.6 (3603)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>2.4 (90)</td>
<td>1</td>
</tr>
<tr>
<td>Took a freshman geology course before A &amp; P I?</td>
<td>No</td>
<td>96.5 (3562)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>3.5 (131)</td>
<td>1</td>
</tr>
<tr>
<td>Took a freshman astronomy course before A &amp; P I?</td>
<td>No</td>
<td>99.3 (3666)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>0.7 (27)</td>
<td>1</td>
</tr>
<tr>
<td>Student enrollment status</td>
<td>Full-time1</td>
<td>73.8 (2727)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Part-time</td>
<td>26.2 (966)</td>
<td>1</td>
</tr>
<tr>
<td>Class length</td>
<td>75 minute class4</td>
<td>56.5 (2086)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>50 minute or 165 minute class</td>
<td>43.5 (1607)</td>
<td>1</td>
</tr>
<tr>
<td>Time of day course offered</td>
<td>Start time is before 4:05pm5</td>
<td>73.8 (2725)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Start time is 4:05pm or later</td>
<td>26.2 (968)</td>
<td>1</td>
</tr>
<tr>
<td>Faculty employment status</td>
<td>Full-time</td>
<td>71.4 (2636)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Part-time (Adjunct)</td>
<td>28.6 (1057)</td>
<td>1</td>
</tr>
<tr>
<td>Campus</td>
<td>Jamestown4</td>
<td>63.4 (2340)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>North County and Olean Combined</td>
<td>36.6 (1353)</td>
<td>1</td>
</tr>
</tbody>
</table>

1Selected took developmental reading and writing before A & P I because college-level reading and writing are a prerequisite and corequisite, respectively. Selected took developmental math before, with, or after A & P I because math is not a requisite.
2Age data were highly skewed to the right (see Figure 1), and thus, did not meet the linear relationship assumption (see Results). To address that, the inverse (reciprocal) of age was used, and that transformation of the age data met the assumption.
3Full-time students were enrolled in at least 12 credits of courses. Part-time students were enrolled in <12 credits. Credits may have been developmental and/or college credits.
4Categories were combined as indicated to reduce multicollinearity (see Results).
54:05pm is the time when the earliest evening classes began. Before 4:05pm is daytime, and after 4:05pm is evening.
6Sample size.
Data used in binomial logistic regression analyses must meet the following assumptions:

- Continuous independent variables should be linearly related to the logit transformation of the dependent variable. One independent variable was continuous, age, and the Box-Tidwell procedure was used to determine if age met the linear relationship requirement. For the Box-Tidwell procedure, statistical significance shows an independent variable does not meet the linear relationship assumption and is based on an adjusted α value, which equals the original α value divided by the number of independent variables. For this dataset, the adjusted α was 0.0025. Age data were highly skewed to the right (Figure 1), and thus, initially did not meet the linear relationship requirement (p < 0.001). To address that, the multiplicative inverse (reciprocal) of age was used, and that transformation of the age data met the assumption (p = 0.031).

- Independent variables should not be linear combinations of each other, i.e., they should not show multicollinearity. Multicollinearity was examined by calculating tolerance and the variance inflation factor (VIF). Tolerance should be greater than 0.1, and VIF should be less than 2.5. Initially, five of the independent variables showed tolerances only slightly greater than 0.1 and a VIF greater than 2.5. This was likely caused by the inclusion of dummy variables to represent more than two categories (Allison 2012). Those variables were re-categorized to contain only two categories, and then, all tolerances were greater than 0.5 and all VIFs were less than 1.4.

- The data should not contain a large number of outliers, i.e., high leverage points. Outliers were identified by calculating Z residuals. Z residuals should be no larger than ±4. Initially, thirty-eight outliers were identified with the largest Z value equal to -53.1. The model was re-run without high school GPA resulting in twenty-two outliers with the largest Z value now -3.7. Because of that, and because of the missing data, high school GPA was not used in the final model. The model was run with and without the remaining outliers. Keeping those outliers did not change which variables were considered statistically significant and only very slightly changed estimates of coefficients and the odds ratio. Therefore, the remaining twenty-two outliers were left in the dataset.

Independent variables were selected for inclusion in the binomial logistic regression model using stepwise forward selection. α levels of 0.05 and 0.10 were chosen for entry and removal of independent variables, respectively, as those values were recommended by Lund and Lund (2016) and so the model would err in the direction of including too many variables rather than excluding potentially important variables. The number of steps used to fit the model was determined using Hosmer and Lemeshow’s goodness of fit test (where an α value below 0.05 is not a good fit) as well as by maximizing the pseudo-R2 value as measured by both the Cox & Snell and Nagelkerke estimations. After 11 steps, the final model was obtained (p = 0.57). For the final model, the Cox & Snell and Nagelkerke R2 estimates were 0.13 and 0.17, respectively. Eleven of the twenty independent variables examined were included in the final binomial logistic regression model and are presented in Table 7. The final model correctly classified A & P I grades 66.8% of the time although correct classification was higher for students receiving a C or higher grade (82.7%) than for students receiving a D+ or lower grade (44.6%).
In addition to identifying associated factors, an additional goal of regression analyses is to quantify the strength of the association of an independent variable with the dependent variable. In binomial logistic regression, SPSS® output provides two measures of association: $\beta$ coefficients and odds ratios. For continuous variables, $\beta$ coefficients measure association well. Age was the only continuous variable in this study, and its $\beta$ value was -37.3 ($p < 0.001$). Because the result was negative and because the multiplicative inverse (reciprocal) of age was used, this means as the reciprocal of age increases, while holding all other independent variables equal, students are less likely to receive a C or higher grade. This can be stated more clearly as older students are more likely to receive a C or higher grade, and is depicted in Figure 2. Calculated from the data in Figure 2, for every five-year increase in age, there is an average 6% increase in the percentage of students receiving a C or higher grade starting at 51% for students 19 years old and under and culminating at 78-79% success for students 40-49 years old. Then, the data fall-off to 65% success for students 50 years and older. For nominal independent variables, due to the logit transformation of the data, the meaning of $\beta$ coefficients is quite difficult to grasp, and so most authors use odds ratios instead. Odds ratios are calculated from the $\beta$ coefficients and are really what the $\beta$ coefficients represent (Lund and Lund 2016). However, odds ratios also are difficult to conceptualize and provide an over-inflated estimate of the degree of an association. Osborne (2006) suggests using relative risk instead which can be directly calculated from the odds ratio and which has a more obvious meaning. Therefore, relative risks for nominal variables were calculated.

### Table 7. Statistical significance of independent variables examined for inclusion in the binomial logistic regression model.

<table>
<thead>
<tr>
<th>Significant variables in order entered into the model¹:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Took a developmental reading course before A &amp; P I?</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Took a developmental math class before, with, or after A &amp; P I?</td>
</tr>
<tr>
<td>Repeat any course before or with A &amp; P I?</td>
</tr>
<tr>
<td>Took a freshman biology course before A &amp; P I?</td>
</tr>
<tr>
<td>Took a freshman chemistry course before A &amp; P I?</td>
</tr>
<tr>
<td>Was a first generation college student?</td>
</tr>
<tr>
<td>Took a developmental writing course before A &amp; P I?</td>
</tr>
<tr>
<td>Time of day took A &amp; P I</td>
</tr>
<tr>
<td>Any college credits earned before A &amp; P I?</td>
</tr>
<tr>
<td>Took a freshman physics course before A &amp; P I?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>With the model above, the following were not significant¹:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Received a Federal Pell grant?</td>
</tr>
<tr>
<td>Faculty employment status</td>
</tr>
<tr>
<td>Campus</td>
</tr>
<tr>
<td>Class length</td>
</tr>
<tr>
<td>Student enrollment status</td>
</tr>
<tr>
<td>Ethnicity</td>
</tr>
<tr>
<td>Took a freshman astronomy course before A &amp; P I?</td>
</tr>
<tr>
<td>Took a freshman geology course before A &amp; P I?</td>
</tr>
</tbody>
</table>

¹See Results for a description of the binomial logistic regression analyses.
then, making sure to account for taking the inverse when stating associations.

β coefficients, odds ratios, relative risks, and the inverse of relative risks for the nominal independent variables are presented in Table 8. Relative risk statements are summarized below:

- Students who did not take a developmental reading course before A & P I were 2.3 times more likely to receive a C or higher grade than students who did take a developmental reading course before A & P I.
- Students who did not repeat any course before or with A & P I were 2.0 times more likely to receive a C or higher grade than students who did repeat any course before or with A & P I.
- Students who did not take a developmental math course before, with, or after A & P I were 1.6 times more likely to receive a C or higher grade than students who did take a developmental math course before, with, or after A & P I.
- Students who did not take a developmental writing course before A & P I were 1.5 times more likely to receive a C or higher grade than students who did take a developmental writing course before A & P I.
- Students who took a daytime class were 1.1 times more likely to receive a C or higher grade than students who did not take a daytime class.
- Students who were not a first generation college student were 1.2 times more likely to receive a C or higher grade than students who were a first generation college student.
- Students who did take a freshman biology course before A & P I were 1.2 times more likely to receive a C or higher grade than students who did not take a freshman biology course before A & P I.
- Students who did take a freshman chemistry course before A & P I were 1.1 times more likely to receive a C or higher grade than students who did not take a freshman chemistry course before A & P I.
- Students who took a daytime class were 1.1 times more likely to receive a C or higher grade than students who took an evening class.
- Students who did take a freshman physics course before A & P I were 1.0 times more likely to receive a C or higher grade than students who did not take a freshman physics course before A & P I.

Table 8. β coefficients, odds ratios, relative risks, and inverse relative risks for independent variables included in the binomial logistic regression model for A & P I grades.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>β Coefficient</th>
<th>p-value</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval for Odds Ratio</th>
<th>Relative Risk</th>
<th>Inverse of Relative Risk²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not take a developmental reading course before A &amp; P I</td>
<td>-0.916</td>
<td>&lt;0.001</td>
<td>0.400</td>
<td>0.313, 0.512</td>
<td>0.430</td>
<td>2.3</td>
</tr>
<tr>
<td>Did not repeat any course before or with A &amp; P I</td>
<td>-0.797</td>
<td>&lt;0.001</td>
<td>0.451</td>
<td>0.376, 0.540</td>
<td>0.510</td>
<td>2.0</td>
</tr>
<tr>
<td>Did not take a developmental math course before, with, or after A &amp; P I</td>
<td>-0.615</td>
<td>&lt;0.001</td>
<td>0.541</td>
<td>0.461, 0.635</td>
<td>0.644</td>
<td>1.6</td>
</tr>
<tr>
<td>Did not take a developmental writing course before A &amp; P I</td>
<td>-0.411</td>
<td>&lt;0.001</td>
<td>0.663</td>
<td>0.518, 0.849</td>
<td>0.685</td>
<td>1.5</td>
</tr>
<tr>
<td>Took any college credits before A &amp; P I</td>
<td>0.299</td>
<td>0.002</td>
<td>1.348</td>
<td>1.119, 1.624</td>
<td>1.3</td>
<td>---</td>
</tr>
<tr>
<td>Was not a first generation college student</td>
<td>-0.307</td>
<td>&lt;0.001</td>
<td>0.736</td>
<td>0.637, 0.850</td>
<td>0.834</td>
<td>1.2</td>
</tr>
<tr>
<td>Took a freshman biology course before A &amp; P I</td>
<td>0.347</td>
<td>&lt;0.001</td>
<td>1.414</td>
<td>1.220, 1.639</td>
<td>1.2</td>
<td>---</td>
</tr>
<tr>
<td>Took a freshman chemistry course before A &amp; P I</td>
<td>0.313</td>
<td>&lt;0.001</td>
<td>1.368</td>
<td>1.162, 1.610</td>
<td>1.1</td>
<td>---</td>
</tr>
<tr>
<td>Took a daytime class</td>
<td>-0.268</td>
<td>0.002</td>
<td>0.765</td>
<td>0.648, 0.904</td>
<td>0.925</td>
<td>1.1</td>
</tr>
<tr>
<td>Took a freshman physics course before to A &amp; P I</td>
<td>0.586</td>
<td>0.038</td>
<td>1.797</td>
<td>1.033, 3.125</td>
<td>1.0</td>
<td>---</td>
</tr>
</tbody>
</table>

¹To provide a consistent reporting format, the category of the independent variable which was associated with a C or higher grade is presented.

²The multiplicative inverse of some relative risks was calculated. See Results for an explanation of why.

continued on next page
Discussion

Distribution of A & P I Grades

The percentage of successful students indicates many students were well served by the course. The course attrition rate of this study, however, was large and was in the mid-range of that reported in studies which used a similar grading scale (Griff and Matter 2008, Hopp 2009, Hopper 2011, Rosenzweig 2012) confirming poor grades are a major issue in the first HAP course. As noted by many other authors, excessive course attrition prevents students from achieving career goals and markedly reduces the allied health workforce (Abdullahi and Gannon 2012, Atamturktur et al. 2015, Beeber and Biermann 2007, Harris et al. 2004, Langtree 2014, Witt-Rose 2003). It also may be causing students to leave college (Hamilton 2011). Preliminary data at JCC show college drop-out rates ranged from 37 – 68% for students who fell into the course attrition category.

Factors Associated with A & P I Grades

Older students did markedly better in A & P I than younger students. This finding is consistent with that of Caplan (2015) and Gultice et al. (2015) who reported a similar result. However, Harris et al. (2004) and Witt-Rose (2003) did not find age was related to grades in the first HAP course. The age ranges for all five studies appear to be reasonably similar and included traditional and non-traditional students so other factors might be causing the discrepancy. At JCC, higher age is clearly and strongly related to better grades so determining what age denotes matters for JCC students. Age might be related to specific educational maturation experiences that if identified could be introduced to students in a progressive fashion throughout their education prior to and in college.

Students who did not take a developmental reading, writing, or math class were more likely to receive a C or higher grade than students who did take a developmental course. This appears to be the first study which has explicitly examined the relationship between developmental reading and writing courses and grades in the first HAP course. Gultice et al. (2015) showed a lower score on a math placement test was associated with lower grades in the first HAP course. The lesser test scores represented students who placed into a developmental math course consistent with the results of this study. It has been well established developmental students struggle at community colleges receiving poor grades with high college drop-out (Bremer et al. 2013). The causes of poor grade performance are multi-faceted including lack of foundational knowledge, learning skills, financial support, and life management abilities (Brunsting 2009). Developmental students represented roughly one-third of the students in this study. Determining how to help them succeed could decidedly reduce A & P I course attrition. Several factors which measured the general ability to be successful in college were associated with the higher grade category: did not repeat any college class before or with A & P I, took any college credits before A & P I, was not a first generation college student, and took a daytime class. Several other investigations have examined common features of college success and their relationship to A & P I grades and have found similar results (Good et al. 2013, Griff and Matter 2008, Gultice et al. 2015, Rosenzweig 2012, Witt-Rose 2003). What specific attributes are represented by those variables is not certain and would benefit from deeper consideration so they could be used to help identify at-risk students.

Students who took a freshman biology or chemistry class before A & P I were slightly more likely to be successful in A & P I than those who did not. Other authors who examined prior science training in a variety of ways have found a similar result (Harris et al. 2004, Hopp 2009, Langtree 2014). Taking a freshman geology or astronomy course before A & P I did not impact grades. This suggests it is not science courses per se but science courses that address knowledge relevant to the study of the human body which impact learning in the first HAP course. Taking a freshman physics course provided a statistically significant odds ratio, but showed a relative risk of 1 indicating no effect. Relative risk is calculated from the sample size of non-exposed cases, i.e., from students who did not take physics. That number was quite large, and thus, reduced the relative risk for physics. Further work with a larger physics sample size will be required to determine its effect on A & P I grades.

Gender and ethnicity were not related to A & P I grades at JCC. The lack of a gender result confirms that of Harris et al. (2004) and Witt-Rose (2003). Ethnicity apparently has not been examined previously. However, student demographics often have not been reported (see Literature Review) so it is not possible to determine if ethnicities not represented in this student population might be linked to grade performance in the first HAP course.

Two other student characteristics were not associated with A & P I grades at JCC: Federal Pell grants and student enrollment status. The Pell grant result is surprising since a high proportion of students in this study received aid suggesting they live at or near poverty levels. Perhaps the Pell grant is not a sensitive indicator of living in poverty or the aid is providing the help needed to allow students to focus on college. The student enrollment status requires more work as three different findings have now been reported: no effect (this study), fewer credit hours increases grades (Harris et al. 2004), and more credit hours increase grades (Gultice et al. 2015).

Three aspects of course delivery did not affect A & P I grades: class length, campus, and faculty employment status. No other studies have examined class length or campus, and one other study did find a difference in grades among instructors (Rosenzweig 2012). At least at JCC, those variables are not impacting student grades and do not require intervention.
Study Limitations
This study used final letter grades in A & P I as a measure of academic achievement. Course letter grades may or may not accurately represent summative course learning (Allen 2005, Sadler 2009). In addition, determination of course letter grades was not standardized and likely varied among instructors, instructional approaches, assessment measures, and grade cutoffs. However, grade distributions were not statistically significantly different across the thirteen-year period of this study, which indicates some level of consistency in how letter grades were administered. Moreover, letter grades in A & P I are the:

1) national standard for representing academic achievement
2) basis for progression in most health-related career pathways including at JCC
3) method tracked in Banner Student software at JCC.

Thus, course letter grades were the most reasonable choice available for examining course attrition and factors associated with learning in A & P I. Although letter grades are the national standard, grade comparisons across studies should be made conservatively due to potential differences in grading schema and content sequencing (see Literature Review).

This study was not a double-blind randomized control study. Grade data were not obtained from an experimentally controlled setting, and instead, were obtained from an authentic context for which, as noted below, it is likely many factors associated with low and withdrawal grades have not been identified. Because of the lack of experimental control, the β coefficients, odds ratios, and relative risk estimates provided by the binomial logistic regression model are correlative and are not causative. Further research is required to unpack the associations and identify causative explanations that can lead to evidence-based learning interventions. Grade data also were not obtained from a random sample of students and rather, were collected from a student population with specific demographic characteristics (Table 6). Caution therefore should be exercised in applying these findings to student populations with different demographic features. The lack of control also suggests grade distributions and associated factors should be monitored at regular future intervals as sources of variability might change.

This study used a binomial logistic regression model to identify factors associated with A & P I grades. The goal of binomial logistic regression is to determine if one or more factors increases the likelihood of an either/or outcome. The overall success of a binomial logistic regression model is determined by looking at how well the set of independent variables as a whole predicts each of the two possible outcomes in the dataset used to create the model. For the dataset used in this study, the final model predicted C and higher grades well but predicted D+ or lower grades poorly.

One possible explanation is the dichotomous scales used for the dependent variable and for nineteen of the twenty independent variables were too broad and may not have been sensitive enough to detect a relationship for the lower grade categories. It also may be the factors associated with the D, D+, and F letter grades are different from those associated with the withdrawal categories. Together, those possibilities suggest there may be several as yet unidentified variables that are not associated with higher grades but are associated with poor grades and/or withdrawal. Examination of that possibility is important so that intervention efforts do not neglect students who fall into those categories.

This study did not examine the impact of high school experiences, college math classes, or repeating the course on success in A & P I, all factors likely to impact grades (Gultice et al. 2015, Harris et al. 2004). High school GPA was not included in the binomial logistic regression model due to missing data and a negative influence on outliers. High school math, science, or other courses were not included in the model because that data is not tracked in JCC’s Student Banner software. College math courses were not included in this study as the goal of this study was to initially examine science courses. Repeating students were not included in the dataset as it was hypothesized factors that impacted success might be different for repeating students. Future studies will examine high school experiences, college math, and repeating the course.

Summary and Future Directions
This study quantified A & P I grade distributions for a large, multi-year dataset at JCC. Students were predominantly white, young women who received Federal Pell grants and almost half of whom were first generation college students. Grade results show many students do well enough in the course to progress to the next step in a health-related career at JCC but also support and confirm the high course attrition rate in the first HAP course. Binomial logistic regression was used to identify factors associated with C or higher grades. Statistically significantly associated factors included higher age; not taking a developmental reading, writing, or math class; taking college credits prior to A & P I; not repeating any college course with or prior to A & P I; not being a first generation student; taking a freshman biology, chemistry, or physics class; and taking a daytime class. Factors not associated with grades were gender, received a Federal Pell grant, faculty employment status, campus site, class length, student enrollment status, ethnicity, and took a freshman astronomy or geology course before A & P I. Because the study was not controlled, associations are correlations and further research is required to confirm the findings and unpack the associations to uncover causative relationships. Higher age and not needing to take developmental courses were the most strongly associated with better grades and thus, are the most important factors to examine in more detail next.

continued on next page
About the Authors

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Distribution of and Factors Associated with Anatomy and Physiology I Grades at a Community College


Predictors of Success of Nursing and Health Science Students in Anatomy and Physiology

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Abstract
The purpose of this investigation was to examine three potential predictors of performance in the anatomy and physiology (A&P) series (ANAT 101, 102 and 103). The study examined the year the A&P series was taken and the High School GPA and SAT scores of the students. Letter grades of students in the A&P series (ANAT 101-103) were converted to a 0-4.33 GPA format. Participants in the study were 311 students majoring in Health Science (HSCI) and 470 students majoring in Nursing (NURS). Correlation and multiple regression analyses were conducted to investigate the relationship between model predictors (the year the course series was taken, HS-GPA, SAT- Math & Verbal) and the A&P courses (ANAT 101, 102, and 103). HS-GPA and SAT-M&V were significant predictors of performance in the 3 A&P courses in both majors. In ANAT 101, year taken, HS-GPA and SAT-M&V all predicted higher grades among students majoring in Health Science. In ANAT 102, year taken was a significant predictor of higher grades for the NURS students. By ANAT 103, year taken was no longer a significant predictor, while A&P scores were significantly higher among students majoring in Health Science. Our findings suggest that, although ANAT 101 may be more difficult to complete during year one, NURS students (who take A&P in their freshman year) adapt to multiple challenges and perform in ANAT 102 and 103 as well as students majoring in Health Science, who complete these courses in their second year.

Key Words: predictors of academic success, prerequisites for anatomy and physiology, anatomy, physiology, GPA

Introduction
Anatomy and Physiology (A&P) is a foundational course series for any health-focused major. It has traditionally been a challenging course for many students and it is associated with variable attrition rates (Sturges et al. 2016). Since students come to A&P at different points in their academic career and with varying backgrounds, determining factors that contribute to, or predict success, in an A&P series is challenging. Many undergraduate health science courses require prerequisite coursework and A&P is often that prerequisite. However, there is no consistent prerequisite coursework required for A&P from one institution to another. Prerequisites for A&P have been a recent topic of interest in the A&P community, with the goal of determining if certain courses such as Biology or Chemistry help to prepare students to succeed in A&P (Hull et al. 2016). There are no consistent prerequisite courses required for taking A&P at Drexel University.

At Drexel University, A&P is taught to all Nursing and Health Science majors in a 3-part series. Anatomy and Physiology 101 (ANAT 101) covers cell biology, tissues, the muscular system and the skeletal system. ANAT 102 covers the nervous system, the digestive system and the endocrine system. ANAT 103 covers the immune system, the cardiovascular system, the respiratory system, and the urinary and reproductive systems. Health Science students start A&P in their sophomore year, while the Nursing curriculum schedules the A&P series immediately upon entry in the freshman year.

The Health Science faculty who teach A&P, which includes physical therapists, exercise physiologists, anatomists and medical doctors, have anecdotally observed that students majoring in Health Science may be better prepared to study A&P than students majoring in Nursing and that students majoring in Health Science achieve higher grades in the A&P series. It has been suggested that the Health Science students perform better due to factors such as: a) having an extra year of collegiate experience, b) their choice of major and c) whether their major is a 4-year terminal degree or a degree that precedes graduate study. A recent study which examined the relationships between course performance, time spent studying, learning styles, and future career choice found that grades were significantly higher among students who chose to pursue medical, dental or pharmacy school when compared to students who pursued occupational/physical therapies or nursing (Farkas et al. 2016).

Differences in A&P performance may be attributed to an extra year of experience or to student choice of major since each major has a suggested core of program plan coursework. In particular, students majoring in Health Science complete prerequisite coursework in their freshman year that may better prepare them to study A&P. Health
Science students are required to take 3 successive Biology courses: BIO 122 Cells and Genetics, BIO 124 Evolution and Organismal Diversity, and BIO 126 Physiology and Ecology, that include topics such as cell biology and metabolism. Exposure to these courses prior to taking A&P may give Health Science students an advantage over the Nursing students. It also may be true that simply completing other program-specific coursework (e.g. courses in Chemistry and Analysis) in their freshman year may better prepare students to be successful in the A&P course series. In a recent study, age or number of accumulated credits has been shown to predict academic performance (Gultice et al. 2015).  

High School GPA (HS-GPA) has also been shown to be a significant predictor of performance in Anatomy and Physiology (Anderton et al. 2016, Sturges et al. 2016, Ahmad and Safadi 2009). Therefore, it is important to account for HS-GPA when examining possible differences in performance outcomes between Health Science majors and Nursing majors. Similarly, SAT standardized testing scores have also demonstrated reliability in predicting college success (Rohr 2012). Although HS-GPA and SAT scores may be correlated, and conceptually overlap as tools to predict college success, there may be important differences between the two that suggest using both to examine student performance is appropriate. For example, HS-GPA may reflect non-cognitive performance-related factors (e.g. effort, attendance, and conformity), whereas scores on the SAT exam may be indicative of reasoning ability (Ewing et al. 2006).  

Understanding what impact the timing of the A&P series has on student success, while accounting for pre-college performance, might help instructors improve retention and grade outcomes in their courses. The purpose of this investigation was to examine three potential predictors of performance in the A&P series (ANAT 101, 102 and 103): the year the A&P series is taken, High School GPA and SAT scores. We hope that the information presented here will help other A&P instructors as they consider the possible factors that may impact student performance in their own A&P courses.

**Methods**

Academic data was pulled from the Drexel University Banner system for Health Science (HSCI) and Nursing (NURS) students from the years 2009-2014. For both majors, letter grades were collected for A&P (ANAT 101, 102 and 103) and were converted to GPA format using a scale of 0-4.33 for a letter grade of F through A+, respectively. High School GPA (HS-GPA) and SAT scores were also collected for both majors. Students were excluded from analysis if they were a transfer student, if they had changed majors, if they had taken any of the aforementioned courses at another institution, or if they had received a grade of Incomplete on any of the courses. Students were also excluded if they did not successfully complete each course in the series. If any students repeated the courses, their first completed attempt was included.

Correlation and multiple regression analyses were conducted to investigate the relationship between model predictors (year course series taken; HS-GPA; SAT- Math & Verbal) and the A&P courses, ANAT 101, 102, and 103. An independent t-test was performed to determine the differences in HS-GPA and SAT scores between HSCI and NURS students at baseline. Pearson correlation was performed to determine the relationship between ANAT 101, 102 and 103, SAT scores, and HS-GPA for both majors and descriptive means are provided. All statistical analysis was performed using IBM SPSS software, version 24.

**Results**

HS-GPA was significantly higher among HSCI students than NURS students (HSCI: \( M = 3.62, SD \pm .34 \); NURS: \( M = 3.53, SD \pm .36 \); \( t(684) = 3.13, p < .001 \), as was SAT-M&V (HSCI: \( M = 1191, SD \pm 108.8 \); NURS: \( M = 1132.9, SD \pm 104.4 \); \( t(645) = 7.43, p < .001 \). Both variables were strongly correlated with performance in ANAT 101 through 103 for both majors (Table 1).

A descriptive examination of the means for course grade reveal a higher grade in the ANAT 101 and 103 courses for HSCI students but NURS students performed somewhat better in ANAT 102 (see Figure 1).

The ANAT 101 multiple regression model, with the three predictors, demonstrated a significant linear relationship to ANAT 101 grades: adjusted \( R^2 = .276, F(3,777) = 100.16, p < .001 \). The Year Taken, SAT- M&V, and HS-GPA standardized regression coefficients were positive and significant, indicating students in the HSCI major (series taken during 2nd year) and those with higher SAT and HS-GPA scores are expected to have higher ANAT 101 grades, while controlling for the other variables in the model (see Table 2). The model explained less of the ANAT 102 grade variance (adj. \( R^2 = .202, F(3,777) = 66.85, p < .001 \)). With the ANAT 102 course, all three variables continued to be strong significant predictors, but Year Taken now favored NURS students, reflecting a slight difference in mean ANAT 102 grade for those students.

By ANAT 103, Year Taken was no longer a significant predictor in the model (\( \beta = .026, p = .429 \)), while HS-GPA and SAT-M&V continued to significantly influence the course grade.

continued on next page
Table 1. Correlations: Anatomy Course Series Grades, High School GPA, & SAT-M&V

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<td>2 = SAT-M&amp;V</td>
<td>.324**</td>
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<td>3 = ANAT101 Grade</td>
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<td>4 = ANAT102 Grade</td>
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<td>.619**</td>
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<td>.379**</td>
<td>.266**</td>
<td>.638**</td>
<td>.677**</td>
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**Correlation is significant at the 0.01 level (2-tailed).

Figure 1. Anatomy 101, 102, & 103 Grades by Major (Means & 95% CI)

Table 2. Multiple Regression Models

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<tr>
<th></th>
<th>adj. R²</th>
<th>β*</th>
<th>SE</th>
<th>Beta</th>
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<td>.000</td>
<td>.261</td>
<td>8.03</td>
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<td>.332</td>
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<tr>
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<tr>
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<td>.000</td>
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<td>.071</td>
<td>.393</td>
<td>11.94</td>
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* Unstandardized coefficient
Predictors of Success of Nursing and Health Science Students in Anatomy and Physiology

Discussion

The purpose of this study was to compare the Nursing (NURS) and Health Science (HSCI) students on their earned grades in the Anatomy and Physiology course series (ANAT 101, 102 and 103) and determine what impact High School GPA (HS-GPA) and SAT scores had on their success. In doing so, our primary analysis built upon the linear relationship of the year the courses were taken, SAT scores, and HS-GPA with grades in each of the series courses.

Our findings suggest that taking ANAT 101 in the second college year (as the HSCI students do) may result in a higher course grade than taking this course during year one. However, year one ANAT 102 grades (NURS major sequence) were higher than those for the year two students (HSCI) taking ANAT 102, while the other variables were held constant. By the time each major completed ANAT 103, whether during year one or two, grade differences between majors could not be accounted for using Year Taken as a possible predictor variable. The predictive trend suggests that, although ANAT 101 may be more difficult to complete during year one, students adapt to multiple challenges and perform in ANAT 102 and 103 as well as those who completed the courses in year two. The grades of students majoring in Nursing improved throughout the course sequence starting from an initial lower ANAT 101 score. The grades for students majoring in Health Science were stable across the series, falling slightly for ANAT 102 but rebounding for ANAT 103 (see Figure 1).

Because the NURS students performed slightly better in 102 than those in the HSCI major and there were no differences between the majors by the time ANAT 103 was taken, the potential preparation provided by courses taken during the freshman year may not be of significant benefit to NURS students if the start of the A&P course sequence for Nursing majors was to be moved to year two. Although multiple complex factors influence college course grades in all majors, in terms of grade performance, it does not appear from our sample that it matters what year the A&P course series is taken.

Previous research has suggested that undergraduate nursing students may feel unprepared for the rigors of collegiate study (Birks et al. 2013) and that the number of credit hours accumulated prior to the time of taking A&P is positively associated with performance (Gultice et al. 2015). We expected similar results, as a year of rigorous science courses prior to taking A&P was hypothesized to help prepare HSCI students for the study of anatomy and physiology. While previous findings align with our analysis of the first A&P course, they diverge later in the sequence, as NURS students move past their initial term of study.

HS-GPA was used as a predictor in the analysis in an attempt to examine the differences in academic ability upon entry to college and explore the linear relationship to performance. Significant correlations were found among grades for the HSCI and NURS students between all three Anatomy and Physiology courses, as well as between all A&P course grades and High School GPA. This is supported by previous findings, indicating that HS-GPA and overall college GPA are strong predictors of performance (Anderton 2016, Sturges 2016, Ahmad 2009).

Finally, SAT- M&V was a significant predictor of performance in all 3 A&P courses in both majors, supporting previous findings that SAT score predicts retention in science, technology, math and engineering (STEM) courses (Rohe 2012). Since HS-GPA determination may vary in GPA by school and region, SAT scores may provide a more reliable way to predict A&P performance in our students. While students majoring in HSCI had significantly higher HS-GPA and SAT- M&V scores, it did not translate into consistently higher scores throughout the A&P series.

The strengths of this study include the large sample size of 311 students majoring in Health Science and 470 students majoring in Nursing and the six-year time period over which this data was obtained. The course sequences for NURS and HSCI majors remained the same over the time period, ensuring that the impact of any prerequisites remained constant from year to year. In addition, limiting the study to new students rather than transfers allowed for evaluation only of Drexel taught courses and eliminated the potential of repeated courses influencing grade outcomes.

There are limitations to this study. Certainly, there are multiple factors that might predict college success in the A&P course sequence. For example, variation in instructors occurred over this six-year period, as six instructors taught the A&P courses (ANAT 101, 102 and 103). Only two instructors taught all three courses during the six-year period and to both majors. Thus, the effect of teaching style or examination questions could not be controlled for or quantified. Each instructor followed the same syllabus, used the same text and had the same lab quizzes and homework. While the structure of all five exams was multiple choice, matching, and true/false, the instructors were not required to use identical examinations. This could have influenced the grade outcomes between the majors, since various instructors taught in both or either major, and in each of the three courses. Unfortunately, the wide variation in the number of times each instructor taught the courses and in the number of students each Instructor taught prevented the utilization of “Instructor” as a model variable.

Another limitation that cannot be accounted for in this investigation is motivational differences between students pursuing a Nursing or Health Sciences degree. Most of the students majoring in Health Science at Drexel expect to pursue graduate study, while Nursing is often considered to be a terminal degree. The desire to study a particular profession, and how that influences outcomes, is difficult to quantify. This could perhaps be captured through measures...
of motivational style, self-efficacy, grit or a variety of other psychosocial factors. Future research should examine some of these psychosocial factors as possible predictors of performance in different majors.

Our findings emphasize the need for further inquiry into the make-up and value of prerequisite courses for A&P. While the Biology series is fundamental to any Health Science or Nursing degree and students who do well in those courses may also generally do well in A&P, we are unable to suggest that offering the Biology classes during year one or two contributes to the higher Health Science grades in ANAT 101. Performance in each major could also reflect the rigor of a year of other freshman science courses. The fact that the Nursing students performed better in 102, and the difference between majors was no longer statistically significant by 103, supports the idea that the prerequisite work may only extend to the ANAT 101. Knowing this, we may be able to offer our Health Science students more flexibility, or the opportunity to take the A&P course earlier than the sophomore year.

Beyond grades, interest in the material presented in A&P classes often clarifies for a student what they are genuinely interested in studying and helps students decide whether or not a career as a healthcare professional is right for them. If students can determine this sooner, it may help them focus their college efforts more productively or shift their career goals. Finally, the grade differences in ANAT 101 suggest that the Nursing students may benefit from a remedial or preparatory course before taking A&P.

Future research should include differences in student outcomes categorized by instructor as well as the impact of learning style or other psychosocial factors on student performance in A&P. In conclusion, High School GPA and SAT-M&V scores are strongly correlated with and predict performance in our sample regardless of major. However, while the year the A&P courses were taken is predictive of performance for ANAT 101 and 102, but not 103, the pattern of performance between courses and majors prevents a clear conclusion about which year might be the most beneficial year for students to take A&P.

**About the authors**

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**Literature Cited**


Student Expected Achievement in Anatomy and Physiology Associated with Use and Reported Helpfulness of Learning and Studying Strategies

Courtenay Dunn-Lewis, PhD, Kevin Finn, EdD and Kathleen FitzPatrick, PhD
Merrimack College, 315 Turnpike Street, North Andover, MA 01845

Abstract
Successful students implement learning techniques that allow them to perform well in coursework. Effective learning strategies are essential for mastering the knowledge required in human Anatomy and Physiology (A&P). The purpose of this investigation was to analyze the study habits that best associated with predicted success in A&P. 136 students in A&P I at the end of the fall semester of 2013 were invited to participate and ninety-eight students completed the survey anonymously. The results of this study showed that there are clear differences between students expecting high (A/B) and low (C/D) grades. Those expecting high grades spent more time studying, studied further in advance of tests, used self-testing resources more actively, engaged more with resources and found all resources to be helpful. Instructors may share and promote the findings on study strategies to optimize student success, providing students with a strong foundation for future courses.

Key Words: Anatomy and Physiology, Study Strategies, Achievement

Introduction
Student academic success is closely associated with the knowledge and application of effective learning strategies (Robbins et al. 2004). Academically successful students develop and implement learning techniques that allow them to perform well in coursework (Elliott, McGregor and Gable 1999, Mathiasen 1984, Robbins et al. 2004). High performing students tend to have better academic skills, including test-taking skills, the ability to identify and absorb the major concepts of the course, and the ability to manage their time (Foley and Epstein 1992: Pressley and Afflerback 1995). There is a direct correlation between standardized test performance, as well as homework completion, with the quantity of study strategies employed by the student (Zimmerman and Martinez-Pons 1986). Thus successful students have a strong understanding of the techniques and study habits required for success in academic work.

In contrast, unsuccessful students implement less effective learning strategies than successful students (Cho and Ahn 2003, Paris and Myers 1981, Tait and Entwhistle 1996). There are significant differences in both the quality and quantity of learning strategies reported by high versus low achievers (Hartwig and Dunlosky 2012, Ley and Young 1998, Purdie and Hattie 1996, Purdie, Hattie and Douglas 1996, Zimmerman and Martinez-Pons 1988, Zimmerman and Martinez-Pons 1986, Zimmerman and Martinez-Pons 1990). High-performing students report using different learning strategies twice as often as the low achievers (Zimmerman and Martinez-Pons 1988). There is therefore a clear disconnect between the practices of high-achieving students and those of low-achieving students.

One likely cause of low-achievement is therefore a lack of awareness of the learning and studying process. Effective study habits allow students to “acquire, organize, retain, and use information,” but these habits require training and practice (Zimmerman 1998). It is a commonly accepted that permanent and significant learning can be achieved only through learner efforts and contributions (Benson 2001). Low-performing students rely on parents and teachers to dictate studying and are otherwise somewhat passive in the learning process. These students typically do not assess their own comprehension and do not review and reread their assignments to improve learning. Low-performing students also may not understand the point of studying and that learning requires a more engaged approach than reading content alone (Gettinger and Seibert 2002). In many cases, students with academic difficulties are not aware of the effective techniques that are used by academically competent students when they study (Gersten, Baker and Marks 1998, Karpecke, Butler and Roediger 2009, Kornell and Bjork 2012, Roediger and Butler 2011). In fact, the students who experience difficulty in school often have academic capability, but have not been taught how to learn or have not developed effective learning strategies (Dembo and Seli 2008; Nicaise and Gettinger 1995). Thus, optimizing student performance likely requires the identification and dissemination of studying strategies to low-performing students, particularly in courses with strong implications for a student’s career.

Foundational courses in the sciences are an important predictor of achievement in the remainder of a student’s...
degree program (Henderson and Orr 1989). At the same time, effective learning strategies are essential for mastering the foundational knowledge in the sciences (Miyake et al. 2010). Human Anatomy and Physiology (A&P) is one such foundational course that is typically required in health professions curricula. There tends to be high demand for, and enrollment in, the first course in the A&P sequence. Many students struggle with the subject matter; as with other foundational courses, A&P tends to have high failure and withdrawal rates (Anderton, Evans and Chivers 2016, Harris, Hannum and Gupta 2004, Sturges and Maurer 2013, Sturges et al. 2016). This is also true in our institution, with some 20-35% of students receiving unsatisfactory grades (less than a C or 73%). In our curriculum, A&P is taken in the first semester of freshman year. Thus students are typically relying on study habits that have been successful in high school, but these may not be adequate for success in college level science. Haycock and Huang (2001) report that some 50% of college students are not academically prepared.

In an interview study of academic underachievement in college, Balduf (2009) reported that students who did very well in high school stated that they had not needed to expend much effort to do so and, by their own report, lacked adequate study skills, time management skills and internal motivation. These students felt that the most important intervention to assist them was improvement of their own behaviors. Most experienced instructors typically have a sense of the strategies used by their students, but this is often based on anecdotes and personal conversations with those students who seek individual help when struggling. It is important to inform these perceptions by systematically gathering anonymous data from an entire class to analyze the trends in study behaviors. By determining the learning strategies used by the students who are, or in this case perceive themselves to be, successful in A&P, we can teach these methods to future students to ensure their success in foundational and future coursework. In addition, instructors typically spend time and energy choosing learning resources such as textbooks and associated web-based and other resources to optimize student mastery of the course material. It is often unclear to what degree and how these resources are actually used by students, how helpful students find them and how much they aid student learning. The results of this study can help to inform and guide instructors in their choices of such materials and in how they present them to students.

The purpose of this investigation was to analyze the study habits that best correlated with success in A&P, as defined by student expected grades of A and B. In particular, we examined student use of various study resources and student perceptions of the helpfulness of each resource. We also examined other study strategies students used and how students used their time. The results indicate that successful students tend to organize their time differently and use certain strategies and resources to a greater degree than C or D students. The findings of this investigation can be taught to science students early in their academic programs to promote their success in foundational science courses and beyond. These findings can also inform instructors as they choose learning resources that will be likely to be used and found effective by students.

**Materials and Methods**

**Context of the Study**

Our institution is a private comprehensive college with 3,000 students, 2,700 full-time undergraduate and 400 graduate students, from twenty-two states and seventeen countries. The student population is approximately 50% male and 50% female and of traditional college age, typically seventeen to eighteen years old when they enter college as freshman. Most students live on campus (75%) and fifteen percent of students are enrolled in the health sciences, which require A&P.

**Anatomy and Physiology I Course**

A&P is offered as a two-semester course required for all freshman in the Health Sciences Department. The course was offered in the form of three sections of a 75 min. bi-weekly lecture enrolling up to 55 students each, taught by two instructors. There were separate weekly 150 min laboratory periods enrolling up to sixteen students that were taught by four instructors (including both lecture instructors). The Anatomy and Physiology I course in 2013 was comprised of 136 students, 37% male and 63% female, with 86% freshmen, 12% sophomores, 1% juniors, and 1% seniors. The students were mainly enrolled in the Health Sciences Department, with 73% majoring in athletic training, exercise science or health science. The remaining 27% of the students were majors in biology, business, psychology, human development, or undecided science.

The fall semester focuses on musculoskeletal anatomy and the nervous system. The course used a custom version of Anatomy and Physiology: An Integrative Approach, 1st Edition (McKinley, O’Loughlin and Bidle 2013), which allowed students to access the web-based McGraw-Hill Connect™ system. This system included adaptive learning assessments for each chapter (LearnSmart™), interactive human cadaver dissection software with self-test quiz function (Anatomy and Physiology Revealed™ (APR), and the ability to add custom assessments. The laboratory used standard models of human arm, leg and torso, bones and muscles, skeletons, brains and spinal cords, along with human palpation exercises and physiology experiments using a computerized human data collection and analysis system (Powerlab®, ADInstruments, Inc., Colorado Springs, CO).

Students took a quiz at or before every class period. Students took seven in-class quizzes, one every two weeks (or every fourth class); these were comprised of multiple choice and true/false questions with 20 questions per
quiz. Students also took 19 pre-class reading quizzes (five questions each) on the Connect interface before any class that did not have an in-class quiz scheduled (or three times every two weeks). The students took midterm and final written laboratory practical examinations. Other assessments (e.g. three-question quizzes) were also completed in laboratory, but the survey did not focus on these.

The final overall course grade was based on quizzes and final exam assessments, pre-class reading quizzes, Connect assignments, two practical exams, and weekly assessments and assignments. Within our department, a C or better grade (73 and above) is required to move from A&P I to A&P II. Students who fail to achieve a satisfactory grade must repeat the course. Tutoring by upperclassmen (undergraduate students) and optional extra credit clinical questions were also available to students, but optional. The extra credit clinical questions consisted of case studies with five questions that were submitted via BlackBoard.

Survey and Data Collection

The College's Institutional Review Board approved this investigation: Protocol Number, 2014-20, Merrimack College IRB, Assurance # FWA00014062. All students in the course were invited to do the survey, provided informed consent and responses were anonymous. There was no reward or penalty involved in participation. The individual constructing the study habits survey and performing data analysis was not the instructor of the course. The study habits survey consisted of 22 multiple-choice questions concerning time use and the use and perceived helpfulness of particular study resources and techniques (See Appendix A). Three of the items allowed for more than one answer choice. The final item asked students to state the grade they anticipated receiving in the class. At the time of the survey during the last week of the term, students had received back all of their graded work and quiz grades except for the final lab practical and final exam and were thus in a good position to predict their final grade. Each question also allowed for narrative responses; this data will be reported elsewhere. 136 students enrolled in A&P I at the end of the fall semester of 2013 were invited to participate, with 98 providing electronic consent and completing the survey anonymously on Survey Monkey (72% response rate). The class was composed of 86% freshman, 12% sophomores and 2% juniors/seniors. Note that this questionnaire was provided well after the withdrawal deadline (week 10), thus the 20 students who withdrew from the course are not represented. No students who completed the survey reported an anticipated grade of F.

Statistical Analysis

To examine factors that differentiated high-performing students (student-reported anticipated grade of A/B) from low-performing students (anticipated grade of C/D), categorical variables were run through cross-tabulation with chi-square analysis (with z-tests as relevant), using SPSS. There were more students in the high-performing group (n=71) than in the low-performing group (n=27). An independent sample t-test was used to compare time spent studying by achievement level. Significance was set at p≤0.05.

Results

Time Spent Studying

Students were asked to account for the amount of time they spent on all required assignments and studying on their own each week (outside of class). High achieving students spent, on average, 45 minutes more than the low-achieving students on the course each week (mean difference 45 minutes, SE 20, 95% CI 4 to 85) (Table 1). We also examined whether having an established time to study (regardless of exams) predicted whether students would be high-performers or low performers. In general, the habit of having a regular study time was somewhat rare (23%). We were not able to detect significant differences between high performers (25%, 18/71) and low performers (19%, 5/27) in this data set (p=0.48).

Studying Habits Prior to Examinations

Anticipated grade performance (high versus low) was compared to preparation time before exams. Note that students could choose as many options as they wanted for this question. As shown in Table 2, there was no association between grade performance and either “all-nighters”, studying the day before, or studying a couple of days before; both high-performing individuals and low-performing individuals engaged in these test-preparation behaviors at least some of the time. Most students in both groups tended to begin study a couple of days before the exam. High-achieving students were, however, more likely to begin studying the week before the exam as compared to low-performing students.

Primary Methods of Studying

When asked to choose all methods they regularly used when studying (Figure 1), high-performing students were more likely to engage with the text chapter by quizzing themselves and copying over notes; they were also more likely to use the APR dissection tool at home. Lower-performing students were more likely to use tutoring, although the class use of tutoring was low overall (15%). Regardless of performance, more than half of respondents read the PowerPoint slides/notes and made flashcards.

High-performing students were also significantly more likely to report engaging with the chapter (as opposed to simply reading through it). In a separate question on textbooks alone, however, there was no difference in engagement with the textbook as seen in Table 3. In particular, it appeared most students skimmed most chapters, regardless of whether they were high- or low-performing.

continued on next page
Table 1. Time spent studying each week outside of class by achievement level.
Reported time spent included time to complete all assignments and time spent studying on their own. * = significant difference between A/B and C/D students, p=0.030.

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<tr>
<td>A or B (n=71)</td>
<td>316 * (SD 91)</td>
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<tr>
<td>C or D (n=27)</td>
<td>272 * (SD 88)</td>
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</table>

Table 2. Studying Habits Prior to Examinations and Anticipated Student Grade Performance. * = significant difference between A/B and C/D students, p=0.013.

<table>
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<th>All Nighter Before</th>
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<tr>
<td>A/B (n=71)</td>
<td>8%</td>
<td>27%</td>
<td>63%</td>
</tr>
<tr>
<td>C/D (n=27)</td>
<td>19%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Total (n=98)</td>
<td>11% (p=0.15)</td>
<td>28% (p=0.77)</td>
<td>65% (p=0.51)</td>
</tr>
</tbody>
</table>

Table 3. Engagement with Textbook by Anticipated Student Grade Performance.
There were no significant differences in textbook engagement between high- and low-performing students (p=0.832).

<table>
<thead>
<tr>
<th>Engagement</th>
<th>A or B (n=71)</th>
<th>C or D (n=27)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never opened book</td>
<td>2.80%</td>
<td>7.40%</td>
<td>4.10%</td>
</tr>
<tr>
<td>Only used for pre-class reading quizzes</td>
<td>21.10%</td>
<td>18.50%</td>
<td>20.40%</td>
</tr>
<tr>
<td>Skimmed most chapters</td>
<td>33.80%</td>
<td>40.70%</td>
<td>35.70%</td>
</tr>
<tr>
<td>Read most chapters</td>
<td>21.10%</td>
<td>18.50%</td>
<td>20.40%</td>
</tr>
<tr>
<td>Read most chapters closely or more than once</td>
<td>7.00%</td>
<td>7.40%</td>
<td>7.10%</td>
</tr>
<tr>
<td>Engaged with textbook</td>
<td>14.10%</td>
<td>7.40%</td>
<td>12.2%</td>
</tr>
</tbody>
</table>

continued on next page
Use of Resource

There were no differences between the high- and low-performing students in use of the models. The mode student (37%) reported carefully reviewing and learning from the anatomy models, but only during lab periods (not on their own time). The models were available for student use at times outside of scheduled classes. Low-performing students were significantly more likely to skip the LearnSmart adaptive learning assignments, while no high performing students skipped them. High-performing students were significantly more likely to carefully study the LearnSmart assignments, but no low-performing students carefully studied them. The mode student completed and tried to learn from the assignments (Table 4).

Most high-performing students used the APR human dissection software at least on occasion outside of lab, while low-performing students were more likely to use the software only in lab (Table 5). The majority of students did not use tutoring (61.20% overall). There was no difference in its use between high- and low-performers.

Reported Helpfulness

Figure 2 summarizes the data on what students considered to rate, at minimum, “Helpful”. In general, high-achieving students tended to find all techniques more helpful than low-achieving students, but the differences were not significant for APR (somewhat highly rated by both, >70%) and the pre-class reading quizzes and tutoring (somewhat poorly rated by both). The most highly rated techniques overall included the anatomy models (86% of all students rated them as “helpful”, “very helpful,” or “would not have passed course without it”), Anatomy and Physiology Revealed (81%), in-class quizzes (81%), Connect LearnSmart assignments (78%), laboratories (76%) and extra credit clinical questions (74%). The lowest approval ratings were for tutoring (57%), the textbook (64%), and the pre-class reading quizzes (66%). The textbook approval was consistent with ratings typically given to any textbooks used in class.

At the end of the semester, the grades students received for the total of 136 in the class were compared with the grades anticipated in the survey for the 98 completing the survey (72%). The survey was anonymous, so it was not possible to match expected and actual grades for individual students. At the time of the survey, students had taken all but the final lecture exam and received back virtually all graded work, except the second lab practical and final lecture exam. There

continued on next page


### Table 4. Use of Connect LearnSmart Adaptive Assignments by Anticipated Student Grade Performance. * = significant differences in use of Connect LearnSmart Assignments between high- and low-performing students, \( p \leq 0.05 \).

<table>
<thead>
<tr>
<th></th>
<th>A or B (n=71)</th>
<th>C or D (n=27)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didn't use or skipped many of them</td>
<td>0.00%*</td>
<td>7.40%*</td>
<td>2.00%</td>
</tr>
<tr>
<td>Completed them but didn't try to figure out</td>
<td>5.60%</td>
<td>3.70%</td>
<td>5.10%</td>
</tr>
<tr>
<td>Completed and tried to learn from</td>
<td>77.50%</td>
<td>88.90%</td>
<td>80.60%</td>
</tr>
<tr>
<td>Studied in preparation for or carefully used them</td>
<td>16.90%*</td>
<td>0.00%*</td>
<td>12.20%</td>
</tr>
</tbody>
</table>

### Table 5. Use of Anatomy and Physiology Revealed by Anticipated Student Grade Performance. * = significant difference in use of APR between high- and low-performing students (\( p=0.007 \)).

<table>
<thead>
<tr>
<th></th>
<th>A or B (n=71)</th>
<th>C or D (n=27)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not use outside of lab</td>
<td>26.80%*</td>
<td>55.60%*</td>
<td>34.70%</td>
</tr>
<tr>
<td>Used outside of lab</td>
<td>73.20%*</td>
<td>44.40%*</td>
<td>65.30%</td>
</tr>
</tbody>
</table>

### Table 6. Expected versus Actual Course Grades: * = significant difference between percent of students expecting a grade and percent of actual grades for failures (\( p<.05 \)). No other differences were seen.

<table>
<thead>
<tr>
<th>Student Grades</th>
<th>Expected N=98</th>
<th>Actual N=136</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21.4%</td>
<td>17.0%</td>
</tr>
<tr>
<td>B</td>
<td>51.0%</td>
<td>40.0%</td>
</tr>
<tr>
<td>C</td>
<td>22.5%</td>
<td>31.1%</td>
</tr>
<tr>
<td>D</td>
<td>5.1%</td>
<td>6.7%</td>
</tr>
<tr>
<td>F</td>
<td>0.0%*</td>
<td>5.2%*</td>
</tr>
</tbody>
</table>

---

*continued on next page*
was no significant difference between the distribution of expected grades and actual grades except for failures, as 5% failed the course (Table 6). No students reported an expected grade of F, perhaps indicating that F students did not bother to complete the survey.

Discussion

The primary finding of this cross-sectional descriptive study is that there are clear differences between high- and low-performing students in A&P based on how much time they spend studying, when they study, what they use to study, how engaged they are with the materials, and how helpful they find the materials to be.

Our data determined that high-performing students spent an average of approximately five hours and fifteen minutes completing assignments and studying for anatomy and physiology each week, 45 minutes more than low-performing students. This extra time would appear to account more for student success than scheduling habits, as high-performing students did not necessarily structure this time into regularly scheduled studying sessions. This additional time is in agreement with previous work (Sturges, et al. 2016) and has been attributed to increased motivation on the part of high-performing students (Gettinger and Seibert 2002). A meta-analysis of 109 studies on the relationship between study skills factors and college outcomes found moderate relationships between academic related skills/academic self efficacy and retention and between academic self efficacy/achievement motivation and grade point average (GPA) (Robbins et al. 2004).

Spacing study over longer periods is more helpful in acquiring long-term memory of material than massing study into large blocks; college students, however, are most likely to be motivated to study and cram their study into blocks directly prior to imminent deadlines, rather than studying regularly (Kornell and Bjork 2012). In a description of study habits of students in introductory biology, Tomanek and Montplaisir (2004) also noted that learning activities focused mainly on the day before exams. Although high-performing students were just as likely to pull an all-nighter as low-performers in this investigation, the high-performing students were more likely to start studying earlier (a week before exams) in agreement with prior work (Hartwig and Dunlosky 2012). Our findings conflicted with their observation that high-performing students were less likely to engage in late night study (Hartwig and Dunlosky 2012, Jones et al. 1992), but supported prior work reporting that high-achieving students are more likely to plan study ahead of time (Nicaise and Gettinger 1995). Indeed, consistency in the implementation of a personalized study routine is a predictor of academic performance (Archambault 1992), which appears to be at play within the high-achieving individuals in this investigation.

All students had access to the electronic version of the text and most also purchased the loose-leaf version. Although less than half the students reported engaging with the text (as opposed to simply reading), high performers reported significantly more engagement with it. This concurs with previous work suggesting that high-achievers were more likely to engage in text rereading (Hartwig and Dunlosky 2012). Narrative comments indicated that high performers used the text for several reasons: for figures, for quiz preparation, for use in lab, and for assignments. Conversely, low-performer narratives reported use of the text only for completing assignments. We have noted a general tendency in our department courses for students to pay much more attention to Power Point notes than to actually reading and engaging the course text. This data supports that observation; with both high and low performers most commonly reporting simply skimming the text, while reading PowerPoint slides was the most heavily used technique. Similar to low-performers, high-performing students were quite likely to read PowerPoint slides and class notes as mentioned. It has been noted that repeated reading of texts and notes is not a particularly successful strategy for long term memory retention, while self-testing is much more effective. Karpicke et al. (2009) report that despite this, a survey of 177 college students found that the majority (84%) reviewed notes and the textbook and 55% ranked it as their number one strategy. Students seemed to be unaware of the differences in effectiveness of these two approaches. Similarly in our case, reading PowerPoint slides was the most used strategy and did not differ between high and low performing groups. Use of PowerPoint slides, course text and flashcards by introductory biology students was also noted by Tomanek and Montplaisir (2004). These students primarily reread these resources, while a few reported engaging with them in some more active way.

In a study on 324 undergraduate students (primarily in freshman-level introductory psychology courses), Hartwig and Dunlosky (2012) reported that higher performing students were more likely to use self-testing. In our study, Connect LearnSmart assignments, APR, and flashcards all represented forms of self-testing for all students. The use of flashcards was somewhat consistent between the two groups in agreement with previous work (Hartwig and Dunlosky 2012). Unlike low-performers, high performers did not skip LearnSmart adaptive learning assignments and were more likely to carefully study them. High-performing students were also more likely than low-performers to use the APR dissection software at home. In fact, our data indicates that the high-performing students were much more likely to use APR outside of class, which was not seen in low-performers. This is somewhat ironic, as both types of students ranked APR as one of the most helpful techniques they used, and unlike many techniques, there was no difference between the two groups in how helpful they felt it was. In fact, self-testing has been shown to be very effective (Roediger and Butler 2011), despite the fact that only 11% of students used the technique in previous

continued on next page
work and only 1% ranked this as their top strategy (Karpicke, Butler and Roediger 2009). This is likely because students do not understand its utility as a study tool (Hartwig and Dunlosky 2012). In a review of testing as a facilitator of long-term retention, Roediger and Butler (2011) note that frequent testing, particularly if feedback as to the correct answer is provided, enhances retention more than equivalent time spent on study. Our finding that self-testing was more common in high-achieving students also agreed with previous work (Hartwig and Dunlosky 2012). While Connect LearnSmart assignments involve self-testing, it is unclear exactly how students were using APR at home and to what degree they worked with the available self-tests, in addition to the interactive dissection images. These assignments are also a form of homework. Richards-Babb et al. (2011) report significantly improved success in terms of higher percent of A, B, C grades with the use of on-line homework in a general chemistry course and students were very positive about the usefulness of these assignments.

High-performers and low performers were in agreement that they did not find tutoring helpful, but the use of tutors was low overall. High performing students were less likely to see a tutor than low-performing students; when they did, high-performers found tutoring to be their least helpful resource. Low performers did not regard tutoring much more highly than high-performers. The narrative comments indicated that some students did not use tutoring because of schedule conflicts; others felt that they did not need to, as they believed they understood the material. This may relate to the illusions of competence phenomenon, in which how students choose to study is influenced by their perceptions that they know the material (Karpicke, Butler and Roediger 2009). It is also possible that the undergraduate tutors were not trained adequately for the responsibility, and certainly a tutor is not able to compensate for lack of studying time on the part of low-performing students. Previous work has demonstrated the effectiveness of a technique called Peer-Assisted Learning Strategies (PALS). In PALS, peer tutoring focuses on reading with the peer, summarizing concepts, predicting, and other higher-order thinking strategies to improve students’ performance (Fuchs et al. 1997). It is possible that such an approach would have improved student responses to the tutoring in our program.

High-performers and low performers were also in agreement that they did not find pre-class reading quizzes helpful. Students reported that they did not like being assessed on the chapter through pre-class reading quizzes before seeing a lecture on it. Further, at five questions each, it is also possible that the pre-class reading quizzes were not long enough to cause students to read the chapter meaningfully. At the same time, a majority of students found in-class quizzes to be helpful, with significantly more high performers (>90%) finding them helpful. Since in-class quizzes are weighted more heavily in the course grade, students may have taken them more seriously and devoted more time and effort to them.

Outside of APR, the pre-class reading quizzes, and tutoring, high-performing students were more likely to find almost all techniques to be helpful. This may be because of engagement; based on the few questions we asked, high-performing students tended to be more engaged with the materials than low-performing students. This is also in agreement with previous work (Gettinger and Seibert 2002).

Advantages and Limitations

There is an extensive body of literature in the field of science pedagogy that focuses on the effectiveness of various teaching techniques in improving student learning and performance. Not as much appears to be known about what students are doing in their time outside of class to facilitate their learning and mastery of course content. Much of our knowledge about this comes from anecdotal information gained in individual conversations with students, often in the context of office hours with those who are having difficulty. As noted earlier, the high rate of unsatisfactory completion of A&P courses, at our institution and others, makes it critically important that we make use of this information to improve success. Since even high achieving high school graduates struggle in college, assistance with improving study skills is important (Balduf 2009). A&P is a gateway course for most all preparation programs for healthcare careers, so student failure is very frustrating to both students and instructors. This study provides a systematic analysis of student study behaviors and use of resources, linked to performance, to distinguish between behaviors of high and low performing students. It also provides unique insight into several modern educational resources, including adaptive learning technology (Connect LearnSmart) and an online dissection tool (APR) with self-test functions. While the resources in this study were linked to a particular text and publisher, the many A&P texts available on the market also include the same types of on-line resources, as do texts for other sciences. It also provides unique insights into how high-achieving and low-achieving students regard the helpfulness of various studying techniques; these observations have implications for understanding student approaches to studying techniques and may provide avenues of future research. The relationships described above were based on anticipated final student grades. As our study was anonymous, we compared our data to the overall class grade distribution. In one survey of A&P students in the third week of class, two-thirds of the students overestimated their expected final grade and almost one third overestimated by 2-4 letter grades (Sturges et al. 2016). In an introductory biology course, Jensen and Moore (2008) reported that after the final exam, A/B students tended to underestimate their course grade, while C/D/F students overestimated. They also reported that low-grade students did not use resources such as help sessions and extra credit opportunities. In our study, students estimated their final grade at the end of the semester, with all graded assignments other than the second
lab practical (which students had taken, but grades had not been posted) and final exam returned to them, so we would expect a higher level of agreement. It is possible that these assessments might push a student whose grade hovered on the B/C border to the higher performing or lower performing category, but we generally find that a student’s grades on these final end of term assessments are quite consistent with their prior work. In introductory biology, Jensen and Moore (2008) saw improvement in exam performance by A/B students across the term, while F students’ performance dropped. We found no significant difference between anticipated and actual class grade distributions except for Fs; this may reflect that students expecting an F had little incentive to complete the survey or that perhaps some of the lower performing students who completed the survey had unrealistic expectations about passing the course. It should be noted that this course in fall, 2013, was the first class to be subject to the requirement for a C or better grade to move on in the program. As a result, there were an unusually high number of withdrawals (20 or 12.8 %) of those registered at the start of term. Presumably these students withdrew because they anticipated an unsatisfactory grade, but the survey was conducted after the W date, so these students are not represented and we have no information on their study behaviors and resource use. The 28% of students who did not return the survey could have altered the overall result if non responses clustered more heavily in the high or low performing categories.

It should be noted that although this course is typically taken by freshman, 14% of the students in the study were upper class students who may have developed more effective study strategies compared to those in their first term at college. Similarly, while 73% of the students were majors in health sciences, 27% were enrolled in other majors and may again have different study techniques related to their major field. In a study of academic performance in A&P, it was found that high performance in A&P predicted higher GPA in the first year. It was also noted that performance did vary by gender, with females performing better, and by the student’s major program, with biomedical sciences and exercise sciences majors performing better. Performance was also higher if students had completed prior courses in biology and chemistry in high school (Anderton, Evans and Chivers 2016). As our survey was anonymous, it is not possible to analyze study techniques either by class year, major or gender. In future it would be helpful to collect this type of demographic information in the survey to allow these analyses.

In this survey, narrative comments were also collected. These indicate differences in the degree to which high and low performing students engage in reflective thinking or metacognition about their learning strategies, with higher performing students showing more reflective comments on their study approaches. These results will be addressed in a separate paper. This investigation was conducted within a somewhat homogenous population of students in a relatively small private four-year primarily undergraduate college in the northeast, and therefore may not be generalizable to larger public institutions and two-year colleges. That said, there appears to be significant overlap between the findings of this investigation and other investigations with differing settings (Hartwig and Dunlosky 2012, Karpicke, Butler and Roediger 2009, Sturges et al. 2016).

Implications

Instructors may share the findings on study strategies, studying ahead of time, total study time, self-testing and engagement with text and other resources to optimize student success. Promotion of these strategies, through encouragement of independent use and through structured required use of the online self-testing resources now included with many textbooks, may prove to be useful in fostering student success in A&P. Future work may also examine how instructors may choose and incorporate effective learning strategies into A&P, as well as other foundational courses in the sciences, which students will use and find helpful.

Acknowledgments

The authors thank the students and faculty of the Department of Health Sciences at Merrimack College for the efforts and support in ongoing curriculum revision and reform and openness to new methods of teaching and learning.

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Kathleen A. FitzPatrick, Ph. D. is Emeritus Professor of Health Sciences at Merrimack College. Dr. FitzPatrick received her Ph.D. in Physiology at the University of Wisconsin-Madison.

Appendix A Sample of Selected Items from 21 Question Survey

1.) How much time did you spend studying A&P I in a “typical” week on your own (NOT including lab assignments, Connect, or other mandatory assignments)

<table>
<thead>
<tr>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
</tr>
<tr>
<td>0-30 min</td>
</tr>
<tr>
<td>30min-1 hr</td>
</tr>
<tr>
<td>1-1:30hr</td>
</tr>
<tr>
<td>1:30-2hrs</td>
</tr>
<tr>
<td>2-2:30hrs</td>
</tr>
<tr>
<td>2:30-3hrs</td>
</tr>
<tr>
<td>3-3:30hrs</td>
</tr>
<tr>
<td>More than 3:30hrs</td>
</tr>
</tbody>
</table>

continued on next page
2.) When did you start studying prior to an exam?
- All-Nighter Before
- Day Before
- Couple of Days Before
- Week Before

3.) How much did you use the Connect LearnSmart Adaptive Assignments?
- Didn’t use or skipped many of them
- Completed them but didn’t try to figure out
- Completed and tried to learn from
- Studied in preparation for or carefully used them

4.) How did you make use of Anatomy and Physiology Revealed?
- Did not use outside of lab
- Used outside of lab

5.) What techniques did you find most helpful when studying?
| Textbook | Connect LearnSmart |
| APR | Laboratories |
| Models | Pre-Class Quiz |
| In-Class Quiz | Clinical Questions |
| Tutor | |

6.) What were your primary study methods in the course?
| Relied on Class Only | Read through chapter |
| Engaged with Chapter | Read Power Points/Notes |
| Engaged Power Points/Notes | Made Flash Cards |
| Used other Flash Cards | Used Anatomy Models |
| Engaged with Models | Used APR at Home |

**Literature cited**


Lactate: Toxic Villain or Metabolic Superhero?

Kerry Hull, PhD and Patricia Marx
Department of Biology, Bishop’s University, Sherbrooke, Canada

Abstract
Since the full elucidation of the glycolytic pathway in 1940, lactate has been negatively portrayed as the toxic and useless endproduct of anaerobic glycolysis and as a sign of inadequate oxygenation. Yet, fifty years of evidence supports the hypothesis that lactate is a useful and portable energy source that is produced even when oxygen is abundant. This article provides a brief overview of the biochemistry of lactate, including its significance in exercise, which will be of use to Instructors of biochemistry or physiology.

Key Words: lactate; muscle fatigue; excess post-exercise oxygen consumption

Introduction
Since the full elucidation of the glycolytic pathway in 1940, lactate has consistently been negatively portrayed as the toxic and useless endproduct of anaerobic glycolysis and as a sign of inadequate oxygenation (Schurr 2014). As pyruvate’s “evil twin”, lactate was blamed for muscle fatigue and it was assumed that the body needed to devote extra energy and oxygen after an intense exercise bout to dispose of it. Lactate’s reputation as a metabolic troublemaker has proven very difficult to repair, despite decades of evidence suggesting that lactate is actually a valuable and portable energy source. This article aims to facilitate lactate’s rehabilitation by providing evidence in support of these five statements:

1. Cells produce lactate, not lactic acid.
2. Oxygen deficiency is not the most physiologically relevant stimulus for increased lactate production.
3. Lactate is actually a valuable metabolic intermediate, not a problematic waste product.
4. Lactate is not the primary factor in muscle fatigue.
5. The purpose of increased post-exercise ventilation is not to eliminate lactate.

Our purpose is thus to provide a brief overview of the biochemistry of lactate, including its significance in exercise, that will be of use to Instructors of biochemistry or physiology. Readers are referred to the many detailed and comprehensive reviews of this topic for more information (Draoui and Feron 2011, Brooks 2007, Hall et al. 2016, Brooks 2009, Adeva-Andany et al. 2014).

LACTATE PRODUCTION
While lactate can also be produced by the amino acid alanine, most lactate results from carbohydrate breakdown (Adeva-Andany et al. 2014). Muscle cells, as illustrated in Figure 1, generate substantial amounts of ATP from carbohydrates stored in the form of glycogen (Connett and Sahlin 2011). The first step in liberating the energy from glycogen is glycogenolysis (glycogen breakdown), resulting in the production of glucose-6-phosphate (G-6-P). Glucose from the blood can also be converted into G-6-P. The process of glycolysis then converts G-6-P into pyruvate; these reactions produce 2 ATPs and add a proton (H+) to NAD+, producing NADH (Robergs et al. 2004). The process of adding a proton is also described as reduction; removing a proton as oxidation. Oxidation also describes reactions that use oxygen; pyruvate can either be immediately oxidized by the mitochondria (via the citric acid cycle and the electron transport chain), generating additional ATP molecules, or converted into lactate by the enzyme lactate dehydrogenase (Connett and Sahlin 2011). Note that these metabolic...
pathways produce pyruvate and lactate rather than pyruvic acid and lactic acid (Lindinger et al. 2005).

Importantly, lactate dehydrogenase can also convert lactate back to pyruvate, and the resulting molecule can be fully oxidized in the mitochondria. At least five LDH isoforms have been identified that differ in their affinity for lactate and for pyruvate (Draoui and Feron 2011). For instance, LDH 1 preferentially converts lactate into pyruvate, whereas LDH 5 preferentially converts pyruvate into lactate. Lactate can thus be considered a metabolic cul-de-sac rather than a metabolic dead-end.

A common misconception is that oxygen availability is the most important determinant of pyruvate’s fate - mitochondrial oxidation when oxygen is available, lactate when oxygen is lacking. However, it has been known for over 50 years that resting muscle produces lactate in the presence of oxygen, and that oxygen consumption (as measured by the arterio-venous oxygen difference) is not correlated with the amount of lactate released (Andres et al. 1956). Moreover, oxygen availability is rarely limited in healthy individuals, even during intense exercise (Wigmore et al. 2008, Breslav et al. 2000). Indeed, the LDH enzyme has a very high affinity for pyruvate, so high that some investigators believe that lactate is always the end-product of glycolysis (Rogatzi et al. 2015, Schurr and Gozal 2011).

**Thus, cells make lactate (not lactic acid) even when oxygen is abundant.**

**What Causes Lactate Accumulation?**

If oxygen abundance is not the determining factor of lactate accumulation, what is? The answer lies in the relative activity of the glycolytic and oxidative pathways (Connett and Sahlin 2011). In order to be oxidized by the mitochondria, pyruvate must first diffuse into the mitochondrial matrix, where the enzyme pyruvate dehydrogenase (PDH) initiates its entry into the citric acid cycle. PDH is the rate-limiting step in mitochondrial oxidation. However, the LDH enzyme is both abundant and high-affinity, so it frequently intercepts newly synthesized pyruvate molecules and converts them into lactate. The longer the pyruvate remains in the cytosol, the greater the chance of an encounter with LDH. So, it makes sense that more lactate will be produced if mitochondrial oxidation cannot keep up with the pace of glycolysis. Indeed, studies show that lactate production increases linearly with the rate of glycolysis, which, in turn, varies according to the rate of glycogenolysis (glycogen conversion to G-6-P) (Parolin et al. 1999). Thus, the high levels of glycolysis that occur in intense exercise result in lactate accumulation. Conversely, mitochondrial activity is comparatively low at the beginning of exercise and in hypoxia; these situations similarly result in lactate accumulation. Type II (glycolytic; fast-twitch) muscle fibers have both extremely rapid glycolytic enzymes and a relative paucity of mitochondria, so it makes sense that they are net producers of lactate (Dubouchaud et al. 2000).

At the enzymatic level, lactate levels reflect the balance between the activities of glycogen phosphorylase (which determines the rate of glycogenesis) and/or phosphofructokinase vs. pyruvate dehydrogenase (PDH) (it produces acetyl CoA) (Parolin et al. 1999). All of these enzymes are regulated. For instance, PDH is inactivated by PDH kinase (phosphorylation) and activated by PDH phosphatase (dephosphorylation). These enzymes are regulated, in turn, by various measures of energy requirements, such as sarcoplasmic calcium levels, the ATP/ADP ratio, and the amount of pyruvate.

**Thus, lactate concentrations reflect the relative rates of glycolysis and mitochondrial oxidation, which, in turn, reflect substrate availability and enzyme activity.**

**Why Do Cells Make Lactate?**

If lactate is indeed a metabolic cul-de-sac, what purpose does it serve? In other words, how does it benefit cells to convert pyruvate into lactate instead of simply accumulating pyruvate? First, lactate production enables cells to maintain a high level of glycolysis. Recall that glycolysis requires a steady supply of NAD+, which it converts to NADH. The conversion of pyruvate to lactate restores NAD* by removing the proton (H+), thereby ensuring continued glycolysis (Rogatzi et al. 2015). Mitochondrial activity (more specifically, the electron transport chain) also converts NADH into NAD+. So, when mitochondrial activity is not keeping pace, lactate production prevents NAD+ depletion and thus enables continued glycolysis.

Lactate production may also protect cells, since it does not use oxygen and thus does not generate reactive oxygen species (ROS) (Haran and Gross 2014). Conversely, high levels of mitochondrial activity generate large amounts of damaging ROS. So, glycolysis and lactate production may be favoured when cells need ATP quickly (during intense exercise) and in cells that are particularly sensitive to ROS damage, such as quiescent stem cells.

As discussed in the next section, lactate may also participate in metabolic shuttles - systems of enzymes and transporters that facilitate the movement of a particular substance from one compartment to another. Lactate facilitates the movement of energy between intracellular compartments and between cells. In addition to the LDH isoforms mentioned earlier, lactate shuttles also involve monocarboxylase transporters (MCTs) (Draoui and Feron 2011). Four MCT isoforms cotransport lactate and hydrogen ions, but differ in their affinity. MCT 1 and MCT 2 are high affinity, low-capacity transporters that likely mediate lactate uptake into cells; they also transport pyruvate. MCT 1 expression is widespread in the heart, skeletal muscle, erythrocytes, and the liver, while MCT 2 is primarily localized in neurons. Conversely, the lower affinity, higher capacity MCT 4 most likely mediates lactate export; it is most abundant in highly glycolytic cells and upregulated by hypoxia.
Thus, lactate is a valuable participant in the metabolic pathways that generate ATP.

**LACTATE AS A PORTABLE SOURCE OF ENERGY**

Once produced, lactate is not a dead-end waste product that must be eliminated to restore homeostasis. Instead, most of the lactate is eventually oxidized to produce ATP (Brooks 2007). **Indirect oxidation** involves the conversion of lactate-derived pyruvate into glucose (gluconeogenesis) by the liver or kidney before it is oxidized. The process of **direct oxidation**, conversely, converts lactate back into pyruvate that is then oxidized by the mitochondria. Direct oxidation can occur in the producing cell, in neighbouring cells of the same organ, and in completely different organs. Direct oxidation accounts for about 75% of the produced lactate in untrained individuals, but up to 90% in trained individuals (Emhoff et al. 2013). The processes of indirect and direct oxidation are further discussed below.

**Indirect Oxidation: The Cori Cycle**

Much of the lactate extracted by the kidney and the liver is used to make glucose; this response is reduced by intense exercise, probably reflecting reduced circulation (Nielsen et al. 2002). In healthy, post-absorptive humans, the relative contributions of the liver and kidney are about 75:25; lactate is the most important precursor (Meyer et al. 2002). This proportion changes to 55:45 under starvation conditions, with lactate contributing about 50% of the total substrate (Owen et al. 1969).

**Direct Oxidation: The Intracellular Lactate Shuttle**

The possibility of direct oxidation of lactate within the producing cell was discounted for years because of two theoretical barriers: the kinetics of the lactate-pyruvate reaction, and the lack of detectable LDH within the mitochondria (Cruz 2012). Thus, lacking an explanation of how lactate could be converted back into pyruvate within the producing cell, investigators assumed that the lactate either accumulated within the cell, causing damage, or was exported into the bloodstream. Recent work, however, has partially or completely addressed these two concerns.

First, the kinetics of the pyruvate-lactate reaction in the cytosol strongly favour lactate production from pyruvate, not the inverse. To address this issue, Brooks (2009) proposed that the cytosol was effectively compartmentalized into lactate-producing and lactate-consuming regions. The mitochondria act as a pyruvate sink, maintaining a steep pyruvate concentration gradient that allows lactate-to-pyruvate conversions. So the lactate to pyruvate conversion will be favoured closer to the mitochondria; the pyruvate to lactate reaction farther away.

Second, many investigators failed to detect the presence of LDH within the mitochondria. Brooks and colleagues proposed that mitochondria themselves import lactate, convert it to pyruvate via a mitochondrial LDH isoform, and oxidize it (Hashimoto et al. 2006, Hashimoto and Brooks 2008). The mitochondrial LDH had similar profile to cytosolic LDH (Brandy et al. 1987). This proposal was, however, met with considerable skepticism, and numerous investigators published studies that failed to observe any mitochondrial oxidation of lactate (reviewed by (de Cruz et al. 2012)). Brooks resisted all attacks, claiming that their negative results reflected methodological inadequacies (Hashimoto and Brooks 2008). Mitochondria are not discrete organelles in skeletal muscle; they are better described as a reticular tubular network (Kirkwood et al. 1986) and are thus very difficult to study.

Indeed, recent work has validated a modified version of the intracellular lactate shuttle hypothesis (Figure 2). Both Jacobs et al. (2013) and Elustondo et al. (2013) were able to observe mitochondrial oxidation of lactate in the absence of any cytosolic enzymes. However, in contrast to the original model, both determined that the LDH enzyme was localized in the intermembrane space and on the inner surface of the outer mitochondrial membrane rather than in the matrix. Thus, lactate diffuses passively across the outer mitochondria membrane, is converted by LDH found in the intramembrane space, and the resulting pyruvate crosses the inner membrane via a mMCT into the matrix for oxidation. This mechanism suggests that mitochondria in skeletal muscle are capable of importing lactate, converting it into pyruvate, and using the pyruvate for oxidative phosphorylation. In other words, *skeletal muscle mitochondria can oxidize lactate to generate ATP*. Kane (2015) argues that lactate production is actually necessary for adequate electron shuttling during mitochondrial activity (the lactate-malate-aspartate shuttle), but this hypothesis remains preliminary.

Thus, lactate can be directly oxidized by the producing cell, but the pathways involved have not been fully elucidated.

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**Figure 2.** Intracellular lactate shuttles. Lactate can be produced and utilized within the same cell.
Direct Oxidation: Intercellular Lactate Shuttles

If the intracellular lactate shuttles cannot keep up with the pace of glycolysis, the rise in intracellular lactate concentration creates a concentration gradient that favors lactate export via the MCT 4 protein described earlier (Figure 3). For instance, while both lactate release and uptake increase as activity levels increase, glycolytic fibers (fast-twitch, type IIx) are net lactate producers at high activity levels (reviewed by Adeva-Andany et al. 2014). Nearby oxidative fibers (slow-twitch, type I or IIa) can take up lactate from the interstitial fluid. Importantly, lactate uptake, unlike glucose uptake, is insulin-independent. Training increases the ability of muscle cells to take up and lose lactate; the expression of both MCT 1 and LDH 1 are upregulated (Dubouchaud et al. 2000). Inactivity, conversely, reduces the expression of MCT 1 (Wilson et al. 1998). Moreover, a polymorphism of the MCT1 gene that decreases its activity is less common in elite Russian rowers than in the general population (Fedotovskaya et al. 2014).

Released lactate can also diffuse into the blood stream for wide distribution in the body. While lactate dissolves easily in plasma, approximately 1/3 of circulating lactate is imported into red blood cells via the MCT 1 (Garcia et al. 1994). Blood-borne lactate can be used by other tissues for energy, including other skeletal muscle cells (Adeva-Andany et al. 2014). Similarly, cardiac muscle cells also release and take up lactate (Stanley 1991), even in the absence of ischemia (Bergman et al. 2009). At rest, the heart takes up more lactate then it releases, accounting for about 4.9% of total body lactate uptake (Bergman et al. 2009).

The central nervous system provides a fascinating model system of the utility of lactate as an energy intermediate. Neurons face enormous challenges in terms of energy production and delivery. Their energy requirements can vary 7-fold between rest and intense activity; this increase can deplete their ATP store in seconds (Attwell and Laughlin 2001). But, unlike other metabolically active tissues, they cannot store energy in the form of glycogen or triglycerides. Not only do they lack the physical space, but glycogen is actually toxic to neurons (Vilchez et al. 2002). Reliance on blood glucose is also problematic, because the neurons are separated from blood glucose by at least two cells: astrocytes and endothelial cells (Barros 2013). This situation is exacerbated in white matter axons, which also have their wrappings of oligodendrocytes but nevertheless require large amounts of ATP to fuel the Na-K-ATPase and other processes.

The quintessential support cell, the astrocyte, may provide a solution to neurons' metabolic conundrums (Figure 4). According to the astrocyte-neuron lactate shuttle (ANLS) hypothesis, these glial cells may act as energy buffers by storing glycogen (Baltan 2015). But, instead of releasing glucose, they release lactate that can then be taken up and oxidized by neurons. While there is not universal acceptance of this hypothesis (see, for instance, (Chih and Roberts Jr 2003)), both structural and functional studies support the existence of the ANLS, at least in some brain areas (Hertz 2004, Baltan 2015). As shown in Figure 4, astrocytes preferentially express the LDH isoform that converts pyruvate to lactate (LDH5) and the transporter that exports lactate (MCT4). Neurons, conversely express the isoforms enabling lactate uptake (MCT2) and conversion into pyruvate (LDH1) (Bröer et al. 1997, Bittar et al. 1996, Brown et al. 2003). Lactate may constitute up to 33% of the energy substrate for the brain (van Hall et al. 2009, Overgaard et al. 2012).

The Astrocyte-Neuron Lactate Shuttle Hypothesis

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Accumulating evidence also supports the physiologic relevance of the ANLS. As reviewed by Fryer and Brown (2015), work in mouse optic nerve preparations has shown that astrocyte glycogen stores provide neurons with needed supplemental energy in the form of lactate when available glucose cannot meet metabolic demands. So, astrocytic glycogen supports neighboring axons under conditions of low glucose or increased activity. In the rat hippocampus, blocking astrocyte glycogenolysis, astrocytic lactate export, or neuronal lactate import inhibits long-term memory formation (Newman et al. 2011, Suzuki et al. 2011). Schwann cells may perform a similar function in peripheral nerves; they contain glycogen and support axon conduction in low-glucose conditions (Brown et al. 2012).

Thus, lactate provides a useful and portable source of energy for skeletal and cardiac muscle as well as neural tissue.

THE LACTATE THRESHOLD

As discussed above, the amount of lactate in the interstitial fluid and blood reflects the balance between systemic lactate production and lactate uptake. During steady state exercise at low intensity levels, virtually all of the lactate produced is oxidized by the producing cell or by a different cell, so blood lactate levels remain constant. The lowest intensity level at which lactate levels rise in blood is known as the onset of blood lactate accumulation (OBLA); the maximal exertion level above which lactate levels increase sharply is the maximal lactate steady state (MLSS) (Faude et al. 2009). These terms are often described as the “aerobic threshold” and “anaerobic threshold” (respectively), reflecting the misconception that lactate production is confined to anaerobic conditions. But, when interpreted in the context of our modern understanding of lactate physiology, the MLSS may still provide a useful method of predicting performance and evaluating training gains. At the MLSS, lactate clearance becomes limited (Messonnier et al. 2013).

Theoretically, an increased MLSS reflects changes that would benefit performance, such as increased mitochondrial capacity in the working muscles, increased capillarization, which would decrease lactate production, and/or increased lactate uptake and oxidation in other tissues. Accordingly, MLSS and OBLA correlate strongly with maximum aerobic power and endurance performance (Joyner and Coyle 2008, Lucia et al. 200, Beneke et al. 2011). These measures can also measure training-induced changes in endurance. Endurance training increases lactate thresholds; it reduces the blood level of lactate associated with a particular workload. In other words, the lactate curve shifts to the right (Jones 2006, Jones and Carter 2000). While this finding could suggest that trained individuals generate less lactate, it appears that the opposite is true; endurance training increases the capacity for both lactate production and lactate clearance (Messonnier et al. 2013).

However, it should be noted that most studies have been done in runners; the links are not as consistent in cyclists, and even less so in other sports (Faude et al. 2009). For instance, studies in elite cyclists have noted improved endurance without a change in lactate measures (Westgarth-Taylor et al. 1997), and MLSS was not associated with endurance performance in recreational cyclists (Smekal et al. 2012) and even varies with cycling cadence (Beneke and Leithäuser 2016).

Thus, lactate measures can be used to predict future performance and to analyze past training practices, but must be interpreted with caution.

LACTATE-ASSOCIATED ACIDOSIS AND MUSCLE FATIGUE

Associated with lactate’s reputation as a metabolic waste product is its potential involvement in muscle fatigue. The ability of myofibrils to generate force depends on a myriad of upstream events and requires the concerted actions of multiple body systems for optimal functioning. It is thus not surprising that muscle fatigue is both task-specific and physiologically complex.

Fatigue at the level of the organism has been described by two different models. The classic, catastrophic model stipulates that fatigue in endurance exercise represents the failure of homeostasis, resulting from accumulation of lactic acid (for instance) or glycogen depletion (Hill et al. 1924). This model still resonates with many to this day. An alternative “central governor” model has more recently been developed by Noakes and colleagues, which stipulates that the brain controls the output to muscles to prevent such a catastrophic failure (Noakes 2012, Noakes 2011). Fatigue is thus an unpleasant perception of discomfort that eventually leads to decreased intensity or task termination. In support of this hypothesis, Baron et al. (2008) actually observed a decrease in arterial lactate and acidity as subjects approached exhaustion. Factors such as motivation, body temperature, and fuel reserve size are all subconsciously considered as the brain modulates output to the muscles (St Clair Gibson and Noakes 2004). This model is supported by the task-specific nature of muscle fatigue. For instance, performing half-squats provokes greater fatigue than cycling, even when both exercises are performed at the same intensity level (Garnacho-Castaño et al., 2014).

Depending on the model, changes at the level of the individual muscle fiber could either contribute sensory information to the “central governor” or act within the muscle fiber itself to inhibit function. Support for the latter comes from studies in isolated muscle fibers. During each cross-bridge cycle, ATP cleavage results in ADP, inorganic phosphate (Pi), and hydrogen ions. As reviewed by Keyser (2010), all three of these substances have been shown to directly inhibit cross-bridge formation. A second negative feedback loop functions at the level of excitation-contraction coupling. Pi reduces Ca2+ release from the sarcoplasmic

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reticulum, and H+ reduces the affinity of troponin for Ca2+ (Debold et al. 2016). However, implicating acidity in muscle fatigue does not automatically implicate lactate, since exercise-induced acidosis is multi-factorial. ATP hydrolysis itself generates free protons (Keyser 2010). Moreover, other investigators propose a different model of exercise-induced acidosis, in which decreased pH reflects a combination of three factors: the partial pressure of carbon dioxide, the concentration of weak acid buffers, and the strong ion difference (Gladden, 2004).

Lamb and Stephenson (2006) go a step further, hypothesizing that lactate and/or acidity may actually facilitate contraction rather than inhibit it. Their review summarizes numerous studies that failed to observe any deleterious effect of lactate ions or protons. Moreover, both may protect against the inhibitory effect of increased extracellular potassium levels (de Paoli et al. 1988). The deleterious effect of lactate ions or protons. Moreover, both may protect against the inhibitory effect of increased extracellular potassium levels (de Paoli et al. 2007). There are, nevertheless, several recent studies that argue for at least a permissive role for lactate in muscle fatigue. Injections of lactate, ATP, and protons together (but not individually) invoke sensations of pain and fatigue in a dose-dependent manner in humans (Pollak et al. 2014) and rats (Gregory et al. 2015).

Fatigue, then, is a multifactorial and task-specific phenomenon that has a significant central component. Lactate may be one of many signals indicating that the exercise intensity and/or duration are approaching levels that could be injurious to the individual.

EXCESS POST-EXERCISE OXYGEN CONSUMPTION (EPOC) AND LACTATE

“Lactic acid builds up, which causes muscle fatigue due to oxygen debt. This is overcome by deep breathing to oxidise the acid. After the exercise is finished, extra oxygen is needed by the liver to remove the lactic acid” (https://revisionworld.com/gcse-revision/biology/human-body/breathing-respiratory-system). This out-dated extract from Biology GCSE curricular materials in the United Kingdom reflects the landmark work by Hill and colleagues in the early 20th century; they developed the concept of oxygen debt to account for the increased oxygen consumption post-exercise (Hill et al. 1924). Based primarily on work in amphibians, they postulated that the extra oxygen was needed to convert the lactic acid produced during intense exercise back into glucose and eventually glycogen. So, the oxygen debt served to pay back the oxygen deficit incurred by lactic acid generation. Later investigators divided the oxygen debt into a fast alactic component, representing replenishment of creatine phosphate and ATP stores, and a delayed lactacid component, involving lactic acid removal (Margaria et al. 1933).

However, work by Brooks and colleagues effectively revealed the limitations of the oxygen debt model in humans (see Gaesser and Brooks 1984 and figures therein). Perhaps the most damning evidence is the significant discrepancy between lactate removal kinetics and the pattern of oxygen consumption. Moreover, as discussed earlier, between 75-90% of produced lactate is oxidized, with the remaining 20% serving as carbon skeletons for amino acids and citric acid cycle intermediates as well as glucose/glycogen (Gaesser and Brooks 1984). Based on these and other findings, Brooks et al. recommended that the terms oxygen debt, lactacid debt, and alactacid debt be replaced a new term that did not imply a causal link between lactate production and post-exercise oxygen consumption. They developed the excess post-exercise oxygen consumption (EPOC) to account for the increased metabolism that occurs in the minutes, hours and even days following intense endurance or resistance exercise (Brooks et al. 1971).

As summarized by Borsheim and Bahr (2003), the metabolic processes responsible for EPOC depend on both the nature of the exercise and the experimental protocol. There is general consensus that the rapid and prolonged stages suggested by Margaria et al. (1933) are still valid; the rapid phase reflects processes such as the replenishment of ATP, creatine phosphate, and oxygen stores in muscle cells as well as the increased metabolic load associated with the increased temperature and the increased breathing rate itself (reviewed by Borsheim and Bahr, 2003). The prolonged phase, which may last hours or even days, is thought to reflect the increased metabolic cost of incorporating fatty acids liberated during exercise into triglycerides (Bahr et al. 1990) and the shift from carbohydrates to fats as the primary energy substrate (Binzen et al. 2001). Under certain conditions, the prolonged phase may also reflect processes such as glycogen resynthesis, the increased protein breakdown and synthesis associated with muscle damage and healing (Viru 1996), increased expression of uncoupling proteins, and exercise-associated increases in metabolic accelerating hormones such as GH, thyroid hormone and cortisol (Ronsen et al. 2001).

Thus, the deep breathing that follows intense exercise does not serve to eliminate lactate. Instead, it enables lactate and other energy sources to fuel the increased metabolic needs post-exercise.

CONCLUSION

The lactate story deserves our attention for its relevance to biochemistry and exercise physiology, and while not discussed in this review, for its potential implication in cancer treatments (Adeva-Andany et al. 2014, Draoui and Feron 2011). Of equal interest is its illustrative power regarding the often ignored subjective aspects of science. For instance, the attribution of a primary causative role for lactate in muscle fatigue is an excellent example of the seductive power of causation; at best, lactate is likely to be only one of many factors. The persistence of beliefs such as hypoxia as a primary instigator of lactate production and of lactate’s reputation as a metabolic waste product indicates the pervasive power of habits of mind, “entrenched responses that ordinarily occur without...
conscious attention and that, even if noticed, are hard to change” (Margolis, 1993). Fifty years of evidence supports the hypothesis that lactate is a useful and portable energy source that is produced even when oxygen is abundant, yet misconceptions persist on the internet (e.g. https://en.wikipedia.org/wiki/Lactic_acidosis), in peer-reviewed journals (e.g. Luft 2001)), in national curricular materials (NGSS Lead States, 2013) and, perhaps, even in our courses.

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Lactate: Toxic Villain or Metabolic Superhero?


Sleep: I Need How Much??

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Abstract
The National Sleep Foundation (NSF) convened an 18-member multidisciplinary expert panel, representing 12 stakeholder organizations, to evaluate scientific literature concerning sleep duration recommendations. The Human Anatomy & Physiology Society, as one of the stakeholders, appointed me as its liaison to this NSF Sleep Time Requirements Expert Panel (STREP). The STREP was comprised of both sleep experts and experts in other areas of medicine, physiology, and science. The objective was to conduct a scientifically rigorous update to the National Sleep Foundation’s sleep duration recommendations, which are reviewed every decade. We determined expert recommendations for sufficient sleep durations across the lifespan using the RAND/UCLA Appropriateness Method (RAM). In this article I report the methodology and outcomes of the STREP study and offer suggestions to evaluate sleep in college students.

Key Words: Sleep, sleep time recommendations, sleep duration, National Sleep Foundation, college sleep

Introduction
Sleep generally is of little concern to people until it becomes worrisome. The most common problems are trouble falling asleep, waking up for no evident cause, trouble maintaining continuous sleep time, inconsistent sleep patterns, insomnia, sleep apnea accompanied by snoring, and poor sleep quality. People with sleep problems such as these might go to the National Sleep Foundation (NSF) website, sleepfoundation.org, or seek assistance from their physicians when it becomes clear to them that sleep disturbances are really medical issues that may be impinging on their health.

The mission of the NSF, through sleep health education and advocacy, is to improve health and well being. Millions of individuals each year seek direction about sleep duration sufficiency from the NSF website. These recommendations are widely cited and distributed by many organizations.

There is a large body of sleep clinicians whose total focus is on studying sleep and helping patients remediate sleep problems through clinical sleep studies. However, the methods for studying sleep and obtaining consistent data are diverse so that comparisons of sleep times between people of different age groups become very difficult.

The NSF-assembled Sleep Time Expert Panel (STREP) study encompassed analysis of the primary literature, with a search focusing on nine age groups, from newborns through older adults, 65+ years of age. The tool utilized by the panel was the RAND/UCLA Appropriateness Method [RAM] (Fitch et al. 2001), which was developed in the mid-1980s, as part of the RAND Corporation / University of California Los Angeles Health Services Utilization Study (Figure 2). The RAM is primarily an instrument to enable the measurement of the overuse and underuse of medical and surgical procedures. Typical sleep studies might utilize actigraphy (sleep motion and other parameters), polysomnography (principally electroencephalography, EEG), or sleep diaries. And therein is “the rub” - multiple study designs, which are not data-consistent across sleep research studies, are often difficult to compare reliably.

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Randomized clinical trials are the “gold standard” for evidence-based medicine but are often either not available or cannot provide evidence at a level of detail sufficient to apply to the wide range of patients seen in everyday clinical practice. In the absence of widespread clinical trials across all age groups and life spans, Sackett et al. (1996) explain that “integrating individual clinical expertise with the best available external clinical evidence from systematic research” defines the RAM method. This is what drove our research approach. The RAND/UCLA Appropriateness Method (RAM) thus combines the best available scientific evidence with collective expert judgment to yield a statement regarding the appropriateness of a recommendation (Hirshkowitz et al. 2015a, 2015b). Panelists received all 312 full-text articles, score sheets, and instructions by mail and electronically.

**Methods**

*Literature Searches, Judgment, and Voting*

**Literature Searches**

A search team, whose members were non-voting, established a Pub-Med database search over three months, utilizing multiple strategies encompassing multiple search terms, alone and in combination, to identify highly-relevant medical reports. The inclusion criteria required an abstract within each published paper to describe a normal population under normal conditions. Fifty-eight searches using combinations of search terms related to sleep (e.g., time, duration, and sufficiency), age groups (e.g., newborn, adolescent), and outcomes (e.g., performance, executive function, cognition) yielded 2,412 articles.

**Judgment**

A second group, the review team, identified 575 articles for full-text review. Of the 575 articles, 312 met our inclusion criteria. Pertinent information (e.g., sample size, study design, results) from each article was extracted and included in the literature review materials. Articles were sorted based on the strength of the study and presented in descending order in a summary chart. These full-text papers were then distributed to the 18 panelists for review over several months’ time. Many of the panelists were physicians specializing in sleep medicine. Panelists rated overall health as well as cognitive, physical, and emotional health for each of the nine age groups agreed upon:

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Figure 3: The RAM modified Delphi methodology

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Voting

Ballots were developed by the NSF team, to allow the expert panelists to apply the “best scientific evidence” and principles of “collective expert judgment” to apply a rating for each age group. Panelists also noted whether their individual scores were based on convincing scientific evidence, weaker scientific evidence, expert opinion, or their own experience (Figure 4).

STREP panelists rated each of the indications twice, in a two-round “modified Delphi” process that consisted of a face-to-face interactive discussion and voting among panelists. The typical Delphi method uses voting and consensus strategy without the face-to-face component. In the first round, the ratings are made individually at home, with no interaction among panelists. In the second round, the panel members met for one day under the leadership of a moderator experienced in using the method. Each panelist received an individualized document showing the distribution of all the experts’ first round ratings, together with his/her own specific rating. During the meeting, panelists discussed the ratings, focusing on areas of disagreement, and were given the opportunity to modify the original list of indications and/or definitions, if desired. After discussing each age group, panelists re-rated each indication individually. No attempt was made to force the panel to consensus. Instead, the two-round process was designed to sort out whether discrepant ratings were due to real clinical disagreement over the use of the procedure (“real” disagreement) or to misunderstanding as an “artefactual” disagreement (Fitch 2001).

The votes by the panel members were based on three criteria as iterated by the RAM. **Appropriateness** refers to the relative weight of the benefits and harms of a medical or surgical intervention, namely the potential benefits exceeds the expected negative consequences. For **inappropriate**, the expected negative consequences exceed the expected health benefits, or **uncertain**, no evidence of a positive or negative benefit based on the data in the 312 papers or judgment of the expert panelists.

“Appropriateness” was solidified during the 2nd round, face-to-face meeting of the STREP panel as follows:

A **median** of 7-9 with agreement among the panelists was judged to be appropriate.

“Uncertain” was a collective decision that included “May be appropriate for some people”. It had a **median** vote of ≥ 4 and it was the category for any median with which there was disagreement.

“Unlikely to be appropriate” or Inappropriate was assigned when the panel **median** was 1-3 without disagreement among the panelists.

Each sleep duration was classified as one of the following (column 4): **Ag** (Agreement), “Agreement” was reached when 80% (15 out of 18 panelists) voted within any 3-point range (1-3, 4-6, or 7-9). There was “Disagreement” when more than 20% (4 or more panelists) vote outside of any 3-point range.

“Evidence” categories, column 3, are **A** convincing scientific evidence, **B** weaker scientific evidence, **C** expert opinion, and **D** own experience.

Figure 4: The author’s round one (“at home”) STREP ballot - a small portion of it for young adults. Light blue circle, my vote; superscripts above the 1-9 rating scale, STREP panelist scores; red shading, **Inappropriate**; green shading, **Appropriate**; yellow shading, **Uncertain**.

**Newborn: 0-3 months**

**Preschooler: 3-5 years**

**Young adult: 18-25 years**

**Infant: 4-11 months**

**School-age: 6-13 years**

**Adult: 26-64 years**

**Toddler: 1-2 years**

**Teenager: 14-17 years**

**Older adult: ≥65 years**
Results
In the face-to-face voting rounds, the panelists discussed aspects of sleep duration for each of the nine age groups. The ballot itself was comprehensive to allow for sleep time duration influence on overall health, cognitive health, and emotional health. Diminished sleep time affected all three health states, especially in individuals who were older than preschoolers.

The STREP agreed that there are sleep time hours that are appropriate for health and well-being, possibly acceptable hours (e.g. those hours that may be appropriate for some individuals), and hours that are not recommended (e.g. those hours that experts agree are not likely conducive for health and well-being). The sleep time recommendations are shown in Figure 5.

Discussion
The panel did not distinguish between routine nighttime sleep durations and naps, but rather the total sleep time. The panel did distinguish between time in bed and actual time asleep which can be very different.

The NSF undertook this study to keep up-to-date with the sleep literature published in the decade since sleep was last investigated and reported on in 2004. In all nine age groupings, panelists discussed aspects of sleep times that should be reviewed with caution (Hirshkowitz et al. 2015a, Hirshkowitz et al. 2015b). Within each group there can be great disparity in sleep “needs”. This disparity can be attributed to people just being different. Some persons with shorter sleep times can show no ill effects. In contrast, there is evidence to suggest that “too much sleep” can be detrimental. In older adults, 65 years and older, there is increased morbidity associated with sleep beyond nine hours per day. Long sleep duration could interfere with toddlers as they explore their physical and social environment and thereby impede motor, cognitive, and social development (Hirshkowitz et al. 2015b).

Watson et al. (2015) performed a consensus panel study but their focus was on healthy adults 18 to 60 years only. The STREP report (Hirshkowitz et al. 2015a, Hirshkowitz et al. 2015b), which was endorsed by the Human Anatomy & Physiology Society and formed the basis for this paper, was far more comprehensive and examined groups of humans across their lifespan.

Major life transitions within groups can upset sleep time. Two of my points posed to the other panelists regarded changes in sleep needs by those people moving into puberty or through menopause. I suggested that the NSF might wish to revisit the way that the age groups were established. Some of the sleep experts concurred.

The panel also discussed the importance of sleep hygiene: the role played by habits and practices that are conducive to establishing restful sleep on a regular basis. Making the bedroom quiet, cool, and soothing enhances easing into restful sleep. Our demand for instant contact with others through wireless devices and phones has moved many people into less restorative sleep behaviors by not allowing a “calm down” period of a half-hour or more before bedtime.

Applications
Among college students, many show what I call “phone busy” behaviors; texting, surfing the internet, earbuds in place while they are listening to music, updating / accessing social media frequently, and any combination of these. This is easily observed in students emerging from classrooms with one hand on a backpack strap and the other holding a smartphone. In an informal poll of my students, few shut their smartphones off prior to sleep. These are factors that
contribute to poor sleep habits among college students and may prove to be a major impairment to student success among millennials.

Sleep deprivation among college students is acute with more more than 70% of students reporting that they sleep less than 8 hours a night (Lund et al. 2010). Prior to our work (Herschkowitz et al. 2015a, 2015b), this might not have counted as sleep deprivation because we showed that between 7 and 9 hours is appropriate for this age group (18 to 65+ years of age).

Daytime sleepiness is reported in 50% of college students compared to 36% of adolescents and adults (Oginska and Pokorski 2016). This may be partly explained in the shift in the circadian period that occurs in adolescents to about 24.3 hours versus 24.1 for adults (Crowley et al. 2007). College students also demonstrate a 1–3 hour sleep deficit on school nights, but they may make it up on weekends, which allow for longer sleep duration and a later wake time (Hansen et al. 2005).

There are recent reports about sleep studies on college-age students that show sleep delays have a direct effect on grade point average, reduced studying efficiency, and memory consolidation. There is an association between insufficient sleep and slowed reaction time, impaired immune function, increased risk of infection, compromised memory function, and the ability to learn (Hershner 2015). Certain types of learning and memory are known to require sleep. Pulling an “all-nighter” may mean the student’s performance might never catch up from that episode of sleep loss (Stickgold et al. 2000).

Sleep before learning may also be necessary. In a study performed by Mander in 2011, subjects were tested after 35 hours of sleep deprivation via an episodic memory-encoding task followed by a recognition test 48 hours later. Memory performance was approximately two letter grades or 19% worse when compared to the non-sleep-deprived subjects (p=0.031; Mander et al. 2011). Granted this much sleep deprivation is atypical, but it nevertheless points out the importance of sleep and in memory consolidation.

Sustained wakefulness can impair performance. Mander et al. (2011) showed also that in another episodic memory task (face and name recognition) there was significant deterioration at 6:00 pm in all subjects, except those who had had a 100-minute nap. In those subjects, not only was performance deterioration halted, but it was also improved.

Hershner and Chervin (2014) offer some remedies for sleep problems experienced by college students including: extracurricular educational programs, sleep courses, scheduling classes at later times (avoid “8 o’clock” classes?), student-centered public health outreach programs, adequate evaluation and screening for sleep disorders, and encouraging naps via educational programs or availability of “nap rooms”.

There are sleep problem resolutions already in place that make nap access available to college students. These include James Madison University’s “Nap Nook”, Savannah College of Art and Design & Texas A&M and their high-tech “Energy Pods” at their Savannah, Atlanta, and Hong Kong campuses, and the University of Michigan’s Ann Arbor campus which features “the nap room”, open 24/7 with cots available for a maximum of 30 minutes per user (National Sleep Foundation 2016).

Conclusions

Sleep durations far outside the normal range should raise concern. Excess or restricted sleep duration may be produced by or result from serious problems that affect health and well being and this requires serious assessment. If an individual purposefully restricts his or her sleep, as in the case of college students, he or she may benefit from education concerning sleep deprivation’s potential health, social, and legal consequences. For a substantive review and a good teaching tool about college students and sleep, see Hershner and Chervin (2014).

About the Author

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The Emerging Role of Partial Thickness Keratoplasty In Corneal Transplantation and Its Use in Fuchs’ Dystrophy

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Abstract
The past decade has seen a decline in the number of penetrating keratoplasty corneal transplants and an increase in less invasive partial thickness keratoplasty. The most common type of corneal transplantation surgery done in the US in 2014 was a partial thickness procedure known as Descemet’s Stripping (automated) Endothelial Keratoplasty (DMEK). The volume of this type of corneal transplant has been doubling each year since 2011. Twenty-two percent of corneal transplants in 2014 were performed for Fuchs’ Endothelial Corneal Dystrophy (FECD) and twelve percent were performed for edema occurring after cataract surgery. This article examines the shift in the preferred method of keratoplasty in the US and the widespread adoption of less invasive partial thickness keratoplasty procedures, using Fuchs’ Dystrophy as a representative eye disorder for which these less invasive procedures may be effective.

Key Words: partial thickness keratoplasty, Fuchs’ dystrophy, cornea, corneal transplantation

Introduction
The first successful corneal transplant was performed by Zirm in 1905 but most of the technological advances associated with corneal transplantation have come about in the last fifteen years as less invasive techniques of corneal transplantation have rapidly gained in popularity (Park 2015).

The Eye Bank Association of America (EBAA) monitors nearly all eye tissue distribution in the US. A total of 72,013 corneal grafts were distributed by the EBAA in 2014 and approximately 64,200 were used in the US for corneal transplantation (Park 2015). EBAA data from 1980 to 2004 indicate that at that time, ninety-five percent of corneal grafts were used for penetrating keratoplasty (PK). Over the past decade three new techniques; deep anterior lamellar keratoplasty (DALK), Descemet stripping (automated) keratoplasty (DSEK or DSAEK) and Descemet membrane endothelial keratoplasty (DMEK) have become very popular in the US for the treatment of corneal dysfunction (Park 2015).

The new less invasive techniques offer several general advantages over penetrating keratoplasty, notably a reduced risk for rejection, less procedure-related astigmatism and faster visual rehabilitation (Park 2015). In spite of a significant learning curve for the surgeon, the new partial thickness techniques have largely replaced penetrating keratoplasty.

The Cornea
The cornea is a complex, multilayered, transparent structure that forms the outer layer of the eye. It is judged to be responsible for 65-75% of the focusing power of the eye (NEI 2016). In humans the cornea is composed of five, or possibly six, layers. The layers of the cornea from anterior to posterior are:

1. Corneal epithelium
The corneal epithelium is made up of innervated, non-keratinized stratified squamous epithelium that is constantly moistened by tears. This layer makes up ten percent of the thickness of the cornea. The smooth curved surface of the cornea, as it comes in contact with the air, is a necessary component of the refractive capability of the eye. Distortion or edema of the cornea has a detrimental effect on visual acuity (NEI 2016).
2. Bowman’s Layer
Bowman’s layer, the anterior lining membrane, is located immediately deep to the basement membrane of the corneal epithelium. It is an acellular, protective layer composed of type I collagen fibrils (NEI 2016).

3. Stroma
The stroma or substantia propria makes up ninety percent of the cornea. Eighty-seven percent of the stroma is water into which approximately 200 layers of type I collagen fibrils and widely scattered keratinocytes are embedded. The stroma gives the cornea its strength and its characteristic dome shape (CRFA 2016, NEI 2016).

4. Descemet’s membrane
Descemet’s membrane is a thin, acellular layer made up of type IV collagen fibrils, which are less rigid that type I collagen. It functions as a barrier to injury and infection (NEI 2016).

5. Corneal endothelium
The innermost layer of the cornea, the corneal endothelium, is a layer of simple squamous cells that are rich in mitochondria. This layer functions to regulate the transport of fluid and solutes between the aqueous humor and the corneal stroma (NEI 2016).

6. In 2013, a sixth corneal layer located between the stroma and Descemet’s membrane, known as Dua’s layer, was hypothesized (Bailey 2013). The existence of this layer and its likely function remain under investigation.

**Corneal Endothelium**

The corneal endothelium, the cell layer responsible for corneal clarity, is the only tissue in which living cells can be directly observed under high magnification without disturbing the cells (Bourne 2010). Cells of the corneal endothelium are normally hexagonal in shape. As a result of the normal aging process, the size of cells in this monolayer increases, the total number of cells in the layer decreases, and the shape of the cells becomes more variable (Bourne 2016). Corneal endothelial cells are arrested in the G1 stage of the cell cycle and therefore they do not display mitotic activity (Bourne 2016). When these cells are subjected to the trauma of surgical procedures such as cataract removal, lens implantation or cornea transplantation, the density of this layer decreases.

Corneal endothelium functions as a barrier to fluid movement into the cornea and as an active transport pump to remove fluid from the stroma into the anterior chamber of the eye (Bourne 2016). Under normal conditions, fluid slowly leaks from the aqueous humor into the stroma. The primary function of the endothelium is to pump excess fluid out of the stroma, keeping the cornea thin and crystal clear (CRFA 2016). If the pumping action is compromised by disease or trauma, edema develops in the stroma and the stroma becomes hazy and ultimately opaque. Conditions that affect the corneal epithelium are problematic because the cells in this layer are not capable of regeneration. When cells die, other endothelial cells stretch to compensate for the dead cells. This ultimately reduces the overall cell density of the endothelium, which adversely influences the fluid regulation of the cornea. In the last decade, surgeons have attempted to limit endothelial cell loss by developing novel ways of handling the cornea (Bourne 2016).

**Types of Corneal Transplants**

**Penetrating Keratoplasty (PK)**

Penetrating Keratoplasty is a full-thickness corneal transplant in which a full-thickness section of the patient’s cornea is removed and replaced by a full-thickness corneal graft from a donor (Donaghy 2016). The donor graft is sutured into position using sutures placed with equal tension to minimize post-operative astigmatism. Sutures are selectively removed to reduce any astigmatism that may have developed (Donaghy 2016).

With the proper care, such a transplant can be expected to last for decades. Using a full-thickness graft, corneal disease can be effectively treated in the epithelial, stromal and endothelial layers at the same time. A full-thickness graft also eliminates the possibility of optical interface complications that can occur where a partial thickness donor graft contacts recipient tissue (Donaghy 2016).

Recovery time is relatively long following full-thickness graft surgery, sometimes requiring up to two years before optimal visual acuity is achieved (Vedana 2016). The patient may be required to wear rigid gas permeable contact lenses after surgery in order to correct astigmatism. Full-thickness grafts carry a higher risk of rejection than less invasive procedures and there is a lifetime risk of wound dehiscence, the rupturing of a wound along a surgical incision, due to weakness that results from the full-thickness surgery (Donaghy 2016).

Approximately twenty percent of PK grafts are ultimately rejected so it is not uncommon for patients to require more than one penetrating keratoplasty procedure (CRFA 2016).

**Deep Anterior Lamellar Keratoplasty (DALK)**

Deep Anterior Lamellar Keratoplasty is a partial thickness corneal transplant in which the corneal stroma is removed, leaving the patient’s own Descemet membrane and endothelium in place (Donaghy 2016). The donor graft is prepared from a full-thickness graft in which the donor Descemet membrane and endothelium have been removed. The donor graft is sutured into position with sutures that are selectively removed post-operatively to reduce astigmatism (Donaghy 2016).

DALK is used where the patient’s endothelium is healthy; for example, in cases where the cornea is scarred but the scars are do not penetrate to full-thickness and in dystrophies of
the corneal stroma (Donaghy 2016). The resultant wound is stronger than that of a full-thickness graft and the risk of rejection is lower than with a full-thickness graft (Donaghy 2016).

Surgery for DALK is more complex and more difficult than the surgery that is required for penetrating keratoplasty (Donaghy 2016).

**Descemet Stripping Automated Endothelial Keratoplasty (DSEAT)**

Descemet Stripping Automated Endothelial Keratoplasty is a partial thickness cornea transplant that requires the removal of the patient’s Descemet membrane and endothelium (Donaghy 2016). The donor graft, which is prepared using an automated microkeratome, consists of donor endothelium and donor stroma (Stuart 2014, Chen 2015, Donaghy 2016). The donor graft must be handled very carefully since any contact with surgical instruments will damage the graft and is likely to result in graft failure (Chen 2012, Donaghy 2016).

DSEAT is employed for endothelial dystrophies such as Fuchs’ dystrophy and for other types of endothelial dysfunction (Chen 2015, Donaghy 2016).

DSEAT is associated with relatively rapid healing time and sight is restored rapidly. There is less risk of graft rejection than with PK or DALK and fewer suture-related complications. Post-operative visual acuity is good but it may be limited by the effects of the stroma to stroma patient/graft interface (Chen 2015, Donaghy 2016).

**Descemet Membrane Endothelial Keratoplasty (DMEK)**

Descemet Membrane Endothelial Keratoplasty is a partial-thickness cornea transplant that involves the removal of the patient’s Descemet membrane and endothelium. The donor graft consists of endothelium and Descemet membrane. Direct contact with the DMEK graft must be avoided during the surgical procedure to prevent damage to the endothelial tissue that might result in graft failure (Chen 2015, Donaghy 2016). The graft is typically inserted into the patient’s eye via an incision in the cornea that is made using a small tool called an inserter. Once the graft is in the anterior chamber of the eye, the surgeon unscrolls and aligns the graft and a bubble of twenty percent sulfur hexafluoride is placed in the anterior chamber to support the proper adherence of the graft in place of sutures (Donaghy 2016).

DMEK is used for endothelial dystrophies such as Fuchs’ dystrophy and for other types of endothelial dysfunction (Donaghy 2016).

This procedure offers the most rapid return to normal vision for the patient of any of the keratoplasty techniques offered to date (Chen 2015, Donaghy 2016). Optical interface effects within the graft are minimal and there is a low rate of graft rejection because only a very small amount of tissue is transplanted (Donaghy 2016).

**Corneal Allograft Rejection**

Corneal transplantation has a high rate of success largely because the cornea, as an avascular tissue, is immune privileged. Rejection rates for penetrating keratoplasty are in the range of 17%. The rejection rates for the newer endothelial keratoplasty procedures are lower, with DMEK estimated to be as low as 0.7% and DSAEK in the range of 9% (Donaghy 2015). However, graft rejection still remains a significant cause of corneal graft failure. When a graft fails it becomes cloudy and pain, redness and decreased vision are present. Graft rejections can be reversed about 90% of the time when treated with topical corticosteroid medications (Donaghy 2015).

**Fuchs’ Endothelial Corneal Dystrophy (FECD)**

Fuchs’ Endothelial Corneal Dystrophy (FECD) is a disease that affects the corneal endothelium. It is a hereditary disease that is usually asymptomatic until after the age of fifty. If not treated, Fuchs’s dystrophy can result in loss of vision but the disease is expressed to varying degrees from mild to severe and loss of vision is not expected in cases where expression of the disease is mild (Vedana 2016, Zhang 2016). Treatment is often a corneal transplant.

Professor Ernest Fuchs described FECD more than 100 years ago as a pattern of symptoms he observed in elderly patients that included progressive clouding of the posterior surface of the cornea, diurnal variations in the function of the corneal endothelium that affected vision, and a reduction in the sensitivity of the cornea (Vedana 2016). The definitive finding for FECD is the presence of guttae, miniature fluid-filled spheres, in the endothelium. Guttae, which can be seen under specular microscopy, typically appear as dark, round areas in the corneal endothelium (Vedana 2016, Zhang 2016). Researchers were able to observe guttae, shortly after the condition was described. It has been suggested that guttae may originate from rough endoplasmic reticulum (Vedana 2016). Clinical signs of FECD include edema of the cornea, reduction of the density of corneal endothelial cells, thickening of Descemet’s membrane, the presence of guttae in the endothelium, abnormal size and shape of endothelial cells, and widely spaced collagen arranged in spindle-shaped bundles (Vedana 2016, Zhang 2016).

The formation of guttae is associated with increased expression of the protein clusterin (CLU) and the protein known as transforming growth factor beta-induced protein (TGFBIp). CLU is associated with oxidative stress and is known to promote cell aggregation. CLU also has a secretory form that has a cell survival function and a nuclear form that induces apoptosis (Vedana 2016). Both of these forms of CLU are upregulated in the corneas of Fuchs’ patients. The secretory form of CLU is found in higher concentrations around the guttae, suggesting that it may play a role in cell survival in areas where abnormal growths abound (Vedana 2016). TGFBIp is an adhesion molecule of the extracellular matrix that has a cell survival function and a nuclear form that induces apoptosis (Vedana 2016).
matrix that interacts with fibronectins, collagen and integrins. It is believed to be protective against pro-apoptosis stimuli (Vedana 2016, Zhang 2016).

There are two clinical subtypes of FECD. Early onset FECD is rare. It typically presents in the first decade of life and progresses as people age through their twenties and thirties. Late onset FECD starts in the twenties and thirties and is often asymptomatic until people reach their fifties and sixties (Vedana 2016). In early onset FECD, endothelial cells actively produce an excess of collagen type VIII (COL 8) protein and the rough endoplasmic reticulum is abundant and unusual in its form. In late onset FECD, melanin is widely distributed intracellularly and extracellularly, the rough endoplasmic reticulum is expanded, and mitochondria appear to be dilated (Vedana 2016, Zhang 2016). These findings suggest that the endothelial cells of the cornea become similar to fibroblasts and epithelial cells as FECD progresses.

Edema of the cornea in FECD leads to epithelial fibrosis, decreased numbers of keratinocytes and optical haze, the result of which is an irregular anterior corneal surface that distorts vision. The visual distortion may persist even after treatment with endothelial keratoplasty (Vedana 2016). The cornea maintains its transparency largely due to a state of relative dehydration of the stroma. Endothelial cells transport ions by Na+/K+ - ATPase pumps to prevent edema of the stroma. The number of ion pump sites per endothelial cell is reduced as FECD progresses, resulting in corneal edema (Vedana 2016).

Oxidative stress plays a roll in the pathogenesis of FECD and there is a marked downregulation of antioxidants and genes related to oxidative stress. Increased oxidative stress can lead to damage to mitochondria and nuclear DNA, changes in the morphology of cells and apoptosis (Vedana 2016).

The genetic basis for FECD is poorly understood and mutations related to the disease have been found in many genes. To date, only the gene for early onset FECD has been mapped and its specific mutations categorized. The gene(s) for late onset FECD are unknown and the disorder has not yet been mapped. Researchers are studying chromosomes 13, 18, 5, and 9 for association with FECD and examining linkages in chromosomes 1, 7, 15, and X as potentially being related to the development of FECD (Vedana 2016, Zhang 2016). The probability that FECD could be inherited as both an autosomal dominant and in a much more complex fashion is currently being explored.

Some of the risk factors for FECD have been recognized. Patients who smoke tend to have more guttae. The disease is more common in females and patients who are diabetic have an increased risk of developing advanced FECD (Vedana 2016, Zhang 2016).

Four clinical stages of FECD have been described:

In stage I, vision is not yet affected but guttae are present in the central area of the cornea (Zhang 2014).

Endothelial cells are reduced in number, enlarged, and thinner in stage II, and guttae are starting to extend towards the peripheral area of the cornea. There are signs of edema in the stroma and a reduction of vision is evident but painless (Zhang 2014).

Stage 3 is characterized by an increase in edema in the stroma, which is accompanied by painful loss of vision and the presence of epithelial bullae, tiny fluid-filled sacs or lesions (Zhang 2014).

Sever edema is associated with stage IV FECD and the cornea gradually becomes opaque and vascularized. The pain diminishes in this stage (Zhang 2014).

The treatment of choice for FECD today is endothelial keratoplasty, with the greatest visual acuity and the fastest recovery being associated with Descemet’s Membrane Endothelial Keratoplasty. On average, the cornea is approximately as thick as a credit card and DMEK replaces only the damaged endothelium, which is less than a twentieth of that thickness (CRFA 2016)

In the Future

Greater knowledge of the corneal endothelium will bring about novel treatments for corneal dystrophies in the future and the less invasive methods of corneal partial thickness keratoplasty will continue to be explored. Research into dependable methods for culturing the cells of the corneal endothelium and the means by which corneal endothelial cells can be coaxied into dividing are areas currently under intense study with the hope that eventually endothelial cells can be transplanted without the stroma or Descemet’s membrane. If these methods prove successful, cultured corneal endothelial cells will be used as one of the components of bioengineered corneas (Bourne 2010).

Investigation into advanced techniques for the cryopreservation of corneas is ongoing and will enhance corneal transplantation protocols. Greater understanding of the genetics of corneal dystrophies and methods of gene therapy will be used to treat existing corneal dystrophies as well as to help prevent the rejection of corneal grafts (Bourne 2010).

The future of corneal transplantation is very bright today with many new, worthy techniques being developed to enhance the eyesight of thousands of people. As each new technique comes to the forefront, knowledge advances and researchers move closer to their goals of visual enhancement and visual restoration for those who are at risk of losing their eyesight.
Illustration courtesy of:
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All Professors Should Take Psychology! Using Psychology of Learning Concepts to Inform the Anatomy & Physiology Classroom

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Abstract

Student success in Anatomy and Physiology (A&P) courses requires mastery of a large amount of content. Cognitive, metacognitive, and motivational skills aid students in acquiring this mastery. A student, concurrently taking A&P along with Introduction to Psychology, shares concepts relevant to the psychology of learning which impacted his study of A&P, including encoding strategies and retrieval practice. A&P instructors may consider integrating activities designed to expose all A&P students to psychology of learning concepts.

Key Words: retrieval, metacognition, learning, memory, psychology

Introduction: “All Professors Should Take Psychology!”

Students come into our classrooms for subject-specific knowledge. In the case of Anatomy & Physiology (A&P), we hope that knowledge becomes a working three-dimensional mental model of the human body, and a deep understanding of the processes that govern its operation. In the course of a year-long A&P curriculum, successful students will construct this knowledge, piece by piece. Yet learning requires more than simply gaining access to information, and teachers must do more than transmit vocabulary, facts, and concepts. The role of teachers must be to effect learning. Herbert Simon, paraphrasing Elliott Dunlap Smith, has said that “The teacher can advance learning only by influencing what the student does to learn” (cited in Ambrose et al., 2010). If we agree, this statement forces us to consider what we can do to change student learning behaviors.

Successful students must strategically draw from an arsenal of cognitive, metacognitive, and motivational skills (Mayer, 1998). Whether students are consciously aware that they are accessing or utilizing these skills is another question. Teachers who struggle to cover all the material in a content-rich course such as A&P may not have the resources in class to address the development of cognitive, metacognitive, or motivational skills. In spite of this sizeable limitation, it may be possible for A&P teachers to implement simple learning activities aimed at facilitating the understanding of how people learn and what learning strategies are most successful. I believe that with deeper awareness of the process of student learning, we can impact our students’ ability to learn, not just in A&P but outside our classrooms. In this essay, I would like to tell you about a student who highlighted this for me.

Interview Quotations and Context

Eventually I admitted that no, I have never taken a psychology course, but in that initial moment I just looked at him quizzically and asked, “Why?” This day, and the others that followed, he shared with me what he was learning in his psychology class. His enthusiasm was unrelenting. After the semester ended, he agreed to an interview, which was recorded and transcribed. Note: This project was approved by the Institutional Review Board of Georgia Gwinnett College (IRB number 15256), and informed consent was obtained from the participant, whose name has been changed.

“Organizing packages in a warehouse:” Encoding, storage, and retrieval

When the semester was over, final exams written and completed, TJ and I sat in my office to reflect on his semester’s experience in A&P1 and Introduction to Psychology. The following quotations are excerpts from our conversation.

I: At one point, early on in this semester (I think), you came into class and you said, “Every professor should have to take a psychology class.” What made you say that?

TJ: Because in psychology I was learning about certain aspects onto how to retain information. And how to study better. Or to just calm yourself, and put yourself into a state where you want to study, in a sense.

I: What specific things did you learn in your psychology class that helped you with your anatomy class?

TJ: Certain things, like how to remember things, and how your mind does remember things. You go through a sensory phase, storage phase, and then you go to retrieval phase. I thought that was really interesting. And how you look at something and taking one piece or a word from it that allows you to remember the definition of it. Also that really helped me too.
Here TJ is referring to the different phases of memory described in psychology textbooks: encoding, storage, and retrieval. “Sensory” is a type of memory which may be one element of encoding. Even though he is using the word “sensory” instead of “encoding,” TJ has clearly understood the process, and he is using his knowledge to improve his encoding strategies, the consolidation of memory into long-term storage, and practice at retrieval.

When TJ had new material to learn in A&P class, he would intentionally create mnemonics, connections or “hooks” for himself. As he described it, “you look at something and [take] one piece or a word from it that allows you to remember the definition of it.” He also created his own movements and songs related to A&P course content, to act as memory hooks. Interestingly, it seemed that creating songs and movements were encoding strategies that TJ used even before he was exposed to the learning theory that helps explain why those strategies are successful. As he learned more about psychology, the whole process made more sense to him.

Memory storage occurs in phases. Short-term memory may be consolidated into long-term memory. However, most short-term memory is not converted into long-term memory. It’s likely that we’ve all been dismayed when students don’t remember our fun anatomy facts a week later, a day later, or even 5 minutes later. For consolidation into long-term memory to occur, the brain needs rest and repetition. TJ compared consolidation to organizing boxes in a warehouse.

TJ: “…you don’t have to study all the time. That’s one thing I realized. You have to give your brain a break. … Just like everything else, your brain needs time to process information, and it needs sleep. It needs a break. It needs to recover, because that information that you’re all embedded in there has to go through a [storage] phase … like packing a warehouse. When you bring stuff in, those are the memory. When you bring stuff in there, and then the people have to label it. And to put it in storage. And to bring it out in trucks, you have to go retrieve that. Sometimes the people that don’t… There’s so many stuff coming in, you may not label it right, you put it somewhere, and that package is lost, where you gonna find it. And you’ll never retrieve it. Because you brought it in too many, that you couldn’t process enough. And then, I think about it like that. That’s what I do.”

The brain needs sleep, in order to consolidate memory. And then the brain needs practice at retrieval in order to make new connections permanent. A&P textbooks typically include a chapter on cortical brain physiology, focusing on short-term and long-term memory. The physiological changes that occur in the formation of long-term memory may involve increased neurotransmitter release, facilitation at synapses, or the physical formation of additional synaptic connections. As we learn, long-term memory creation is changing the physical structures of our brains. It’s intriguing to think about this in the context of the Testing Effect, which says that long-term retention is improved by repeated, spaced tests (Roediger et al. 2011).

Practice at retrieval requires a student to search within for the answer to a question. It can be accomplished by self-quizzing or quizzing a partner, as long as the information is retrieved from memory. In the classroom, we help our students practice retrieval by giving them formative or summative, written or oral assessments. For his part, TJ was committed to practice at retrieval, starting with making flashcards to quiz himself.

TJ: Flashcards really helped. ‘Cause like, reading off notes is just so much words, it’s like all I see is words. And like flashcards is like a way to quiz yourself. Now also, throughout the day, I would just think of questions that was asked on the study guide, because also in like psychology it said that there’s no such thing as photographic memory, you just have really high detailing skills, like you’re able to take what you see, anything that you see, you’re able to remember it easier. And that’s what I do, I try to take up everything in the area, which causes me to remember that situation better. So it’s like, I’ll look at the study guide, or like certain questions that I know that’s important, and I’ll put that in my brain, and while I’m walking, or if I don’t even have my book, I’ll ask myself those questions, to see if I know that answer. And if I don’t, then when I get my book, I go to the exact questions and find the answer.

I: You do that intentionally? Like you sit down and say, OK, today I’m gonna think about these 5 questions, and you like memorize them, and then ask yourself throughout the day, or it just is coming to your mind because you have anatomy in your head all the time?

TJ: I’ll think about anatomy, and I’ll think, “OK, I need to study,” in my head, and then I’ll think of the questions, and then I’ll think of the answers. And the fact that I got it wrong, that’s…

I: But how do you know at that point if you got it wrong? right or wrong? I mean, maybe you know if you don’t know.

TJ: I know the ones that I do know off the top of my brain, I know that I got it right. It’s coming from somewhere. But the ones I don’t get, I know that I need to go back and look at it. And the fact that I don’t get it, I remember that question. Which causes me to go back into my book and find out what it is. And me finding out what it is, causes me to remember on the test, ‘cause I went through all that to find out the answer. So it’s, everything correlates together. … Say for example you asked the pathway to the ear canal. I would do that throughout the day. And that’s what causes me to remember. And if I miss one step, then it’s like, OK, something’s supposed to be here, but I don’t know what it is, I’ll go back and look at what path, or what part did I miss.

“I see you at the front of the class:” Context-dependent learning

Retrieval is aided through another phenomenon called context-dependent learning. In one study, the initial learning event occurred either on land or in the water in diving gear. Later, recall of the content was improved if the retrieval condition matched the learning condition (Godden and
Baddeley, 1975). This suggests that the brain is better at retraining the neural circuits if the environment, or context, of the retrieval event matches that of the learning event.

I: I remember you saying to me, was that you said something about how you sit in the room influences your learning. Do you remember that?

TJ: Oh yeah yeah yeah. It helps you retrieve the information more when you’re sitting in the same place where you get the information. It’s statistically known, that even when you test, it’s better to go to the same room that you were before, that you got the information into your mind, your memories retain the information. I know that there’s times where I took a test in your class, and I would look at the question, I’m like, “Oh, I don’t remember this,” but then, I remember you saying it up front, or something like that. Or I remember

I: So you could go back in your head to the moment when we talked about that and you could see me, sort of, in your head, standing in the front of the room

TJ: with the PowerPoint

I: and you could sort of like hear what I was (talking about)

TJ: Yeah

I: Oh, OK.

TJ: Or hear other people’s reactions towards the answer. To the question. Or hear that person answer the question. All that. Which makes sense.

I: OK, but if you’re in a different room, can’t you just imagine yourself in that room? It’s harder, huh?

TJ: It’s harder.

I: Interesting.

TJ: It’s definitely harder. Because it’s a different structure, a different place, a different desk, different people. “Up front” may be right here, or something like that. It’s harder.

TJ had a favorite seat, in the fourth row, on the right. And he did generally sit there at test time also.

“A state where you want to study”

As TJ originally said, he was learning “how to study better. Or to just calm yourself, and put yourself into a state where you want to study.” The psychology course curriculum included the benefits of meditation, a spiritual or mental practice of seeking calm and quiet. Two days before the course reached this topic, TJ had already started meditating for 10 minutes at the end of the day. When the class talked about meditating, he was primed for the discussion.

In many ways, TJ was a unique student. He was intrinsically interested in learning about the human body and the mind. Fascination with the course content is a good foundation for success in a class. The conversation that we had after the semester ended came about because of his curiosity and his ability to make connections between his classes. He came in knowing that A&P was going to be hard, but he was prepared to do whatever he needed to do in order to “get it.” In the end, TJ felt that he would have been successful in A&P 1 even if he hadn’t been taking Introduction to Psychology, but he would have had to invest significantly more time studying, and mental energy “stressing.” Because TJ was continuously thinking about how learning works, and different strategies for learning, he was able to step back from his immediate situation. He was able to relax in class more, and avoid feeling overwhelmed by the sheer volume of information. He accepted that he wasn’t going to instantly “get it” all in class, and that was okay, because he knew he would go home and immediately review. And he was confident that with review, he could “get it” or get help.

In the spring, TJ took A&P 2, and his encoding strategies didn’t work so well for him there, as the second-semester content is focused more on physiological processes and less on memorizing anatomic structures such as the names of all of the bones. The first few weeks of the semester, we both knew that he was not performing up to his personal expectations. One day at the end of class I asked him how it was going, and he confirmed both that he felt that he wasn’t doing well, and that his mnemonic strategies weren’t working. I suggested to him that he needed to focus on understanding the diagrams and flow charts in the text: what is the cause, what is the effect, and why. With this one suggestion, TJ was able to change the way that he studied, and his test performance improved by a whole letter grade.

Reflection: Ideas for Implementation

I don’t know that I can provide every student with one study tip that drastically improves test performance. There are so many factors that play into a simple encounter like our conversation after class: trust, rapport, previous test experience, hours of conversation about anatomy and psychology and learning. I do believe, however, that integrating some form of metacognitive training about memory strategies into our non-psychology courses can benefit our students’ performance on course-specific objectives as well as their abilities to learn in other courses and outside the classroom. An entire psychology course cannot be compressed into a single class period, but we can adopt specific concepts as appropriate.

Stephen Chew (2010) has published a workshop activity focused on enhancing metacognition by demonstrating different levels of processing. He first asks the group to choose an answer to the question: “What ingredient is most important for successful learning?” This is followed by a demonstration that the type of thinking a student practices while listening to a list of words will affect the ability to recall that list, regardless of whether students know that the recall test is coming. This activity could be replicated in a classroom setting, to help students reflect on what type of thinking is most helpful to learning, which is an intentional way to work on encoding strategies.

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A similar activity has been demonstrated by Saundra McGuire (2015). This time the audience is requested to “Count the Vowels” in a list of words shown on the screen. After focusing on vowels only, it is challenging to recall the list. A second chance to work on memorizing the list, focusing on the meanings of the words and connections between those words, yields much improved recall results, again demonstrating that the process of thinking about content can have a dramatic effect on memory. These two activities both highlight the importance of making thought connections with content while studying.

Another idea came to me through a conversation with Andrew Kelly, a psychology faculty member also at Georgia Gwinnett College, who was kind enough to share with me some of his “first day” PowerPoint slides. In 2008, Karpicke and Roediger published the results of a study where college students were asked to learn a list of 40 Swahili-English word pairs. Each student had four opportunities to study and then get tested on the word pairs. Critically, approximately half of the students were tested on all 40 words during every test cycle, whereas the other half were only tested on the items they had gotten incorrect during the previous test session. One week after the learning period ended, students who were consistently tested over the entire list of words recalled about 80%, regardless of whether or not the students studied (read over) the entire list. In contrast, students who were tested only over the words they had previously missed recalled 33-36%, depending on whether they continued to study the entire list. This study dramatically shows the benefit of repeated retrieval attempts to improving learning. Talking through the experiment and results could help students consider the benefit of increased practice at retrieval while they are studying A&P content.

In my own classroom, I have started to introduce the phases of encoding, storage, and retrieval, especially the need for practice at retrieval, to help consolidate short-term learning into long-term memory. Then, when I talk about how to study, or what is assigned for homework, I remind students of our process. First students must access new information through the textbook, videos, or in-class lectures; next students work to organize information using flowcharts, lists, or graphic organizers; and then students need to practice, practice, practice by writing, explaining, sharing, and quizzing. Ideally, students watch lecture videos or read the textbook before class, so that class time may be spent organizing information and practicing retrieval. Completing graphic organizers may be accomplished individually, as pairs, or as a group. On-line practice questions supplement in-class quizzes, and increase the number of attempts at retrieval, repetitively firing along the new neuronal connections we are trying to make. All formative and summative in-class assessments present additional opportunities for retrieval practice, which is why it is important to ask questions about factoids worth committing to long-term memory. I try to ask students to think deeply on exams, to use essential information to solve problems or figure out answers to questions, to make use of this last chance to encourage practice at retrieval.

Would explaining to my students how this course design aligns with learning theory improve their performance? In A&P1, we do talk briefly about short-term versus long-term memory, and I highlight the formation of new neuronal connections that create new physical structures necessary for long-term learning. Students planning for a career in health care understand that long-term learning is the class goal, and that A&P needs to become part of their lifelong vocabulary. If students have both intrinsic motivation and an understanding of how learning works, perhaps they would be better prepared for further training in the health professions.

In conclusion, I do agree that all professors can benefit from learning psychological theory about how students learn. It can help us learn how to help students learn more effectively. Even the process of learning something in a new discipline, starting from scratch, helps us remember what it feels like to be confronted with a whole new set of ideas, expressed in what may seem like a whole new language. Being a successful teacher requires an ability to see things from a student perspective, and at least a curiosity, if not a robust understanding of the inner workings of the student mind, as individual students approach the study of this complex and intricate structure that we call the human body.

About the author

Tracy Ediger is an Assistant Professor of Biology who spends most of her professional time teaching anatomy and physiology and chatting with students about course choices, career plans, and life outside the classroom. Tracy is interested in how people learn, and how students make decisions about life direction.

Literature Cited


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A Methodology of Optimizing Abstraction in Anatomy and Physiology Infograms: Abbreviations and Acronyms

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Abstract

There are hundreds of standard abbreviations in Anatomy and Physiology curricula and related health fields that students are expected to recognize, understand, and use correctly. This learning process is facilitated by using Anatomy and Physiology Infograms that the author developed and has been testing in the last few years (Kolchenko 2015). Infograms are graphic symbolic summaries that use keywords, pictograms and abbreviations to encode complex material and promote effective learning. In this paper we explore a methodology of optimizing abbreviations in Anatomy and Physiology Infograms. Finding the appropriate level of abstraction is one of the key challenges in the design of the effective learning materials. We address this fundamental problem by highlighting some basic types of abbreviations and proposing a few guidelines for designing effective abbreviations in the graphic and curricular context of the Infograms. For the first time, we define abbreviation homonyms and synonyms and discuss the preventable learning problems they present. We describe a new class of abbreviations, narrative initialisms, which are used to encode a storyline that provides helpful mental cues for information retrieval. The evolution of our pedagogical approach and examples associated with HAPS learning outcomes illustrate the theory and provide practical suggestions for anatomy and physiology instructors.

Introduction

The use of letter symbols as effective mnemonic devices has been established since the ancient Greek and Roman times and has been accelerated in the last few decades with the advance of computers and Internet. For ancient Romans, the shortened name of their empire and the earlier republic since at least 80 BC has been SPQR (Senatus Populus que Romanus, the Senate and People of Rome). In modern times, abbreviations like OMG and LOL, associated with texting, email and social media, became common knowledge (Fig. 1). Professional shorthand in every field uses capitalized initials to symbolize concepts and phrases for greater efficiency, particularly in medicine and biology. We habitually abbreviate names of the months and days of the week, organizations and countries, professional titles and degrees, units of measurement and familiar phrases (Fig. 2). We also create and use our own unique abbreviations. Most people do it because this is the way the human mind tends to operate.

As you put your pen to paper writing down a brief note in a hurry, pressed for time, you may shorten the words and omit some letters, without giving it much thought, effectively creating your own shorthand. It may be quite useful as long as the meaning of the scribbling remains clear. Then the guessing begins: what did I mean by that? Similarly, we are sometimes frustrated by a certain mysterious

Figure 1

Figure 2
abbreviation: what could it stand for? We can easily come up with a few suggestions, either serious or funny, but the actual meaning is often elusive. Both the cognitive benefits and the cognitive problems associated with abbreviations seem clear.

In education, symbolic representation is essential for the effective learning. Re-reading and simply reviewing the dense and complicated information found in the anatomy and physiology textbook is a time-consuming and ineffective way to learn. Studies have shown that students spend a great deal of time reviewing the text but the information is forgotten shortly (Karpicke et al. 2009). Furthermore, memory research has shown that repetitive re-reading alone will not suffice if one’s goal is to promote learning and long-term retention. A more efficient way of learning is practicing retrieval, which produces better results and meaningful learning (Karpicke et al. 2011).

Utilizing abbreviations and acronyms in the learning process is one important way of practicing information retrieval. Abbreviations are proven to have positive effects when studying and understanding information (Kolchenko 2015). They play an important role in the efficiency of language usage; they occupy less space, and are more cost efficient (Hodge et al. 1973). Some abbreviations, such as “NY” or “USA” are immediately familiar. People are usually able to properly resolve the meaning of most acronyms and abbreviations even if only given a very limited context (Moon et al. 2015). Abbreviations and pictograms form the substance of the Infogram, a unique learning tool developed at New York City College of Technology (City Tech). The potential of the Infograms to improve learning outcomes is well documented (Kolchenko 2015).

However, confusion can arise if the graphic symbols, abbreviations and acronyms are ambiguous, vague or contradictory (Hearn 1993). In the medical context, one physician may not understand another physician’s abbreviations if there are no standards and regulations governing their use (Saufl 2004). Misunderstandings of medical abbreviations may even result in death, with one study suggesting that there may be up to 350 patient deaths annually in the US as a result of confused medical abbreviations (Hearn 1993). To minimize these problems, most hospitals maintain a list of approved abbreviations and restrictions for their use.

Confusion may also occur when the same abbreviation has two or more different meanings that may be mistaken for one another (Hearn 1993). For example, AP may stand for Anatomy and Physiology, action potential, Advanced Placement, or Associated Provost. In linguistics, the same words with different meanings are called homonyms. For example: left (opposite of right) and left (past tense of leave).

Here, we define abbreviation homonyms as identical abbreviations that stand for different concepts. The correct meaning of the homonym is usually recognized from the context.

We also define abbreviation synonyms as multiple abbreviations that stand for the same concept. For example, MC, MCH, MIT, Mito and Mi stand for mitochondria and “mt” or “m” stand for mitochondrial (mtDNA or mDNA). Some abbreviations have been registered in certain dictionaries but not in others (Terada et al. 2004). Inconsistencies among dictionaries can cause even greater confusion in deducing the true meaning of the abbreviation. Both abbreviation homonyms and abbreviation synonyms have the potential to impede learning. This problem should be recognized by the instructor and prevented by highlighting common homonyms and synonyms of abbreviated terms in class.

In this paper we focus on a methodology of optimizing abbreviations in anatomy and physiology learning materials. This is a continuous iterative process based on literature analysis and student feedback. There appears to be little research on the methods of finding the appropriate level of graphic and linguistic abstraction, which is one of the key challenges in the design of the effective instructional graphics. When do graphics become too abstract or too detailed? Neither extreme is helpful, as these materials may be more confusing than illuminating. We address this fundamental problem by highlighting some basic types of abbreviations and proposing a few guidelines for designing effective abbreviations in the graphic and curricular context of the Infogram.

**Materials and Methods**

Our research of abbreviation types and methodology is based on the analysis of Anatomy and Physiology Infograms that have been developed and tested at City Tech in the last few years (Kolchenko 2015). Infograms are graphic symbolic summaries that use keywords, pictograms and abbreviations to encode complex material and promote effective learning (Fig. 3). In an Infogram, a chapter of the Anatomy and Physiology textbook is condensed to one page of graphics, which is supplemented with the side notes, an explanation of the graphics, a list of terms and a homework assignment. The specific learning activities help students learn and internalize the Infogram content, which becomes a cognitive tool for the fast and multiple retrieval of the material. It also serves for identifying connections between the concepts and better understanding of the topic’s big picture.

We analyzed the original Infogram set and the current one (Fig. 5 and Fig. 6). The main difference between them was the degree of abbreviation and the level of abstraction. In a separate section, we describe the evolution of the Infogram design and the underlying logic of the structural changes.

continued on next page
Figure 3

A methodology of Optimizing Abstraction in Anatomy and Physiology Infograms: Abbreviations and Acronyms

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**Infogram 4**

**Cell, Cell Cycle and Membrane Transport**

1. **Cell:**
   - C: Mt → ATP / O₂ → Peroxisis
   - M: RER / SER
   - O: Golgi / Lysosome
   - N: Chr-n, N/lus → rRNA → Ribosome → Protein
   - N: Chn, N/lus → rRNA → Ribosome → Protein

2. **Cell Cycle:**
   - A. I/phase, 23 h
     - a. Mitosis, phases:
       - Pro- 46 Chrom.
       - Meta- Align
       - Ana- Split
       - Telo- 2 Nuclei
   - B. Division, 1 h: Somatic C / Gametes
     - Meiosis-I: 46 → 23
       - II: Split, 4 cells
         - 4 M, 1 M ½ DNA
       - XY, XX / XO, XYV

3. **Membr Transp:**
   - P/lipid-2 → Pr: Tr, Rec, Enz, CAM
     - I. Passive T:
       - a. Diff-n O₂, CO₂ → c
       - 1) Simple D → Na⁺
       - 2) Facilitated D → Na⁺
       - 3) Osmosis H₂O → H₂O
     - b. Filtr-n P → P Urine

4. **Saline**
   - A. Isotonic .9% S/W ↔ W - Normal S
   - B. Hypo- < S/W → W - Hemolysis
   - C. Hyper- > S/W ↔ W - Crenation

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♀ - in the egg only

... - ribosomes

/// - microvilli

--- - flagellum

∥∥ - n. envelope

- translation

G - growth

S - synthesis

Sex chromosomes:

XY - male
XX - female

← chromatid

- membrane

Pr - proteins

C, c - concentr-n

D - diffusion

Na - sodium

O - vesicle

P, P - pressure

→ Na⁺ channel

S - salt or solute

W - water

S - saline

○ - red blood cell (RBC)
Classification of Abbreviations

Based on the literature review (Hodge et al. 1973, Terada et al. 2004, Moon et al. 2015) and our own analysis we describe five major types of abbreviations: truncations, contractions, combinations of truncations/contractions, initialisms and acronyms.

1. **Truncations** result from the removal of one or more letters at the end of the word. For example, Na for natrium (sodium) and min for minutes.

2. **Contractions** result from the omitting one or more letters in the middle of the word but preserving the last letter. For example, Dr for doctor. The letters being removed can be consecutive (Dr) or not (Bldg for building).

3. **Combinations** of truncations /contractions do both. For example, mt for mitochondrial or apprx for approximate. This type is relatively rare except for the combinations of the word part initials (see the next section).

4. **Initialisms** preserve the first letters only, the initials of the terms. They are the extreme cases of truncation and can be subdivided into:
   1) One-word *initialisms*. For example, A for adenosine
   2) Phrase initialisms that combine the initials of a few words. For example, CNS for the central nervous system.

The one-word *initialisms* are not as numerous as phrase *initialisms* because the number of letters in the alphabet is limited and using the same letter for a number of different concepts may become confusing.

5. **Acronyms** combine initials of a few words creating a combination that is pronounced as one word. For example, SARS for severe acute respiratory syndrome. It is quite common to confuse *initialisms* and acronyms but there is an important distinction. For example, ATP, CSF and DNA are *initialisms* but AIDS, radar and NASA are also acronyms. HAPS (Human Anatomy and Physiology Society) is an acronym as well because it is pronounced as a word, not spoken one letter at a time.

There is a cognitive advantage to learning a short word instead of spelling it out but it is not easy to create a good and memorable acronym. In our experience, the major difficulty of acronym design was the lack of vowels among the initials.

As a result, it is not surprising that the most common type of abbreviations in biology and medicine is the phrase *initialisms*. It represents the great majority of thousands of entries in the online List of Medical Abbreviations (Wikipedia contributors 2016). In this case, the letter combinations are mostly unique and unambiguous while the economy of time and space is the greatest.

The Use of Abbreviations in Educational Graphics: Problems and Suggestions

Many of the phrase *initialisms* became standard in biology and medicine but the majority of anatomy and physiology terminology are single word terms, not phrases. The main
problem with using their initials for brevity is clear: too many words start with the same letter. How can we approach the condensing of the single terms in the educational graphics? These pictures are often overcrowded with long names or confusing abbreviations.

First, we need to analyze the words. They are often easily split into familiar parts. For example, iso-tonic, hyper-tonic, iso-metric. In this case, the initials of the word parts can be used for the abbreviation. For example, hypothalamus may be reduced to HT but hippocampus is reduced to HC.

This type of abbreviation is widely used but was not defined in the available literature. We call it *internal initialisms*, which are the abbreviations that use initials of the word parts, not of the separate words. Usually it is sufficient to use two initials of the two word parts to create a relatively unique and unambiguous abbreviation. It also makes it easier for the students to recognize the name because instructors often split the term and emphasize the meaning of the word parts in the classroom.

However, doubling the number of symbols will significantly reduce the economy of space and time. Is there a better way of conveying the meaning of the concept? Another important consideration is the graphic context. For example, abbreviations for the parts of the familiar picture are easier to recognize because the picture itself serves as a cue for recall. In other words, the combination of the letter and the picture makes the letter symbol unique and recognizable.

There are other ways of distinguishing the letter symbol: underlying it, using a different font, font size or italics. In our experience, the most powerful approach was grouping the concept initials in a meaningful way. We called these abbreviations *narrative initialisms* because each one encodes a narrative, a storyline that incorporates a number of concepts that reinforce and explain each other as they are recalled together.

For example, the initials of the major organs of the respiratory system may be grouped as NPL TBL (nasal cavity, pharynx, larynx; trachea, bronchi, lungs, Fig. 4). The order of the initials is determined by the sequence of the organs in the respiratory tract. The space between NPL and TBL has meaning as well. It separates the organs of the upper respiratory tract from the organs of the lower respiratory tract. Most students have heard about the upper respiratory tract infections. Now they can visualize the organs. The arrow under the initials reminds the students about the movement of the air along the tract.

In isolation, the organ initials could be confusing. In a group, they are meaningful and provide helpful mental cues for information retrieval. Another distinguishing feature is the number of concepts. Many familiar *initialisms* represent one particular concept that has a complex multi-word name. For example, PNS for the peripheral nervous system. In contrast, the *narrative initialisms* may describe many concepts that can be quite different from each other but related in a certain way. Similar to any password, the longer the letter combination, the more unique it would be. Chunking it (NPL-TBL) is similar to chunking a telephone number. Remembering smaller groups of symbols is always easier but linking them to the meaningful associations makes this process particularly efficient and useful for learning.

**The Evolution of the Infogram: a Confession of the Instructor**

When I started developing the Infogram concept, my goal was to preserve as much information as possible. I would rather have complete terms on the page than abbreviations. Students need to know the spelling of the names that sound strange to them, I told myself. On the other hand, the basic original constraint was ‘one chapter on one page.’ As a result, I had to gradually condense the material using all kinds of symbolic representations. Otherwise big parts of the curriculum would not be represented at all. As a reluctant abbreviator, I overloaded the page with text. You can see the difference between the original unit for the cell life cycle and the current version in Fig. 5 and Fig. 6.

The main reason why the original Infogram looked so crowded and dense was the lack of trust. I could not imagine that my students were capable of learning from the big number of abstract symbols. In fact, for a while I have been moving in the opposite direction providing students with an additional and even more detailed graphic version of each Infogram.

It took me a few years to realize that students learn better when Infogram abbreviation is taken to the extreme. Condensing Infograms to their essentials and enriching them with content was like cleaning a dirty window. It was easier to see what the topic was about without full names and definitions. The clarity and immediacy of mental vision was greatly increased. The mind was freed from reading and focused on recalling and imagining the meaning of the symbols. Of course, this recalling has to be practiced and expressed in words. This is all we have for describing the content and expressing ideas: images and words, both of them symbolic and abstract to some degree.

Words are abstractions because they are symbols. They represent reality by substituting actual concepts with sounds and graphic characters. Therefore, abbreviations are the symbols of the symbols (words), twice removed from reality. If so, what is the reason for using them in the classroom? In addition to economy of time and space, there is a critically important cognitive benefit, which lies in exercising abstract thinking. There is also some cognitive cost, particularly for the students who do not have highly developed abstract thinking skills. But this is exactly the point: many students fail Anatomy and Physiology or drop the course because they do not have sufficient abstract thinking skills. Developing and exercising them may be the only way to truly master the material.

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One of the first breakthroughs for me was the grouping of the organ system initials. For example, I encoded the four systems that transported chemicals for metabolism as CURD, for circulatory, urinary, respiratory and digestive systems. To my surprise, students immediately understood and loved it. Moreover, it reinforced their comprehension of metabolism. 

The next challenge was to encode the particular organs of each organ system. It took me another two years to jump into the water. Here, I used the narrative initialisms to represent 11 organ systems and 59 organs in three lines of the Infogram (Fig. 4). The organs were illustrated by the slide images but also by the mental images of the organ systems that most students already had. Again, it was hard to believe that my students could recite all the names and also visualize and describe the structures.

For example, digestive system was represented by the initialism OPESI / GL for oral cavity, pharynx, esophagus, stomach and intestines (small and large) plus the biggest digestive glands. The arrow under OPESI indicated the movement of the digestive tract content.

When we studied histology, the students knew the major examples of the stratified squamous epithelium as ED (epidermis), OPE (oral cavity, pharynx and esophagus), An (anus) and V (vagina), all united by protection (function). For students, it takes less than a minute to make the connection. This way their knowledge of organ systems and histology reinforce each other.

**Abbreviation Methodology Guidelines**

Based on our Infogram experience, we propose the following guidelines in order to improve the abbreviation efficiency and clarity:

1) Preference for standard abbreviations: Use standard abbreviations if available.

2) New abbreviations: If the standard abbreviation is not available, a new one can be helpful. After being used for a while, it will become familiar to the students and may improve their learning efficiency.

3) Consistency: Use the same abbreviations consistently in the complete set of the learning materials.

4) Avoid abbreviation homonyms and synonyms: Having more than one abbreviation for the same term or using the same abbreviation for different terms may cause confusion and should be avoided.

5) Unavoidable homonyms: If the same abbreviation has to be used for different terms, the graphic context may help in recognizing the correct meaning. For example, the same initial may mean different structures in different pictures or in different groups of initials.

6) Use numbers: Numbers can help students recall how many items are in a group. For example, I-5 for the 5 signs of inflammation.

7) Use initials: The preference is to use one letter for each word, and that letter can be the first letter, capitalized. For example, D for dermis.

8) Use word parts: When a word is built from familiar and recognizable parts (sub-cutaneous), the abbreviation can be created using the first letter of each part, capitalized. For example, MC for melanocyte.

9) Truncation: Truncating the term to a few letters, capitalize the first letter only. For example, Prot for protein.

10) Truncation exceptions: Avoid using the low case letters if they can be easily confused with the other capitals. For example, GI for glands can be mistaken for GI for gastrointestinal; the better choice is GL.

11) Use one-concept initialisms: Use initialisms for phrases that describe one concept. For example, CNS for the central nervous system.

12) Use multiple-concept initialisms: Group a few related concepts and use the term’s initials for the abbreviation. For example, CURD for the organ systems transporting chemicals needed for metabolism: circulatory, urinary, respiratory and digestive.

13) Create acronyms: If possible, construct easy to memorize acronyms. When the order of terms does not matter, it is better to use the initials to form a pronounceable word, which would be easier to remember. For example, CURD is preferable to RUDC or DUCR.

14) Construct narrative initialisms: in some cases, the order of terms has meaning and will support the content narrative. For example, KUBU for kidneys, ureters, bladder and urethra. Here, the sequence of initials will help students remember the order of the urinary tract structures as well as the names of the organs.

As mentioned earlier, the spaces between the initials, arrows and other graphic details such as italics, bold and underlining may also serve an important function in the Infogram emphasizing the importance of a term or implying the connection between the concepts.

**Conclusions and Further Research**

Using various types of abbreviations in the learning materials such as Infograms can provide much greater cognitive benefits than the typical use of standard abbreviations. Recognizing these types and following the suggested guidelines may help in designing better learning materials. 

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and more effective instructional techniques. *Narrative initialisms* add the advantage of encoding the coherent storyline and introducing the mental cues for the retrieval of information. Further research may include the following:

1. Quantifying and analyzing abbreviations in each Infogram and in both Infogram sets.
2. Assessing the Infogram abstraction levels in terms of information density vs. graphic density.
3. Evaluating the effectiveness of the current Infogram set vs. the original one.
4. Determining student preferences for different types of abbreviations and abbreviation efficiency for information retrieval.
5. Creating a list of standard and suggested abbreviations for Anatomy and Physiology curriculum.
6. Further developing the theory and methodology of the abbreviation design.

This methodology extends beyond one subject and can be beneficial to many fields. Symbolic representation by Infogram abbreviations, if used correctly, engages students’ imagination and exercises their abstract thinking skills. As a result, students successfully learn not only Anatomy and Physiology. They also learn how to learn.

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Vasiliy Kolchenko is a Professor of biology at New York City College of Technology, The City University of New York. Vasiliy teaches Anatomy and Physiology and Bioinformatics. His research includes biosensor development and graphic representation in science education. He also writes and performs music. This is his Teaching Science song: [https://www.youtube.com/watch?v=Cpel5wHvKE4](https://www.youtube.com/watch?v=Cpel5wHvKE4)

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Bringing Evolution into Anatomy and Physiology: The Uvula and the Story It Tells

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Abstract
Adding an evolutionary perspective to the teaching of human anatomy can introduce students to evolutionary concepts, emphasize that humans are a part of nature and a product of natural processes, help to develop critical thinking skills, and increase student engagement. Unfortunately, it is difficult for most instructors of anatomy and physiology courses to entertain the inclusion of even more material into an already time-challenged course. One way to “sneak evolution in” is by using specific anatomical structures that have compelling, and sometimes even entertaining, evolutionary stories. One such structure is the human uvula.

Key Words: anatomy, evolution, uvula, teaching anatomy and physiology

Introduction
As a comparative anatomist, one of the things I have always struggled with when teaching human anatomy and physiology, is the desire to give the students more of an evolutionary perspective on the structure of the human body. On one hand, this is just my bias (although see “Perspective” below). I see anatomy as primarily being concerned with “the parts” of an organism, and as an anatomist, I find that compelling as far as it goes. But, add in some biomechanics, a little development and embryology, and an overall evolutionary perspective, and anatomy becomes morphology, and morphology tells a more complete story that I believe students find interesting and useful.

The challenge in adding evolutionary content is two-fold: 1) there is of course never enough time, and 2) the students are not always interested. Unfortunately, I have not found a way to warp time, but I have attempted to “sneak evolution in” here and there by selecting anatomical structures that illustrate interesting evolutionary concepts and have compelling, and sometimes even entertaining, stories. What I have come to realize over the years is that almost any anatomical structure has an evolutionary story to tell and can serve as a way to engage students in broader questions of the evolution of human form.

For some of these structures, I have prepared written essays that can be assigned as outside reading. Sometimes I simply fold these stories into my lectures using PowerPoint slides to augment the story. In either case, I have found that the resulting discussions can be lively and that students seem more likely to ask “big picture” questions throughout the course.

What I present below is one such essay I have shared with my students. It is about the human uvula, a structure I think it is safe to assume, does not get much attention in human anatomy and physiology courses. It gets some mention when discussing the soft palate and its function in sealing off the nasal passages during swallowing, but probably not much more. I refer to it as a sort of “oddball” anatomical part – interesting to note mostly because of its funny sounding name, but of little interest in terms of critical function. As it turns out, even this small oddball body part has a story that includes some anatomical history, addresses a little evolutionary theory, allows for some simple hypothesis testing, gives a nod to the importance of development in the evolution of form, and reveals a possible example of an evolutionarily unique character of the human species.

The Grape in Your Throat – an essay

Unless you’ve studied the back of your throat recently, you really need to find a mirror before you get to the next paragraph. When you’re in front of it, open your mouth wide and look deep into your throat. What I want you to look for is that little dangly piece of flesh hanging down in the middle, way back there.

See it? That is your uvula. It may not be much to look at, but it is your very own. It seems to be a body part that may have reached its highest degree of development in humans, and it has a great name. Anatomists love to name things, and as long as you know a little about word derivation, the multitude of anatomical names actually makes some sense. In this case, the term comes from the Latin uva, which means “grape”, thus the title of this essay.

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Structure and Function: How is it built and what do we think it is good for?

The uvula is not very complicated structurally. It is a piece of soft tissue packed with connective tissue and simple glands with some muscle fibers distributed among the glands and connecting into the soft palate just anterior to it. The epithelium that covers the underside of the uvula is similar to that of the oral cavity, while the upper surface is covered with an epithelium like the lining of the nasal cavity.

Essentially, the uvula is an extension of the roof of your mouth; what anatomists call the secondary palate. Ancestral vertebrates (e.g. fish, amphibians, reptiles) have a different type of palate, which protects the ventral surface of the brain from the contents of the oral cavity. Since it is evolutionarily older, this palate is called the primary palate; making the one we are talking about the secondary palate. You can get a good idea of the anatomy of your palate by taking the tip of your tongue and running it along the roof of your mouth from front to back. From just behind your teeth for about two inches you can feel the hard or bony palate, which is formed by four bones that come together to form a relatively thin shelf of bone. Behind the hard palate, you will feel your tongue move off of the bone and onto soft tissue, the soft palate. Above both of these parts of the palate is your nasal cavity.

To understand the main function of the secondary palate, just imagine life without it. Think of chewing some nice warm tortilla chips. If you did not have a secondary palate, all of those rough pieces and that tasty guacamole would not only be in your mouth, but also in your nasal passages. Not only would that be painful; it would also mean that you would have to hold your breath until you had finished chewing and swallowing your chips and dip.

So, our secondary palate functions to divide our oral cavity from our nasal cavity, and if you look at all vertebrates, it turns out that the presence of a secondary palate is mostly a mammalian characteristic. The high metabolic rate of mammals requires a high level of oxygen and therefore requires a constant airflow into and out of the lungs. We cannot stop breathing while we chew our food. The secondary palate allows us to multitask - to chew and breathe at the same time.

The function of the uvula seems pretty clear if we consider it as merely an extension of the soft palate. As we swallow, the soft palate (and the uvula) is pushed up and back so as to form a seal and prevent food or drink from sneaking up into the nasal cavity. It works pretty well, although if you have ever taken a drink of soda pop and started laughing, you know this seal can be broken!

If all vertebrate soft palates had a uvula extending off the end, that might be the end of the story. What is curious is that we humans may be one of the ONLY vertebrates with this extra piece of tissue dangling off the back end of our soft palate. An evolutionary biologist would call this an autapomorphy, which is a term used to refer to an anatomical feature exhibited by a single taxon (in this case a single species, Homo sapiens) within a larger evolutionary group (in this case, the class Mammalia). In laymen’s terms, we might call it an oddball feature, and oddball things usually call for explanation.

Anatomists have attempted to explain the uvula for a long time. Galen (122-199 AD), one of the fathers of anatomy, believed that the uvula was important in speech and contributed to the beauty of the voice (Fritzell 1969). Leonardo da Vinci (1452-1519 AD) wrote that, “The uvula is the drip-stone whence drips the humor which descends from above and which falls by way of the oesophagus into the stomach. It has no occasion to go by way of the trachea to the spiritual regions.” This is based on the belief at the time that excess fluid from the brain and pituitary gland drained into the nasal cavity (da Vinci 1983). While Galen believed that this fluid would drip onto the larynx to lubricate the voice and lungs, Leonardo took the opposite view, that the uvula directed this brain fluid away from the larynx and into the esophagus and on to the stomach, thus avoiding the lungs and the thoracic region where vital spirits resided.

A traditional belief of the Bedouins of the southern Sinai Desert is that the uvula is the source of thirst, and its removal leads to less of a need or desire for water. More scientific ideas of uvular function concern its role in producing certain sounds in human speech, in directing mucus from the nasal passages toward the base of the tongue, in assisting with the immunological response of throat tissue, in protecting the openings to the Eustachian tubes, and in the sensation of temperature to prevent the swallowing of overly hot food (Back et al. 2004). Its association with the gag reflex has both clinical and potential adaptive value.

All of these hypotheses respond to our almost automatic assumption that everything has a purpose, an indication of how we have been influenced by the concept of adaptive evolution. I see this all the time in anatomy classes when students ask, “What’s it for?” or “What’s it do?” If a structure exists, we think it must be good for something or it would be eliminated by evolution.

Well, to paraphrase Sigmund Freud, “Sometimes a uvula is just a uvula”. It is sort of like asking what the function of the male nipple is. As far as we know, there is none. Rather, the male nipple exists because it is a part of mammalian development that responds to female, but not male, hormones. I like to refer to such structures as phylogenetic (evolutionary) baggage.

I always like to entertain the phylogenetic baggage hypothesis and I have had it in mind for the past 30 years when my students asked me why we have a uvula and the cats we were dissecting didn’t. Maybe that little piece of

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tissue is just a little piece of tissue, an extension of the soft palate and nothing else.

I have not been alone in this line of thinking, but one of the more creative phylogenetic baggage hypotheses was suggested by A.E. Ewens in a 1934 paper in which he suggested that the uvula was a vestigial remnant of a more extensive soft palate that served as a protective curtain in the throat of animals to prevent insects and other foreign objects from getting into the throat while running through the forest (Ewens 1934). This seems an unlikely explanation for a couple of reasons. First, and we will get back to this, embryological development would suggest that the uvula is an evolutionary addition, not a leftover from our ancestors. Second, this hypothesis suggests that only humans retain this vestigial structure even though we are surely not the only animal to run around the forest. Maybe we’re the only one who doesn’t know when to keep our mouth shut!

Testing Functional Hypotheses: What is it really good for?

A true examination of function requires more than casual observation and conjecture. It takes detailed analysis, comparison, and if possible, experimentation. Yehuda Finkelstein, an Israeli otolaryngologist and researcher, and his colleagues have done all of this regarding the uvula, and they did not limit their analysis to the human condition (Finkelstein et al. 1992). They examined the detailed anatomy of the soft palates of sheep, cows, horses, dogs, cats, pigs, macaques, baboons, and chimpanzees, as well as humans. Macroscopic examination of these specimens showed that while two of the four baboons examined exhibited a very small “uvula-like” extension of the soft palate, only the human specimens showed a clearly distinct uvula.

It should be noted that although Finkelstein et al. (1992) found no convincing evidence of a non-human uvula, there are of course many more mammals than the few included in their study. The presence of uvulae in other mammals has been reported, but solid documentation in the literature is lacking. Such reports may reflect the lack of a common definition of when a soft palate extension is or is not to be considered a uvula. Perhaps the characterization of the human uvula proposed by Finkelstein et al. (1992) will serve as a guide to future comparative anatomical examination.

Histological examination by Finkelstein et al. (1992) showed that the human uvula is packed with mucous glands. This was not surprising when comparing to the soft palate tissue of the other mammals, which also had mucous glands. However, the human mucous glands were seromucous glands. As opposed to “regular” mucous glands, seromucous glands secrete a much higher volume of a more watery fluid.

Finkelsten et al. (1992) present some very nice detailed anatomical analysis and put it in a phylogenetic perspective. Obtaining experimental data on humans is of course a much dicier proposition. What happens if you remove the uvula? Well, you cannot just go around asking people if they would mind if you cut out their uvula and then see how it affects their speech or if they get corn chips and soda pop up their nose when they swallow. (Well, I suppose you could ask….)

As it turns out, we do not have to ask people to do this. Some people choose to do it! Specifically, some people with obstructive sleep apnea, a condition in which the tissues of the throat become enlarged to the point that during sleep, these tissues obstruct the airflow into the trachea and lungs – not a good thing! Mild sleep apnea can lead to poor sleep and daytime sleepiness while severe sleep apnea over time can deprive the body of oxygen to such an extent to cause serious physiological damage. While there are a number of treatments for obstructive sleep apnea, the one of interest here is uvulopalatopharyngoplasty (UPPP), which involves removal of the uvula, at least a portion of the soft palate, and usually other excess tissue in the throat region that might relax during sleep and constrict and even close a person’s airway. The success of this “Roto-Rooter” treatment seems to be variable, but for our purpose here, it results in an experimental group of people without a uvula (but with a heck of a sore throat for a few days).

Once healed, these “uvuless” folks seem to have a period of adjustment to life with a shortened soft palate. There are sometimes minor problems with reflux of food or drink into the back of the nasal cavity and some minor changes in voice quality. Since the seal between the oral and nasal cavities is disrupted, there is some leakage of air that interferes with creating the suction needed to drink through a straw or the ability to forcefully blow without air escaping through the nose. Luckily, patients seem to adapt to their new anatomy, and most of these problems disappear in six to nine months. One consequence that seems to linger longer however is dryness and resulting discomfort in the throat, especially associated with talking (Back et al. 2004, Finkelstein et al. 1988, Finkelstein et al. 1992).

So, it seems we are back to Galen’s 1800-year-old idea that the uvula is important in the lubrication of the voice. What gives us some confidence in this hypothesis is additive evidence. Evidence from comparative anatomy tells us that the only organism that clearly possesses a uvula also has well-developed vocal cords and relies to a large degree on spoken language for communication. Histological evidence shows that the uvula is packed with glands that produce lots of lubricating mucus and is located so that most of that lubricant bathes the throat and larynx. Experimental evidence shows that without a uvula, lubrication and speech is compromised or at least uncomfortable.

Not only does all of this add up, but in a 2004 study, G.W. Back et al. directly observed the uvula in action using a
flexible nasoendoscope. During speech, they found that the uvula swings back and forth while secreting saliva, essentially “basting” the throat, larynx, and vocal cords.

**Evolutionary Process: How did it evolve?**

We could end this uvula story here. We know details of its structure, what its function seems to be. We know why such a function would be adaptive in humans and we even know why it is called what it is. But there is another question we can ask about any body part – where did it come from or how did it get to be that way? The general answer is easy. It evolved - often well before the origin of the human species.

For example, if we think about the evolution of the human secondary palate the answer is pretty easy. The secondary palate evolved in early mammals, long before humans or any other apes even existed. There have been slight modifications of size and orientation, but essentially your secondary palate is the same as your dog’s, or a chimp’s, or any other mammal’s. We all have one, it’s basically the same, and it serves the same functions. This does not answer the question of the origin of the secondary palate in the first place, but it easily explains ours. We have simply inherited it from our ancestors.

Most human anatomy can be explained similarly, but the uvula is possibly unique to humans and begs the question of evolutionary origin. If it is a human autapomorphy, how did evolution “build” this thing since our divergence from the apes? As far as I know, this question has not been addressed, but I would like to suggest here that the answer might be found by examining the development of the human secondary palate.

Four bones grow together during our embryological development forming the hard palate. The anterior two bones are a pair of extensions from our upper jawbones. These maxillary bone extensions grow from the sides toward the midline of the oral cavity and in the adult make up about the anterior two thirds of the hard palate. Behind the maxillary bones, a pair of palatine bones grow similarly from the sides toward the midline, and behind the palatines, the soft palate follows suit.

Ultimately, the bones and soft palate fuse and seal along the midline so that the division between oral and nasal cavities is complete. This fusion does not happen all at once; rather it proceeds from anterior to posterior with the maxillaries fusing first, then the palatines, and finally the soft palate. This zipper-like closure begins during the sixth week of our embryonic development and is finished approximately six weeks later.

Unfortunately, this process does not always work properly. If there is not enough tissue in this region or if this growth pattern ends early, the result is the condition known as cleft palate. An extensive cleft palate can extend from the very front of the oral cavity leaving little division between the oral and nasal cavity. The resulting condition is severe and results in problems with nursing and feeding. On the other hand, the process may mostly finish, leaving only the very back of the soft palate with a slight notch or the uvula divided into right and left parts.

Whatever the underlying cause of cleft palate, it essentially results from the truncation of a developmental process, and I think this suggests a possible mechanism for the evolutionary origin of the uvula. If slight truncation of human soft palate development results in a soft palate without a uvula and with an appearance similar to other mammals, might the origin of the uvula be the result of prolonging the same developmental process?

Such hypotheses that implicate changes in developmental timing leading to evolutionary changes in adult anatomy are not new. Embryologists have seen evolution reflected in development for nearly 200 years, and differences in developmental rates of the face and cranium have long been thought to be important in the evolution of the human skull. Until recently, the relationship of evolution and development was mostly implied, but more and more, molecular biologists are making tremendous strides in our understanding of gene regulation and finding the underlying causes of changes in developmental timing. Such *evo-devo* studies are giving us added insight into how evolutionary changes in anatomical structures occur.

**Uvular lessons**

The uvula has proven to be a bit of a surprise to me. I initially thought the uvula would be of interest for three reasons. First, and most personally, I have always been amused by it. It has a funny name and it is easy to make jokes about in class. Second, in spite of it being easy to see, I assumed most people had not given their uvula a lot of thought, but would also find it amusing. Third, I hoped to illustrate that even the most obscure little human structure can tell us something about the bigger picture of the function and evolution of form.

Well, I am still amused by my uvula, but now I see more than just its entertainment value. I have to adjust my attitude on a couple of issues. First, as a comparative vertebrate anatomist, I prefer to illustrate how similar humans are to other vertebrates; how most structures are not unique to us and that we in fact are not much different from those cats in an anatomy lab. Sure, we are bipedal instead of quadrupedal, have less hair, and our brain is more well-developed (at least in some ways). The uvula, I am afraid, is an exception in that it may very well be found in its most derived form only in humans. Sometimes we are unique!

My other preconception about the uvula reflects, I think, the timing of my scientific training. As a graduate student in the 1980’s, I came under the spell of Stephen J. Gould and others who suggested that not everything is adaptive (Gould and Lewontin 1979). Some structures exist merely as phylogenetic baggage or as the result of some basic
developmental pattern. There is not always a functional or adaptive explanation. In fact, one should make this assumption until evidence can be gathered to show otherwise. This idea is part of my baggage, and a part I hold dear, so my assumption has always been that the uvula is nothing more than an extension of the soft palate with no specific function of its own. Thanks to some good work by a number of uvula enthusiasts, it appears that the uvula is indeed functionally useful, and while it may perform a number of functions, it is likely that at least in part, it is an adaptation associated with our propensity for language and for talking so much.

Additionally, if there is any substance to my idea that the uvula may have evolved by the modification of the process of our palatal development, this amusing little grape-like uvula might even give us insight into the process of the evolution of form. Not bad for something that has been dangling right in front of us in the mirror each morning.

**Perspective**

In addition to the uvula, I have used a number of other human anatomical structures to tell evolutionary stories. The coccyx is a great way to introduce the idea of vestigial structures and to illustrate that while humans lack a true tail, its development and subsequent reduction *in utero* link us to the vast majority of vertebrates that possess one. Eyebrows allow for interesting debate about their current function and deeper consideration about the evolutionary loss of most of our hair. The gubernaculum (one of my favorite anatomical terms!) offers a wonderful opportunity to not only discuss the process of testes descent, but to also examine the question of why they descend in humans but do not descend in some other mammals.

My hope and supposition is that such anatomical vignettes accomplish several things:

1. The introduction of evolutionary concepts to students, some of whom may not have had such exposure.
2. An increased student appreciation “that humans are not “creatures” set apart from nature but are clearly animals and, therefore, both part of nature and a product of natural (biological) processes… profound ideas of the last two centuries” (Nickels, *et al.* 1996).
3. The development of critical thinking by examining historical and current hypotheses concerning human form and function through the filter of the scientific process.
4. Increased student engagement and participation by developing their desire and ability to ask deeper questions about the human organism many of them will spend their careers trying to understand.

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**About the Author**

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**Literature Cited**


Leveraging Creative Writing as a Tool for the Review of Foundational Physiological Content

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Abstract
For students to succeed within an advanced course, they must be able to rely upon their foundational knowledge. Unfortunately, without a review of foundational material there is no assurance that students have retained any knowledge from previous courses. This issue is paramount in the human biosciences because the complexities of the concepts these courses teach. We developed a creative writing activity that allows students to examine a previous semester’s material without relying solely upon a series of instructor or peer-led teaching moments. This paper outlines the activity, serving as both insight into student knowledge of previously covered topics and a mechanism to review previously covered information. Students included instances relating to the nervous and muscular systems in their initial drafts and included these systems as well as the cardiovascular system in their final draft. Students avoided mentioning cellular biology during their initial drafts and avoided mentioning the skeletal system in their final narrative. Students were able to apply the information that had been reviewed which translated to improved scores on areas of assessments that covered the same topics that students focused upon in their creative writing stories. This activity was generally well received and was seen as a worthwhile experience.

Key Words: Creative Writing, Content review, Physiology Education

Introduction
One of the major issues faced by instructors who teach courses embedded in a series is gauging the degree to which students retain content knowledge from previous courses (Kamuche and Ledman 2005). So prevalent is this problem that the loss of knowledge between sequential courses has been highlighted in a number of academic publications over the past 40 years (Alexander et al. 2007, Bahrick 1967 and 1984, Cooper et al. 1996, Dunlosky et al. 2013, Kamuche and Ledman 2005). These studies indicate that as much as a 50% decline in retained knowledge can occur in as little as four weeks following the last day of instruction (Bahrick 1967). These studies have either directly or indirectly encouraged faculty to embed review activities either at the end of the initial semester in which the knowledge has been introduced or at the beginning of the subsequent semester. There have been a variety of methods identified that are effective at reinforcing previously covered content in an effort to reduce knowledge loss between semesters (Hoffmann and McGuire 2009). These mechanisms include the administration of an exam, either at the end of the initial semester or during the onset of the subsequent semester (Dunlosky et al. 2013), a lecture or “review session” led by student-peers (Cortright et al. 2005, Kim et al. 2012) or an instructor (Herbert and Burt 2003), or a variety of active learning activities (Krätzig and Arbuthnott 2006, Raines 2010). Each of these techniques aims to allow students to review information previously covered in a uniform and expedited manner before moving on to new information.

It has been shown that the mastery of knowledge in the human biosciences requires foundational information from a wide range of conceptual areas ranging from subcellular mechanisms to systemic function (Caplan 2010, McCarthy 2004). When teaching a course like Human Anatomy and Physiology, which relies heavily on basic biological knowledge introduced in previous semesters, the inter-semester loss of knowledge is more apparent and the review of knowledge is more critical (Logan et al. 2013). In the administration of a year-long sophomore-level anatomy and physiology course at the University of Minnesota Rochester, students were found to lose an average of 13.74% of knowledge as determined by performance on quizzes administered during the second semester of a two-semester course as compared to performance on similar quizzes during the initial semester of instruction (n=157, p<.01).

To combat the intra-semester loss of knowledge, we have developed an active-learning activity that allows students to use creative writing to explore the ideas that were previously covered in a manner that is generally not used in the sciences (Wellington and Osborne 2001), though has been employed continued on next page
in the past to differing degrees of success (Kirkland 1996, Lee and Maerz 2015, Ritchie et al. 2011). Over the past twenty years, there have been a number of concerted efforts to use creative writing in the sciences for a variety of reasons including “humanizing the scientist” as part of an effort to increase scientific citizenship (Morris 2003, Osbourn 2006), creating a more approachable area of study for young girls (Ha and Song 2009) or incorporating an area of the sciences that is normally considered to be a part of the social sciences (Ritchie et al. 2011, Steglich 2000, Tomas et al. 2011). This type of interdisciplinary approach to learning has been shown to increase student learning, especially when applied to the health sciences (Cooper et al. 2001). These varied approaches, which include creative writing, seek to use a humanities lens to increase knowledge gain in the sciences. However, most successful applications of creative writing within the sciences have examined attitudinal changes rather than changes in actual content knowledge, a point that was specifically made in some of the articles themselves (Steglich 2000). The creative writing activity discussed here aims to examine both attitudinal responses to the activity and the utility of the activity as content review. This activity leverages active learning based techniques and group work, both of which have been shown to increase retention of knowledge (Butler et al. 2001, Rao and DiCarlo 2001, Rother and Byrne 2014), to re-examine the previously covered material. Students are asked to write a story about a protagonist who encounters a variety of situations that allow the student to review the anatomical and physiological processes of the protagonist and other characters as they move through the narrative. The overarching goal of this activity is to provide students with an active learning technique that does not rely upon lecture yet effectively aids in the review of previously covered information. Ideally, students are also able to examine a variety of ways of explaining the complexity of physiology while still maintaining a semblance of plot and storytelling, thus fostering creativity, ingenuity and the utilization of proper scientific terminology. Through this activity students are able to focus on what they find interesting and potentially allow for a bit of a “cathartic release” being able to place their professors, or other protagonists in precarious situations.

To allow all students to participate in the study without being overwhelmed by the grading burden of having every student submit his/her own story, the activity is structured using a “Round Robin” technique in which each group of three or four students begins a story using either a provided prompt (see Methods section) or by creating their own story-arc. Once a story-arc is chosen, students are given time to craft a beginning to the story, introducing the protagonist and the situation while incorporating a number of review topics. While students are able to use their notes for reference during the crafting of their narrative, it is suggested by the faculty that students try to use their own knowledge. After establishing the beginning of the story, the group passes their story on to the next group of students. This process continues until the class time is nearly finished, at which time the story is returned to the initial group (Figure 1).

Students are then able to augment the story they initiated to ensure that it includes all of the required elements of a traditional story. The required physiological concepts should be seamlessly tied into the narrative while still maintaining scientifically accurate details (see examples of student work below). Students are asked to fill out the included rubric to provide an initial grade so that they can reflect upon the writing that has been accomplished during the hour.

To determine the merits of this style of concept review, we compared performance on quizzes and exams that directly related to concepts that were covered in the activity. Furthermore, we examined student preference for inclusion of topical material on both the initial and final drafts noting performance on the pre and post activity quizzes. Finally, we examined student attitudes towards the activity to determine, anecdotally, whether students were in favor of departing from the traditional style of review that is normally found in the biological science curriculum.

Methods

Institutional and class makeup

The Bachelors of Science in Health Science (BSHS) program at the University of Minnesota Rochester (UMR) integrates diverse areas of health science--natural sciences, social sciences, health professions--with the goal of preparing students for careers in health care. The Bachelors of Science in Health Science (BSHS) program at the University of Minnesota Rochester (UMR) integrates diverse areas of health science--natural sciences, social sciences, health professions--with the goal of preparing students for careers in health care.

**Figure 1.** Schematic of delivery of creative writing activity. A small group of students begin a story using a provided prompt and are allowed to expand upon that story for a set amount of class time (20 minutes is given as an example). Students then pass this story to the next group. This new group works on the story for an additional amount of time (15 minutes). This group will then pass the story on to the next group, who will work on the story. This process continues until the class is nearly over when the initial group receives their story. The initial group edits the story for content and clarity while providing a cohesive story with a logical conclusion.

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sciences, quantitative sciences and humanities--into a single program. Students who enter the BSHS are mostly traditional-aged college students coming from within fifty miles of campus, which is located in the upper Midwest of the United States. Approximately 70% of students identify as female and 17% identify as persons of color. Students in the program have a common curriculum during the first three semesters. This allows faculty to design curricula across disciplines to provide better formation of knowledge surrounding a given subject (Carey 2011). During the fourth semester, students begin to specialize the remainder of their degree program targeting their courses toward their eventual career aspirations.

All students are required to take Anatomy and Physiology I during the first semester of their sophomore (2nd) year. This course aims to provide a backbone of biological knowledge that serves as the foundation for more advanced courses that are taken in the junior and senior years. It also provides basic human anatomical and physiological concepts to students who will follow a path outside of patient care. While not required by the BSHS major itself, Anatomy and Physiology II acts as a continuation of the information that students have gained during the first course.

Arrangement of Course Content and Pedagogical approach

All the courses in the Anatomy and Physiology series share a “confluent classroom” pedagogical approach. Within this multifaceted instructional space, students receive information in a largely flipped classroom with a hands-on approach to learning that allows for conceptual exploration through group learning, while maintaining individual accountability. The design of the Anatomy and Physiology II course focuses on a curricular review of the material learned during the previous Anatomy and Physiology course in an abbreviated introductory “module” to ensure that students are able to build upon the previously gained knowledge. To that end, students are given two days of instructor led review before undertaking the creative writing activity.

Structure of activity

Students were separated into groups of three or four determined by random number generator and the enrollment in sections. Following a brief description of the activity, students were given a prompt (see below) to begin writing a story about a protagonist who is found in one of the following scenarios while accurately depicting physiological concepts from the previous semester. Students were given twenty minutes to begin their story as a group. When the twenty minutes are up, the story was “passed” the next group. This subsequent group reads what has been written and continues the story, adding and expanding the current plot and scientific knowledge for an additional fifteen minutes. The advancement of the story by additional groups continues, with groups shifting stories every fifteen minutes, until only fifteen minutes of class time remain (diagrammatic of class schedule and timeline in Figure 1). For the last fifteen minutes of the class period, the story was returned to the original group to read and revise for continuity and appropriate anatomical and physiological detail. It was the job of the original group to write a conclusion for the story. Students were given an additional class period to continue working on the story to ensure that all needed physiological concepts were covered in a consistent plot. Grades were assigned by the rubric included with this article.

Student prompt for writing:
The following possible scenarios were presented as the prompt for the creative writing activity:

Your protagonist was

a) paddling a canoe after snacking on trail mix
b) running to their gate from the airport bar
c) swimming after enjoying a picnic of hot dogs and watermelon with his/her family
d) dancing at his/her cousin’s wedding after eating a huge piece of wedding cake
e) enjoying a hike in the mountains after a large dinner that included wine

Students were allowed to pursue their own plotline if a faculty member approved it. The faculty approval process was to ensure that students maintained an appropriate level of professionalism.

Distribution of categories covered within the creative writing curricular review

Students were given a list of nine broad concept categories:

1. General Biology and Cell structure
2. Integumentary system
3. Skeletal system
4. Musculature/NMJ
5. Nervous/Special Senses
6. Cardiovascular system
7. Respiratory system
8. Digestive system
9. Urinary systems

These broad categories were broken down into twenty-seven subtopics that could be covered in their creative writing story (see Table 1). The total number of concepts that were included in the student narrative was counted to determine the areas most covered and least covered during their initial and final drafts. A concept was considered covered when students mentioned a physiological feature or process related to that concept or one of the sub-topics. Analysis

continued on next page
of categorical representation was done by first coding each mention of a concept and linking it to the broader nine categories. The mean number of times each category was represented per year was analyzed using an ANOVA with a Turkey-Kramer post-hoc with an $\alpha = .05$

**Association of activity with performance on quizzes and exams**

Student data was obtained using Moodle and stored in the iSEAL database (Dunbar et al. 2014) covered by Exempt IRB protocol #1008E87333 as approved by the University of Minnesota Institutional Review Board 2009-2015 (ongoing). Data of all students who opted out of the use of data was excluded. Grades on questions from the cumulative final exam from the first semester of Anatomy and Physiology were compared to pre-class quizzes containing similar rigor of questions during the second semester. The difference among performance on these questions was compared using a paired t-test with the mean of the difference between these values being reported.

**Student attitudes towards activity**

To determine student attitudes towards the activity and its utility, students ($n=88$) were given a simple survey in which students could rank attitudes using a Likert Scale (1 to 7). This survey included seven questions that addressed student attitudes towards the activity. These questions included:

1. the assignment helped me review previously covered material
2. the creative writing assignment was fun
3. the assignment helped me remember what I had forgotten
4. the assignment helped me clarify topics I had not understood
5. the assignment forced me to be creative
6. I enjoyed doing the creative writing assignment
7. I would recommend that this activity be repeated in Anatomy and Physiology
8. I would recommend that this activity be repeated in other courses.

A positive response to 5, 6 or 7 (out of 7) of these questions was considered to be a favorable response. To determine percentile rank, a difference of the mean from a benchmark was determined and divided by the standard deviation to calculate a z-score (Dawis 1987).

**Results**

**Distribution of categories covered in the creative writing curricular review**

Students were provided with both a list of biological concepts to be included in the narrative and a rubric with the total number of categories covered associated with grades (on a scale of 1-4) (See Appendix). Since students were not given a prescribed order to include information within their narratives, and were only allotted a single class period to write the initial draft of their narrative, it was expected that narratives would either focus on all categories equally or alternatively, that the most memorable content areas would be covered more than others. In their initial drafts, students focused more on the musculature and the nervous system and focused least on cellular biology (Figure 2A). Unsurprisingly, most likely due to the ability to review, revise and extend their stories for the final draft, there was an overall increase in the total number of topics covered in the final draft (an increase of 4.42±0.29 topics) though the distribution of the increase in these topics was not uniform (Figure 2B). Overall, in the final version of the narrative, there was a preference for including all of the topics covered in the last half of the previous semester (nervous, cardiovascular and digestive systems) over topics that had been covered in the first half of the previous semester (cell biology, integument and skeletal systems) (Figure 2A and 2B).

**Examples of student work**

Students were generally able to review curricular material by weaving the information in a creative writing narrative. The variability of student inclusions of topical areas ranged from a seamless incorporation of physiological concepts while still maintaining the traditional elements of a narrative (examples 1-3) to a disjointed narrative disrupted by merely listing items or terminology whose inclusion was required (examples 4-6). This range of incorporation of physiological topics was present within the entire sample at the class level and at the individual story level in both the initial and final draft, though there was a marked reduction in the latter style in final drafts.

**Student narratives:**

“...the sight and smell of the nutrient rich food lead the [protagonist’s] salivary glands to moisten their parched hard and soft pallets” Story 1

“...everything was happening so fast--not unlike the rapid opening of voltage gated sodium and voltage gated potassium channels along the axons of his nerves in the form of an action potential. The summation of potential in the form of a local graded potential were building much like [the protagonist’s] accumulating worry. He wished his mother was here to support and protect him like a glial cell would to a neuron.” Story 2

“...to further calm his senses, [the protagonist] hummed a song his mother used to sing to him when he was young, to the tune of “Twinkle Twinkle Little Star”.

Oxy, oxy, oxygen

Four will bind to hemoglobin

But the carbon dioxide

Likes to chill and stay outside

Floating in the blood plasma

As bicarbonate, oh yeah!” Story 3
Figure 2. Inclusion of specific physiological elements divided by category. Physiological concepts covered in student creative writing assignments included nine categories. Representation of these nine categories was not distributed equally in either the initial draft (A) or the final draft (C) (* denotes least covered areas; ** denotes more covered areas; groupings determined by ANOVA with Turkey-Kramer post-hoc test for significance). B) Distribution of the increases of inclusion did not follow an equal distribution either. D) Students performed significantly better on assessment questions associated with topics that were better represented within the final drafts of the stories (preferred; * p=.03) but not when looking at topics that were not covered as much (non-preferred; p=.13). E) Percentile rank of students that responded favorably (5, 6, 7 on a 7-point Likert scale) when asked seven questions surrounding the creative writing activity.

“...The alcohol in the whiskey he was drinking had inhibited his ADH which can affect the nephron which is the functional unit of the kidney. With the ADH inhibited the reabsorption of water in his collecting duct was hindered so water in his body went right through his renal corpuscle, through his proximal convoluted tubule, down his Loop of Henle, through his distal convoluted tubule and down his collecting duct into his bladder. This process left him with a burning desire to urinate.” Story 6

“The bolus then enters the small intestine, now called chyme, where it continues to be broken down and the nutrients from the feast he ate are absorbed into his body. As it moves into his large intestine, water is reabsorbed into his body forming feces. Once the feces hits his rectum, his sacral nerves signal his brain telling him he needs to go to the bathroom.” Story 4

“As the action potential reached the synaptic knob, calcium entered into the knob and caused the vesicles inside to merge with the knob and releasing acetylcholine into the synaptic cleft. This caused the muscle fibers to depolarize and contract.” Story 5
Association of activity with performance on quizzes and exams

The performance on questions that were associated with topics that were either frequently represented or least represented categories was assessed to determine if students improved following the activity. This comparison examined outcomes on similar questions between the first semester and the beginning of the second semester following the activity. There was an overall improvement from the performance on the first semester activity to the second semester (p=.01). When examined more closely, the specific area of improvement was associated with those topics that were better represented in the creative writing stories (p=.03) (Figure 2C: preferred). There was no significant improvement in performance on questions relating to areas that were not represented in the creative writing stories (p=.41) (Figure 2C: not-preferred).

Student attitudes towards activity

To determine student attitudes towards the activity and its utility, students (n=88) were given a simple survey in which students could rank attitudes using a Likert Scale (1 to 7). Overall, the majority of students responded favorably (5,6 or 7 on a 7-point Likert scale) on most questions (Figure 2D). This showed that, at least in their own minds, students felt the activity aided in their remembrance of topics from the previous semester (Question 1 and 3) and that the activity was worthwhile and enjoyable (Questions 2, 6 and 7). Students did not respond favorably when asked if the activity helped them understand information that they had previously not understood (Question 4).

Discussion and Conclusion

A review of previously encountered material as a mechanism for reducing inter-semester loss of knowledge is a common practice in courses that occur as part of a series (Kamuche and Ledman 2005). A variety of techniques have been shown to reinforce previously learned knowledge ranging from review exams to active learning techniques. Creative narrative writing in the sciences is an established technique for stimulating interest in novel scientific ideas and for the humanization of scientific principles (Grobstein 2005, Kerr et al. 2011). By coupling creative writing with the review of previously covered material, we have created a method that allows students to potentially explore previously covered information in an informal way that is normally not considered in the natural sciences (Wellington and Osborne 2001). The method covered in this paper does not aim to create a completely novel mechanism for review of material, but rather aims to provide those who teach courses in human anatomy and physiology a unique method for conducting a review of material covered in other courses that is needed as preparation for more advanced physiology courses. Specifically, this creative writing activity allows students to structure their assignment to review foundational content while devolving a story of their own choosing, allowing for both creativity and flexibility in the construction of the narrative.

While composing their narratives, students focused on different areas of physiology in the preliminary draft, tending to focus on the nervous and muscular systems over all other categories. Cellular biology was the least represented area (Figure 2A). This initial preference towards the nervous and muscular systems could be due to a variety of reasons, including the ease of discussing both nervous and muscular processes in the context of a story. Alternatively, the complexity of these two systems requires students to spend more time focusing on them during their study, which was then recapitulated into their stories. There was a significant avoidance of cellular biology and its relationship to physiology in the student narratives. Students who did include this information introduced the concepts in a less creative manner, generally listing topics and mechanisms rather than incorporating the information into the narrative. The discrepancy in student ability to narrativize some categories—namely, the nervous and muscular systems—and not others, could result from greater ease with thinking creatively about some physiological processes than others. For example, it is much easier to describe physiological changes due to the activation of the sympathetic nervous system when being chased by a bear than it is to relate an interesting story regarding the structure of a plasma membrane and how elements are passed from one side of the membrane to the other. Another potential explanation for the discrepancy in the inclusion of certain physiological material is that students were less comfortable with the information that was only included in non-creative terms. Some students were unable to move beyond the simple recall of facts and therefore were unable to create a narrative by synthesizing the information into a creative discourse. Finally, it must be noted that the nervous system and the muscular systems are inherently linked, not only in their presentation in the first semester of the anatomy and physiology series, but also physiologically. While this may be a contributing factor in student recall and therefore inclusion of these systems in narratives, it should be noted that students generally did not include the nervous system and the muscular systems in the same area of their story, but rather spatially separated them, unless they were discussing the neuromuscular junction.

Students were able to incorporate an average of 4.42±0.29 more topics (1.8 times) in their final drafts compared to their initial drafts (Figure 2B). There was also a shift in the inclusion of material in the final draft to stress information that had been more recently covered in the previous semester. Three of the topics, the nervous system, the digestive system and the cardiovascular system, were more frequently represented in the final draft of the paper when compared to other topics while the skeletal system continued to be the least represented of the nine topic areas (Figure 2B). The inclusion of descriptions of the skeletal system tended to be less creative and generally more deliberate, reciting names of bones or skeletal elements rather than creatively incorporating them into the narrative. Those students who were able to incorporate physiological concepts into the narrative displayed a greater understanding of the embedded material and the potential for a true understanding of the material being reviewed.
In general, students responded favorably to the creative writing activity and indicated that the activity was successful in helping them review and remember material from the previous semester (Question 1; 68.75% favorable response; Figure 2D). Students indicated that the activity did not help them learn information that they had misunderstood during the previous semester (46.2% favorable response). Students enjoyed doing the activity (73.9% favorable response) and recommended that the activity be repeated in future offerings of the course (70.5% favorable response).

Limitations

Due to the creative nature of this topic, it is fairly easy for students to ignore the specifics of physiological processes to focus more upon the plot of the story. While this may be the case for some students, it has been our experience that stressing the importance of the review of previously covered material as the in-class preparation for a review exam provides enough of an impetus for students to maintain focus on the task at hand. A drawback to the “Round Robin” activity design is that a group might focus solely on one or two areas that are required for review and add only this information to the stories they receive. This drawback could be avoided by having stories written by a single group or individual instead of as a round robin. Additionally, requiring groups to edit their stories into a coherent final draft should also, at least partially, avoid this drawback. Even though a student group may not have specifically contributed knowledge on a given topic, they will have to read, and therefore review, as well as incorporate additional topics that were not covered in the initial draft. When analyzing a group of responses that did include the names of students associated with each section only a small number (4 groups out of 22) actually included a myopic view of the material. Most of the groups included an average of five different topics in their contributions to their own and to other initial drafts (5.04 ±1.86, n=22). An additional potential limitation to this activity is a consideration of class time and structure. Group size may need to be altered to fit in a tiered lecture hall instead of a room with rows of movable desks or tables. Additional considerations and potential alterations must be made to fit classroom make up and space to ensure success of the activity.

Conclusions

This activity provided students with an opportunity to use styles of thought and expression that are not commonly found in the natural sciences to explore the review of topics covered in previous courses. Students were able to easily review concepts without relying solely on self-led discussion groups, lecture or other activities. This review provided them with an opportunity to review material needed for continuation of the course sequence. Students were able to apply the information that had been reviewed, which improved scores on areas of assessments that covered the same topics that students focused on in their creative writing stories. This activity was well received by the students within the course and was seen as a worthwhile experience.

Appendix

Assignment Prompt

Today we will begin a creative writing assignment that will hopefully help you review some of the material covered in last semester’s class. This will be done in groups in a round-robin fashion. Each group will begin by spending 15 minutes crafting an introduction to the story, including some details from the list below. They will then pass (via shared Google Doc) the story to the next group, who will pick the story up and add more elements from the list below. This process will repeat every 15 minutes. Each new group that adds material needs to make sure that the names of the group members are listed at the end of the group’s contribution. This will continue until all elements have been covered OR we run out of time. Each group is welcome to use their book or other resources to ensure that the physiological principles they include are accurate.

Example themes and starting points include, but do not need to be limited to:

Your Protagonists (this can be your Professors, yourselves or anyone else) was

(a) paddling a canoe after snacking on trail mix
(b) running to their gate from the airport bar
(c) swimming after enjoying a picnic of hot dogs and watermelon with their family
(d) dancing at his/her cousin’s wedding after eating a huge piece of wedding cake
(e) enjoying a hike in the mountains after a large dinner with wine.

Remember that all concepts in the story must make sense. Characters must be introduced (minimally) and all concepts must flow.

Example:

Group #1) Your Protagonists was enjoying a hike in the mountains after a large dinner with wine. Thankfully, neurons in their motor cortex were faithfully sending signals down to motor neurons in their spinal cord. These neurons then sent signals along their axons to the muscles of his legs driving alternating contractions of his quadriceps and hamstrings. Up and up they went, aided by the levering actions of muscle acting on the pelvic, femur, tibia, and fibula bones of their spindly but willing legs.

Group #2) After awhile they came across a bubbling mountain stream and stopped to take in the sights and sounds of nature’s grandeur. “Bubble, bubble, bubble” they heard as if the stream were talking to them. It did not take long for them to get the message loud and clear, “You have to pee!” the stream seemed to say. It was true, everyone’s bladder was full. Antiuretic hormone was being thoughtlessly inhibited by the ethanol in the wine they drank at dinner and a respite behind a tree was desperately needed.

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Group #3) Quietly they got up and found an appropriate arbor where they could cease inhibition of the micturition reflex that would bring much needed relief. Relief...And then...Terror! The bold and very large creature seemed indifferent to your Protagonists' exposed position and approached with the look of chef surveying the fish that they were about to prepare for dinner. The sympathetic branch of your Protagonists' autonomic nervous system...

Group #4)...etc.

Assignment Rubric

<table>
<thead>
<tr>
<th></th>
<th>4 Advanced</th>
<th>3 Competent/meets expectations</th>
<th>2 Progressing/does not fully meet expectations</th>
<th>1 Beginning/does not meet minimum expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>The different parts of the story connected extremely well and transitions were well executed.</td>
<td>The different parts of the story flowed well and transitions were adequate.</td>
<td>The different parts of the story were partially connected and transitions were sometimes present.</td>
<td>The story did not flow well and there were no real transitions.</td>
</tr>
<tr>
<td>Number of Items Covered</td>
<td>The story touches on all of the major topics in the list and includes some additional topics.</td>
<td>The story covers all the topics on the list.</td>
<td>The story includes some of the topics but not all.</td>
<td>The story included very few if any of the topics.</td>
</tr>
<tr>
<td>Scientific Accuracy</td>
<td>The descriptions of the topics covered in the story were very accurate and appropriately detailed.</td>
<td>The descriptions of the topics covered in the story were mostly accurate and appropriately detailed.</td>
<td>The description of the topics covered were partially accurate and either too detailed or lacking in detail.</td>
<td>The descriptions of the topics were inaccurate.</td>
</tr>
<tr>
<td>Creativity</td>
<td>The story and all of its parts was very creative and engaging.</td>
<td>The story and all of its parts was creative and engaging.</td>
<td>Part of the story was creative.</td>
<td>The story was neither creative nor engaging.</td>
</tr>
</tbody>
</table>

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About the Authors

Drs. Petzold, Nichols and Dunbar serve as faculty at the University of Minnesota Rochester in the multi-disciplinary department of the Center for Learning Innovation. They strive to research-driven innovations to improve student learning in the health-sciences.

Literature cited


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The Impact of Rapid Change in Educational Technology on Teaching in Higher Education

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Abstract
The rapid change in educational technology is revolutionizing teaching and assessment in higher education. The latest teaching technologies offer enormous opportunities to enhance teaching methodologies, embrace student-centered classrooms, and to serve diverse learning styles. This review provides an appraisal of how the speed at which the technological shift in education occurred is potentially limiting a thorough assessment of its effectiveness and, therefore, impacting the strength of evidence supporting its use. Recent implications of such technological shift on higher education, while questioning whether the speed of advancement is limiting a thorough assessment of evidence-based teaching is attempted in this review article.

Introduction
Over the last two decades, the traditional classroom environment has experienced a rapid growth in educational technology. In many instances, this has resulted in a significant shift in how educational content is delivered and assessed; how students engage in their learning; and how faculty are choosing, or being asked to change the nature of teaching, learning, assessment, and evaluation. Many students and faculty alike are adapting to a new and more technologically driven paradigm of pedagogy in the classroom, and the concept of the “classroom” has expanded beyond four walls.

Although there is modest evidence of recent adaptations of technology in teaching and assessment, the momentum with which new technology is introduced is too rapid to remain current and, therefore, it a challenge to project the long-term impact of education technology on higher education. This article provides a brief review of the chronological journey of the development or adaptation of teaching aids, an examination of current classroom devices and methodologies using newer technologies, and a prediction of new directions for advancement in technology-enabled teaching tools.

Historical Perspective in the Development of Educational Tools
Teaching tools have existed since the age of the pyramids, although they may not have been identified as such. In 2400 BC, the earliest time period to be traced for the teaching aids, the Egyptians used papyrus leaves for written communication. In 105 AD, a major revolution was witnessed when the Chinese invented wood fiber paper (Hogben 1951), followed by the later creation of the quill pen in 700 AD (Mugo et al. 2014). The invention of the printing press in 1436 AD (Pollak,1972), introduction of the pencil as a writing tool in 1565 AD (Ben-Menahem 2009), and the slate and colored chalk in the early 1800s (Greenhalf 2015) added further to the prevailing list of innovative technology use in education. Distance learning became another practical educational strategy once radio and television emerged in the 1950s (Reiser 2001); this has taken a new twist with online education and the Massive Open Online Courses (MOOCs). The progressively widespread use of computers from the 1970s onward for business, personal, and education use, arguably precipitated the most rapid development of new educational tools. Furthermore, Michael Sokolski’s invention of the Scantron data sheet in the 1970s transformed the way testing could be provided and graded (Clarke et al. 2000), reducing a substantial amount of time spent in grading.

The evolution from the papyrus paper to the Scantron was considerably slow, lasting centuries, compared to the rapid changes we are witnessing today. Interactive whiteboards, clickers, and document cameras are now often the standard implements of a typical classroom. The most recent innovations in wireless technology have led to a massive surge in the development of prominent social medias such as Skype, YouTube, Twitter, Instagram, LinkedIn, Facebook and Snapchat. The latest additions in mobile technology, such as the smartphone and tablet computer, have resulted in the development of new learning platforms which have drawn significant attention amongst educational software developers, content providers, and educators at all levels. Cloud computing and data storage capabilities enable real-time collaborations between individuals separated by time and distance, expanding the opportunities for educational gains.

Impact of Educational Technology on Students and Educators
Many students of the millennial generation are exposed to more information and communication technologies than their educators. While some evidence suggests that students are able to adapt more quickly to changes in technology than educators themselves (Bennett et al. 2008), there are studies that refute this assertion, primarily emphasizing student’s...
knowledge of social media, but not of general technological ability (Tanner 2011). The digital advances have brought numerous opportunities for students to take a more active role in the learning process. For example, students readily acknowledge that they access the internet to obtain new information related to course work (Browne et al. 2000, Junco 2012), thus indicating a shift in student strategies with respect to how information is acquired. Providing a well-defined structure to develop effective technology literacy for students has become one of the new roles of educators.

Instant access to information outside the classroom has revolutionized both learning and teaching. Moreover, the fast pace at which technology is changing, although exciting, can cause confusion and frustration for some faculty and discourage them from developing valuable technology-based educational processes (Kemp 2014, Yilmaz 2013). In The College of 2020: Students (2009) Van Der Werf and Sabatier predict that this shift will continue in a variety of manners: greater student access of online courses, improved access via portable devices, increased connectivity and creativity from colleges, personalization of education, exploring concepts through games and simulations, and other pedagogical changes. With the expansion of classroom technology, it is vital that educators acclimate to such innovative implements to fully prepare students for advancement in education.

Technology Resources and Student Learning

Web-based learning is becoming an important component of the teaching-learning process in higher education, as it appears to be a successful model by which faculty can integrate e-learning into their curricula (Cook et al. 2005, Kukolja et al. 2008). Several studies have demonstrated a high acceptance of various kinds of e-learning by students such as eBooks (Boeker et al. 2005, Davids et al. 2014, Estus 2010, Fordis et al. 2005, Gold et al. 2004, Shaffer 2004) and research supports its benefits (Cook et al. 2005, Fordis et al. 2005, Lyon et al. 1998, Selukumaran 2011).

The incorporation of the course management system (CMS) is currently a common-place technology used at the college level (Barros et al. 2013, Selukumaran 2011). A typical CMS, such as Moodle or Blackboard, allows instructors to direct students to guided studies; provide links to articles and blogs; and offers students news and chat forums (Barros et al. 2013). It also provides a platform for a variety of questionnaires and assessments. The CMSs prove integral in the facilitation and dissemination of institutional course work. Online assessment has permitted instructors to reduce their grading time as well as to allow more class time for teaching, while shifting the assessments out of class as needed (Dobson 2008).

In a study of college students who have used Moodle, this CMS was rated favorably for its ease of access, its real-time discussion board, and its use as a complement to the face-to-face classroom sessions (Barros et al. 2013, Selukumaran 2011). Although students like using many of the course management tools, they do not see the tools as highly effective at enhancing the learning experience (McCabe and Meuter 2011). Such differences could be due to the fact that CMSs provide the tools but planning and executing depends on the instructors using the technology (Barros et al. 2013).

Mobile devices were once considered distractive in the classroom. However, now that CMSs support mobile platforms, students have the ability to access the entire course content via the smartphone. For many students, smartphones are replacing computers in the classroom (Bruce-Low et al. 2013, Gikas and Grant 2013, Longmuir 2014). Additionally, smartphones are also replacing clickers (NMC Horizon Report 2015). For example, Poll Everywhere uses text messaging for polling and voting, a technology that provides not only quick feedback but also engages students in learning. The m-Learning is fairly new and research evidence is yet to be gathered to assess students’ experiences compared to other computing devices. Similarly, web conferences, and social networks can also be utilized to facilitate student learning (Borges and Mello-Carpes 2014, Dabbagh and Kitsantas 2012, Estus 2010, Vargas et al. 2014, Varsavsky et al. 2014).

Lecture capture (LC) is an additional classroom technology that allows real-time recording of live lectures as an optional resource for the students (Newton et al. 2014). While students benefit from using these recorded lectures for review purposes or to replace a missed class, faculty members could also revise teaching strategies based on analytical information regarding topics students accessed due to the level of difficulty (Prodanov 2012). LC, however, could pose a significant concern, the student absenteeism (Maynor et al. 2013, Prodanov 2012). The benefits of the use of LC on student learning are mixed (Secker et al. 2015, Stroup et al. 2012). While some studies suggest that LC provides little to no grade improvement when combined with live lecture (Brotherton and Abowd 2004, Hadgu et al. 2016, Karnad 2015, McLaren 2004, Navarro 2000), other studies have shown that LC significantly improved student performance and retention when it was used to supplement live lecture (Cramer et al. 2007, Danielson et al. 2014, Secker et al. 2015, Whitley-Grassi and Baizer 2015). Yet another concern is the cost of implementing this technology in the classroom.

Adaptation of New Teaching Technology in the Development of Student-Centered Learning Methodologies

The didactic method of teaching has proven to be less engaging than inquiry-based learning, especially due to the abundance of easily accessible resources such as animations, interactive websites, and videos (Persky and Pollack 2011, Rawekar et al. 2013, Simonson 2014). The use of in-class active learning strategies, on the other hand, has been shown to accelerate learning while reducing lecture time (Clark et al. 2006). There are newer teaching strategies such as flipped learning (FL), which may help overcome limited class time.

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The FL methodology is a student-centered teaching approach. Here, the didactic content is delivered outside the classroom in multiple ways such as lecture video, lecture PowerPoint slides, guided readings, and work sheets that students complete prior to class time. The in-person class time is used for active learning where students process the information and practice the content in a variety of strategies. This approach provides an opportunity for enhanced time-efficiency, student self-pacing, and classroom time for more interactive learning. Although FL was in existence when educators used reading resources to engage students prior to the classroom session, the lecture video has stirred new interest in this style of teaching. It is possible that FL is often predominantly lecture videos because instructors have access to an abundance of choices of video recording technology or may depend on videos that are readily available online such as the Khan Academy. The production of videos, using gadgets like Zoom or Camtasia, and the ability to host the videos on the CMS creates easy access from anywhere. The FL is being adapted by many educators perhaps due to two key reasons: the FL replaces the passive didactic teaching and the tools required to prepare the course content in the form of lecture videos is made simpler. This approach requires students to assume responsibility for important aspects of their own learning – mainly the basic knowledge and comprehension of content, which are often considered to be the foundational elements of the learning process (Clarke et al. 2000). The additional opportunities available in the classroom via active learning strategies allow students to apply and analyze the content to achieve more in the overall learning process. In fact, the FL model has shown to improve student preparedness and increase students’ level of engagement during class (Estes et al. 2014, Herreid and Schiller 2013, Tune et al. 2013). Some of the success of this emerging teaching methodology, however, depends on the use of highly structured activities before, during, and after class (Estes et al. 2014). Students, on the other hand, often perceive this approach as increased workload due to the fact that it demands regular study habits and upfront time commitment. Students can no longer only spend time outside of the classroom studying for upcoming scheduled exam (Estes et al. 2014, Tune et al. 2013).

The FL often involves case-based learning (CBL) as one of the active learning strategies. CBL uses clinical scenarios and requires students to apply newly learned concepts (Hudson and Buckley 2004). Evidence suggests that CBL can be successfully implemented in a team-based learning (TBL) format by engaging students in the classroom to work cooperatively to solve a CBL challenge. Students are assessed once with the individual readiness assurance test (iRAT). This is often completed outside the class time in the form of an online quiz. iRAT, as an online assessment, sanctions additional class time for the TBL session. During the actual TBL session, students work in their predetermined groups to complete a team readiness assurance test (tRAT) and receive immediate feedback (Lord 2008, Michaelson et al. 2002).

Students’ scores on the iRAT, combined with a tRAT, helps students earn higher grades than the tRAT alone (Gopalan et al. 2013). Evidence suggests that integrating these resources with active teaching models provide ideal opportunities and promotes basic knowledge acquisition and critical thinking, while providing a rich learning environment. It should be noted that the TBL and CBL methodologies have been used successfully even before the educational technology dramatically invaded the classrooms. The newer tools, such as Google document or Wiki, can be blended to facilitate the group process.

Course delivery methods are undergoing major transformation as well. Live streaming of lectures from one location to several campuses, bypassing the need for instructors on each campus, is becoming a new strategy. Additionally, MOOCs (Massive Open Online Course), which are courses made available for free online to a large number of people, are an alternate to university degrees. Effectiveness of this technology needs to be explored, however.

In summary, the adaptation of newer educational technology into teaching has allowed educators to become creative in revolutionizing teaching, however, it is important to scrutinize what tangible educational gains are being attained from such modifications. Learning Technology Effectiveness, a report from the Office of Education Technology, U.S. Department of Education in 2014 suggests that the new technology and comprehensive teaching schemes appear to enhance student performance and the overall learning experience. With these innovations, institutional goals of facilitating student engagement, knowledge development, and higher-order critical thinking can be achieved. However, the fast-paced changes in technology and its adaptation without significant evidence, is a concern. In order to maximize the effectiveness of the exploding classroom technology; and ensure student engagement, knowledge development, and critical thinking, assessment of these tools and techniques is vital to the education community.

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**About the Author**
Dr. Gopalan earned her PhD in Physiology from the University of Glasgow. She has been teaching Anatomy, Physiology, and Pathophysiology at both graduate and undergraduate levels for a variety of programs in allied health profession. As an educator, she has revolutionized physiology teaching to include active learning strategies such as team-based learning, case-based learning, and the flipped classroom. She has written a digital physiology text for pharmacy students and she is available on the Life science Teaching Resource Community (lifescitrc.org) website. In addition, Dr. Gopalan has been conducting research of her innovative teaching approaches.

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### HAPS-I Opportunities

#### Spring 2017
**Mechanisms of Disease: Type 2 Diabetes Mellitus**  
(2 credits) February 27 - April 17, 2017  
Dr. Brian Shmaefsky  
Lone Star College - Kingwood  
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**Register for Graduate Credit or Professional Development!**

This course will examine the cellular, molecular, epigenetic basis of endocrine disease as a model disease that connects the cellular processes with the physiology and pathophysiology at the tissue and whole organ level. The spectrum of disorders that produces type 2 diabetes will be the focus of the course. Type 2 diabetes, or metabolic syndrome, is globally growing in incidence and is showing up in a younger population. This course uses case studies and current literature reviews in an asynchronous virtual format and will require an online coursework. The ability to interact in formal discussions will be available at the annual HAPS conference. The content of the course is directly applicable to those teaching classes ranging from introductory nutrition, human anatomy and physiology, and upper level courses in physiology. This course is designed to facilitate your teaching as well as updating your content knowledge. This 2-credit course will follow a completely online format with some synchronous communication.

#### Summer 2017
**Anatomia Italiana del Sud: The Cultural History of Anatomy in Southern Italy**  
(3 credits) June 10 - 22, 2017  
Dr. Kevin Petti  
San Diego Miramar College  
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This course is an international experience preceded by the completion of an online curriculum that employs a series of readings in peer-reviewed journals and scholarly books that put the travel experience into context, and are followed by the development of a teaching module after the travel. This interdisciplinary experience allows for students to connect art and anatomy in a unique manner. The result is a deeper and richer understanding of the historic and cultural underpinnings of anatomy education.

Students will participate in a 12-day visit to Southern Italy, with nine of those days in Sicily, and three days in Naples and the vicinity. The itinerary examines ancient Greco-Roman depictions of the human form in sculpture, painting, and mosaic - including the body as a vehicle for religious expression in two Capuchin Crypts. Also featured are university anatomy museums in Palermo and Napes, as well as the ruins of Pompeii, a city covered with volcanic ash 2,000 years ago. Highlights also include historic anatomy theaters and centuries old anatomical wax models, as well as the Riace Bronzes, 4th century BCE sculptures that are amazingly accurate anatomically as well as culturally important. These masterpieces will be considered with the context of how they were influenced by the dissections conducted by the artistic masters.

The travel expenses are not included in the 3-credit tuition for this course. See website for more details.
The Novel Use of Silicone Dielectric Gel for Central Nervous System Encapsulation and Preservation

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Abstract
Anatomical sciences education is currently at a crossroads. Cadaver dissection is widely considered an essential part of an anatomical sciences curriculum. However, facilities are often expensive, and with pressures to reduce cost and concentrate anatomy learning into fewer hours, there is a clear need for alternative teaching tools that preserve vital characteristics of cadaveric specimens. We report here on a new method for the encapsulation and preservation of the central nervous system (CNS). The encapsulation material is a high performance, silicone dielectric gel adhesive that provides a stable environment without any significant visual distortion. This method is cheaper and simpler than plastination, can be repaired or changed after initial encapsulation, preserves fine detail, and can clearly demonstrate anatomical variations. With the current need to balance the use of digital technologies with cadaveric specimens, these types of specimens can be a valuable addition to any anatomical sciences curriculum.

Key Words: Encapsulation, Anatomy, Cadaver, Silicone gel, Education

Introduction
Historically, the classic method of teaching human anatomy has focused on hands-on learning through human cadaver dissection, often recognized as providing better outcomes in student learning than either prosected cadavers (Winkelmann et al. 2007) or models only (Anyanwu and Ugochukwu 2010, Wright 2012, Preece et al. 2013). However, many anatomy departments have greatly reduced the amount of time students spend in the lab, often in part due to the lack of support from educational administrators. In general, cadaveric dissection has leveled off and lab hours have decreased as medical schools and undergraduate institutions move towards digital teaching and other alternatives in this technologically advanced era (Shaffer 2004, Drake et al. 2009). In some cases, cadaver dissection has been completely phased out of medical schools as they transition to a curriculum with computer simulations, synthetic cadavers, and plastic models (McLachlan et al. 2004, Nguyen et al. 2012). The effects of this shift in medical and anatomical education are still not clear, though recent studies suggest that students learning with digital teaching tools do not perform as well as those directly interacting with cadavers (Biasutto et al. 2006, Saltarelli et al. 2014, Mathiowetz et al. 2016). Some programs that discontinued anatomical dissection in favor of model-based teaching have later re-adopted it as an integral part of their program in response to a drop in student performance (Rizzolo and Stewart 2006). Whether or not computer-based anatomical software is more beneficial, or equal for student performance in traditional dissection courses remains a topic of considerable debate (Leung et al. 2006, Bergman et al. 2011, Johnson et al. 2012).

However, with the advent of more advanced computer imaging, synthetic models, and other alternatives, student interaction with real human tissue may begin to decline. With pressures on institutions to reduce cost, and often decrease the time-consuming hours dissecting (Shaffer 2004, Dissabandara et al. 2015), there is a clearly demonstrated need for alternative teaching tools that preserve as many qualities as possible of actual cadaveric specimens. Synthetic, high fidelity models are durable and give clear representation of three-dimensional relationships (Chan and Cheng 2011) but lack the detail of real tissue. These models also demonstrate “normal” structures of the human body while overlooking variations or pathology, an important aspect for students pursuing a future in health sciences. One solution to this problem is the use of plastinated cadaveric tissue, where water and fats are replaced by plastic, yielding specimens that retain more "lifelike" properties than a traditional model (Tamura et al. 2014, Stancu et al. 2015).

Plastination, invented by Gunther von Hagens in 1977, has produced spectacular models both for education and display (von Hagens and Tiedeman 1987, Baker et al. 2013, Stancu et al. 2015). Often considered the gold standard in human anatomical model creation from cadaveric tissue, plastinated models have been demonstrated as more beneficial for student learning in anatomical sciences as compared to...
computer-based models (Fruhstorfer et al. 2011, Riederer 2014, Tamura et al. 2014). While this technique produces high-quality specimens, it is often a laborious, time-consuming, and expensive process to perform, frequently requiring special lab facilities that may not be accessible or affordable (Cornwall 2011, Stancu et al. 2012, Riederer 2014). While some specimens may last for many years, handling of these specimens can also lead to damage, making them potentially less cost-effective. Additionally, plastinated nervous tissue shrinks considerably and becomes more prone to breaking (Riederer 2014).

In this paper, we present a material and novel method for the encapsulation and preservation of the central nervous system (CNS) of a single cadaveric specimen; an additional tool for teaching anatomy to a broad range of students from diverse backgrounds, including both undergraduate and post-graduate students. This method is cheaper and simpler than plastination, shows greater detail than plastic models, and provides students a physical object to view. Additionally, this method has great potential to reclaim and restore older specimens preserved in formaldehyde, as often this fluid darkens with age, and the teaching value of these specimens is diminished.

Materials and Methods

Body donation program

Northern Illinois University (NIU) offers a body donation program that supplies cadavers to courses at both the undergraduate and graduate levels. This program works in conjunction with a local funeral home where initial cadaver preparation is completed. Cadavers are perfused with a solution of Dodge Chromatech Pink-21.5 index, Metasyn-20 index, Metaflow arterial conditioner, and Rectifiant pH stabilizer equaling 2.5-3 quarts of final solution. Perfusion fluids are administered through a cannula in the right common carotid artery as a closed system. Cadavers are then transported to NIU and again perfused for storage.

The cannula from initial embalming is used to perfuse with a solution containing 4L phenol, 4L 95% ethanol, 1L formaldehyde. This solution is introduced into the cadaver by a gravity-driven system and takes 1-2 days.

Cadaver dissection

The CNS (brain and spinal cord) were removed from the cadaver as a single unit and transferred to a solution of 1:8 formaldehyde:H₂O. It should be noted that the complete dissection and removal of an intact human CNS can be a complicated and time-consuming endeavor which should be undertaken by an experienced dissector. As part of this project, a comprehensive digital atlas of the central nervous system and excision manual was compiled (Persino 2014). Storage of the nervous tissue consisted of six washings and re-fillings of the holding solution to ensure no additional particles or fluids would be introduced into the encapsulation.

Materials used in the encapsulation

The encapsulant for this project is from Noelle Industries, Inc. Noelle 810-47 is a low viscosity, soft, transparent, two-component (1:1 mixing ratio), high performance, silicone dielectric gel adhesive. It was designed for use in applications that require a highly flexible, shock resistant material, to cushion coat sensitive or fragile components/fine electrical wires. The material has a specific gravity of 0.88 with an operating temperature of -45°C to +150°C. Working time for this material is 3 hours with a cure time of 16 hours at 25°C, according to the manufacturer (Noelle Industries 2004). This product was purchased directly from the manufacturer at a price of $25/lb.

Encapsulation process

Prior to encapsulating the finished product, a test CNS specimen was used to determine the proper steps to be taken during the final encapsulation. The vacuum apparatus and test specimen are diagrammed at the end of this section (Figure 1, Figure 2).
Encapsulation was completed within a cast acrylic tube suitable in size to contain the entire CNS. This tube was first closed off at one end with machined sheet acrylic and sealed with adhesive to ensure no leak of encapsulation material. A two-inch diameter circular hole was machined in the center of this piece for a cap and pressure-release system. Three inches of encapsulant was then poured on this end with a temporary plug coated with a silicone cast releasing agent in the two-inch hole; it was then allowed to set for 25 minutes to act as a cushion for the CNS as it was lowered in. Immediately following the pour, a vacuum was pulled on the system for five minutes to encourage dissolution of any trapped air in the encapsulant. The specimen was lowered in brain first with a clear monofilament secured to the cauda equina to maintain the spinal cord in the central position of the display. A second pour was done to cover the base of the brain up to the pons. At this point, a custom-designed acrylic-sheet support was lowered and secured at the new level of encapsulant. A second vacuum was then pulled on the system. Three final pours with subsequent vacuuming were then performed until the entire specimen was within the encapsulant (Figures 1 and 2).

**Curing and finishing**

This system was allowed to settle for several months to observe changes before the final pour and sealing of the tube was complete. The tube was then sealed at the end of the cauda equina with a machined acrylic sheet. The entire specimen was then turned right-side up for a final filling before sealing. A steel cap with a hole (<1mm) was machined as a pressure release for the top of the encapsulation to replace the temporary plug used during the encapsulation procedure. In the event the specimen was ever in a high temperature situation, this cap allows for pressure equilibration between the system and its surroundings.

**Results**

Upon completion, the encapsulation revealed a crystal-clear specimen without any distortion of structures, by gross visual inspection. During the process, we also demonstrated that the material was repairable with freshly mixed encapsulant, allowing for the repair of any mistakes or gas inclusions. Repairs were easily accomplished with a Pasteur pipette and freshly mixed encapsulant. It should also be noted that within the first week nearly all of the gas inclusions, which were unable to be removed, had vanished. This was the case for nearly all of the inclusions under one centimeter. A few larger inclusions remained in the encapsulation, but did not affect the overall quality and visibility of the specimen. It is important to note that this material does not set solid, but rather to a stable gel-like consistency. Though the working time of this material is listed as 3 hours at 25°C, we found that for our application, the reasonable working time was only approximately 30-45 minutes. However, though the working time was significantly reduced, we found it to be more than adequate for this type of application.

This medium was found to be superior to both liquid systems and solid systems. In our experience, liquid systems allow for too much diffusion and exchange between the specimen and its surroundings, which creates cloudiness and discoloration to the system. On the other hand, solid systems (e.g., epoxy) have a significant exothermic reaction, only allowing small pours to be done at a time; this allows any larger specimen to potentially desiccate before encapsulation is complete. Another issue with solid encapsulants in acrylic tubes is distortion, as structures cannot be visualized without distortion in a larger epoxy-based system. While acrylics may be useful with smaller plastinated systems, it may not be feasible for larger specimens, as distortion produces a model that is not an accurate representation. Noelle’s dielectric gel did not produce any significant distortion in the display. Structures covered by several inches of encapsulant are still clear and non-distorted during visual inspection. The equilibrium of the system, as compared to holding solution, does not allow for diffusion of discolored perfusion fluid beyond the confines of the tissue; unlike exclusively fluid systems.

Since the primary pour and encapsulation of this specimen, it has been over two years. There has been no observable change in either the specimen or surrounding encapsulant. While the total lifetime of the specimen cannot be determined at this point, the lack of change is a promising indicator that this method may produce a stable specimen for the long term. However, as this is the first time that this material has ever been used for this specific application, it will be several years before the complete efficacy of this dielectric gel as an encapsulant will be established.

**Discussion**

This method of CNS encapsulation is both simpler and cheaper than traditional plastination methods. The total cost of encapsulant for this application was < $700. Considering the large amount of encapsulant used to complete this project, it is still significantly cheaper than plastination. Fast pouring and setting of the two-component silicone based dielectric gel can prove to be a valuable addition to labs that do not have plastination capabilities. As large anatomical sciences courses pose a barrier to students direct contact with cadaver dissection (Simpson 2014), or ideal prosected specimens, these types of models for both teaching and examination purposes may help eliminate the need of prosections that have a limited lifetime. Older anatomical specimens in storage may also have renewed teaching value by removing them from darkened formaldehyde and encapsulating them. Additionally, as body donation waxes and wanes at our institution, this method also offers labs a way to retain parts of cadavers in an easy, cost-effective manner. This may prove to be especially important in the preservation of pathologic features for teaching purposes in both undergraduate and medical institutions alike.

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One drawback of this method as compared to plastinated specimens is the lack of “direct” physical interaction with the specimen, as our method encapsulates the material in a cast acrylic tube; which may be a possible source of hindrance to student retention of information (Preece et al. 2013). However, we argue that different anatomical regions may be more or less suited for this type of model. Our encapsulation of the entire CNS allowed for detailed examination of the superficial surface of the brain, cranial nerves, and the spinal cord. However, the encapsulation of something very small (e.g., the middle ear) or something very complex (e.g., infratemporal fossa) may be challenging for this type of model without the benefit of close “in-hand” inspection.

Though it was not done for this project, these types of models can be tagged and labeled before encapsulation, allowing them to be used with guides to structures or as specimens for laboratory examination questions. Additionally, the use of red laser pens for instruction could also be utilized to highlight untagged structures or to draw attention to larger areas of the encapsulated specimen. Future work should experiment with other ways to maximize the potential of encapsulated specimens for student learning and assessment.

The authors acknowledge that this encapsulation specimen and its precursors are the only of their kind, but recognize the potential of using this material as an encapsulant for a variety of anatomical specimens. The size and construction of this specimen is clearly not meant to be handled extensively by students, but is a starting-point for future encapsulations. More efficient use of space within a display can dramatically decrease the cost, size and weight of the completed product; making it more maneuverable and convenient for students. This material should not be limited to CNS structures, but should be experimented with and tested on all tissues. Though the efficacy of the silicone dielectric has not been tested with other anatomical specimens, it is our opinion that it will also provide highly detailed encapsulations of a variety of tissues.

Conclusions

Anatomical sciences education has been moving away from costly and time-consuming cadaver dissection to cheaper and more technology-based approaches (Nguyen et al. 2012). When implemented properly, computer based models and other educational tools that do not require a wet laboratory can certainly be beneficial to student learning (Wright 2012, Hochman et al. 2015). However, it has been shown that three-dimensional analysis of anatomical specimens is an advantage to learning outcomes of students, specifically those that retain qualities that make cadavers or high-fidelity models unique and valuable learning tools (e.g., variation, pathologies; Preece et al. 2013). Obtaining structurally detailed and long-lasting specimens is vital to the success of students’ structural understanding of the human body.

This new method of encapsulation is a cheaper and more accessible alternative to traditional plastination techniques, and may provide a longer-lasting teaching tool. Though this model required a great deal of encapsulant, its production was significantly cheaper than that of traditional plastination methods. Future encapsulations can maximize specimen space while minimizing the amount of encapsulant required. As the multimodal approach is demonstrated to enhance student learning (Drake and Pawlina 2014, Fasel et al. 2015), this technique offers an additional tool that, when combined with other methods (e.g., digital models, small-group learning, integration of clinical correlates) may help to enhance and enrich the student experience; though this investigation has yet to be initiated. While encapsulated specimens lack the ease of handling and manipulation of in-hand models, we believe that with the current need to balance the use of digital technologies with cadaveric specimens in a cost-effective way, these types of specimens can be an important addition to any classroom or laboratory. It is not the authors’ intention to replace any traditional or new tools for teaching anatomical sciences, but rather to introduce an adjunct to the lab or classroom to enhance student learning (Figure 3).
Acknowledgements

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Literature Cited


The Pedagogical Value of Mobile Devices and Content-Specific Application Software in the A&P Laboratory

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Abstract
The purpose of this study was to evaluate the pedagogical utility of mobile devices and content-specific application software in the Anatomy and Physiology laboratory. Four core topics were examined: Tissues and Integument, Skeletal System, Muscle System, and the Heart. Five lab instructors were involved; each instructor taught one “experimental” lab section where students used mobile devices with histology and anatomy apps, and taught a second “control” lab section in which students used their lab manuals. The experimental students’ metacognitive responses were measured via exit surveys; the instructors were also surveyed and interviewed. Using a Likert-type scale we analyzed the student response, which indicated that overall the students reacted positively to the digital technology in the lab, felt that this modality was effective in motivating them to learn the subject matter, and considered the apps to be more effective as a learning tool than the lab manual.

Key Words: iPad, tablet, histology, anatomy, learning

Introduction
In today’s super-charged information age, most of us expect information to be at our fingertips and this is especially true of our current students, who are more likely to look for information on the Internet than to reach for a book or visit a library. Mobile devices have become an extension of personal outreach to the world, the last thing our students use before falling asleep and the first thing they reach for when they wake up. Mobile devices offer many pedagogical opportunities, especially easy access to textual information and visual resources, three-dimensional representation of anatomical structures, as well as the ability to study dynamic processes, powerful capabilities that traditional textbooks cannot match.

We conducted a survey among our own students, which revealed growing use of electronic devices in the study of Anatomy and Physiology, with a variety of mobile devices playing an important role (Figure 1). A recent systematic literature review of the use of mobile devices in higher education indicated that while instructors and students are positively inclined toward the use of such devices, there is a great need for longitudinal and large-scale studies to explore and assess the best pedagogical strategies for digital mobile learning (Nguyen et al. 2015).

Furthermore, there is a dearth of studies relating to mobile device use in the environment of biology laboratory classes at urban community colleges. In the current study, our primary hypothesis going forward was that mobile devices and content-specific apps would increase student enthusiasm and engagement.

Anatomy and Physiology 1 (A&P 1) is a required course for pre-nursing students at Hostos Community College of the City University of New York (CUNY). The demographic profile of our students is predominantly female and minority. Because there is no science prerequisite for A&P 1, students may enroll...
without a background in biology or chemistry. The course consists of a three-hour lecture and a separate three-hour laboratory. Experiments and dissections make up only a small part of the lab work, which mostly consists of examining tissue slides under the microscope or looking at skeleton, muscle, or heart models. Many of our students are disengaged from lab work, and it is often difficult to motivate students to devote sufficient time to viewing the tissue slides or studying the models.

We decided to explore the possibility that introducing digital technology, tablet mobile devices and software applications (apps) into the A&P 1 lab would stimulate student engagement and active learning. Histology and anatomy apps provide powerful features that are not available in the traditional lab: all structures are labeled and may have detailed annotations, there is no need to focus slides, and anatomical structures can be viewed in three dimensions as well as rotated and sectioned. Such apps would reduce the frustrations that many students have when attempting to identify tissue or organ structures without the assistance of the instructor.

**METHODOLOGY**

A one-semester study was designed to investigate the pedagogical efficacy of using tablet mobile devices and apps in the laboratory portion of the A&P 1 course. Our main focus was on student attitudes towards the digital technology, and whether student engagement with lab work could be increased. To that end a qualitative approach was taken, using exit survey questionnaires that the participating students and instructors completed, as well as in-depth interviews with each of the instructors. Conventional quantitative assessment was also carried out, albeit without statistically significant results. As such, therefore, our results and discussion are mostly couched in general principles and observations.

Because our project involved live subjects, we submitted our study plans to our University Integrated IRB, which approved the study and determined that it was exempt from IRB Review, qualifying as research conducted in established or commonly accepted educational settings involving normal educational practices (Collaborative Incentive Research Grant C3IRG-2015). Informed consent was obtained from all participants.

The study involved five laboratory instructors and ten A&P 1 laboratory sections, representing a student enrollment of two hundred and eighty (i.e., N = 280). Five lab sections used tablet devices and apps; these sections were designated as “experimental.” The other five sections, which used the assigned lab manual and did not use digital technology, served as the “controls.” Each of the five instructors taught one “experimental” lab section and one “control” lab section.

Five lab exercises, each representing one lab period, were included in this study: Tissues 1, Tissues 2 and Integument, Skeletal System, Muscle System, and Heart. (At our institution, the cardiovascular system is taught in A&P 1 instead of the nervous system).

Students in the “control” lab sections participated in traditional lab exercises with lab manuals, microscopes and slides, and models. Specifically, during the two Tissues labs, students used microscopes to view tissue slides, and looked at related photomicrographs in their lab manuals. During the Skeletal System and Muscle System labs, students used anatomical models to study these organ systems, with the assistance of diagrams in their lab manuals. During the Heart lab, students dissected a sheep heart and looked at heart models.

In contrast, students in the “experimental” lab sections used tablet mobile devices and content-specific apps to complete the work, instead of the traditional lab manuals, microscopes, or models. During the two Tissues and Integument labs the students used Smart Histology v1.1.3 (Smart in Media 2014), a virtual microscopy app that contains 103 human tissue slide images annotated with identifying labels and brief descriptive annotations describing the tissues (Figure 2). For the three anatomy labs—the Skeletal System, Muscle System, and the Heart—students used Essential Anatomy 5 (3D4Medical.com, LLC, 2016), a three-dimensional anatomy app with identifying labels that can help the student visualize the different layers and cut-away views of body structure (Figure 3).

Two sets of detailed lab worksheets were created to guide the students through their lab activities. Worksheets for the traditional “control” lab sections were designed to be used in conjunction with the regular lab manual for the course, whereas worksheets for the mobile-device enhanced “experimental” lab sections were designed for use with the histology and anatomy mobile apps.

We used Apple iPads as mobile device platforms to run the digital apps in the experimental lab sections. The educational technology office at our college provided the iPads for each lab period, and removed the iPads afterward. Therefore, students in the “experimental” lab sections had the use of an iPad and associated apps only during the lab period, and could not use the apps for personal study unless they had their own mobile device and purchased the app.

![Figure 2. Students use the Histology app in conjunction with worksheet.](continued on next page)
Pedagogical Assessment

At the beginning of the semester all students (both the experimental and control groups) completed a questionnaire concerning their use of technology. At the end of the semester, in the experimental sections, students were asked to complete an online survey to elucidate their metacognitive reflection on the effectiveness of the apps in helping them absorb and retain the information that they learned in the lab. Because student participation in all aspects of the study was voluntary, as per IRB requirements, and because of the usual student attrition during the semester, only a subset (N = 37) of the original experimental group of 140 students completed the end-of-semester exit survey.

At the end of the semester, participating instructors were individually interviewed. The instructors also completed an online survey, where they could express their views on the relative effectiveness of the app-assisted experimental lab exercises.

Students

A survey of student opinion at the end of the semester indicated that most students were enthusiastic about the apps, and valued the introduction of digital technology into the lab (Table 1). Overwhelmingly, they enjoyed using the iPads and apps in the lab and had a positive learning experience (86% agreement), and felt that they were motivated to learn more about the subject matter (81% agreement). Students reported that the digital technology made it easier for them to learn about the topics covered in the study, tissues and skin, bone, muscle, and the heart (ranging from 81 to 95% agreement). They also identified the two most helpful aspects of the apps, first, that the anatomy app helped them to visualize structures in three dimensions more clearly, and second, that the histology and anatomy apps provided a convenient source of information about the structures.

In comparing the benefit of using digital devices and apps instead of the traditional mode that used the lab manual, 73% of the students thought that using apps enhanced their knowledge and understanding. However, only 57% said that they preferred replacing the lab manual with the apps, indicating that many students still resist a complete shift to digital technology. This may have been because the students’ own learning styles did not find a comfortable fit with the apps’ format, or because of the complexity of the apps, particularly the anatomy app. Several students explicitly commented that they had experienced difficulty in mastering the two apps.

Instructors

In general, the five instructors who participated in the study found that mobile devices and apps could play a positive and useful role in the lab. This modality was a “new and attractive way of presenting the material taught for that class,” which kept the students engaged in learning. Information in the apps helped students to see details as well as the whole structure, and provided “an efficient and easy” way for students to access information. In addition, the instructors felt that the novelty of the apps triggered a positive response from the students, who were then stimulated to engage in active learning.

With respect to the histology app, the instructors agreed that such apps could have a positive value in helping students understand tissues. The histology app was more successful than the microscope in holding the attention of students. Additionally, the app facilitated learning by making information about the tissues more accessible, it allowed students to move from one tissue image to another more efficiently, and it provided a uniform learning experience in the classroom compared to the variety of glass slides that students use in a typical microscope lab exercise. However, as a practical matter, all of the instructors found that the histology app used in the study lacked sufficient resolution to allow students to clearly visualize tissues and cell types at high magnifications.

Regarding the anatomy app, the instructors recognized the value of anatomy apps in helping students identify, slice, layer, and rotate anatomical structures, as well as in helping students understand the location and orientation of structures in the body. The anatomy app kept the students engaged, and also solved the ongoing problem in our labs of not having enough muscle and bone models to go around; with individual mobile devices and apps, each student had immediate and personal access. Although all of the instructors liked the anatomy app’s treatment of bone and muscle, they found fault with the lack of detail in the heart.

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The instructors had mixed feelings about the amount of student learning that was actually taking place when the students used the digital technology. On the one hand, the apps engaged the students and helped them to see the lab material in a fresh way. On the other hand, some instructors felt that this modality added a new layer of confusion to the lab work, because some students had difficulty in mastering the apps, especially the feature-rich anatomy app. It was suggested that increased access to the mobile devices and apps throughout the semester would obviate this problem, because then the students would have enough time to become proficient.

Table 1. Results of an exit survey conducted online, as measured by a Likert-type 5-point scale. The two “Agree” categories were combined, as were the two “Disagree” categories. Respondents are a subset of students enrolled in the experimental lab sections. N = 37.

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>% Responding</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td>1</td>
<td>I enjoyed using the iPads and Apps in lab.</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>Using the iPad and Apps in lab was a positive learning experience.</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>Using the iPad and Apps in lab motivated me to learn more about the subject matter.</td>
<td>81</td>
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<tr>
<td>4</td>
<td>Using the iPads and Apps helped me to increase my knowledge and understanding more than if I had used the lab manual.</td>
<td>73</td>
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<tr>
<td>5</td>
<td>The iPad and Apps made it easier to learn about TISSUES and SKIN structures.</td>
<td>81</td>
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<tr>
<td>6</td>
<td>The iPad and Apps made it easier to learn about BONE structures.</td>
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<td>7</td>
<td>The iPad and Apps made it easier to learn about MUSCLE structures.</td>
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<td>The iPad and Apps made it easier to learn about HEART structures.</td>
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<td>I prefer using the iPads and Apps in lab instead of the lab manual.</td>
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<td>I would prefer to take an Anatomy &amp; Physiology II lab that used the iPad and Apps.</td>
<td>62</td>
</tr>
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<td>I would prefer to take an Anatomy &amp; Physiology II lab that did NOT use the iPad and Apps.</td>
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</tr>
<tr>
<td>12</td>
<td>I found it helpful to use the lab Worksheets that accompanied the iPad exercises.</td>
<td>78</td>
</tr>
<tr>
<td>13</td>
<td>I would buy an Anatomy App for my own smart phone, tablet, or computer to help me in my studies.</td>
<td>73</td>
</tr>
<tr>
<td>14</td>
<td>I would prefer taking lab quizzes on the iPad.</td>
<td>59</td>
</tr>
</tbody>
</table>

Discussion

Our goal in this study was to analyze the pedagogical usefulness of histology and anatomy apps as a means of encouraging student enthusiasm and engagement, and thereby increasing student learning and information retention in the A&P 1 lab.

Our primary hypothesis was that mobile devices and content-specific apps would increase student enthusiasm and engagement. This hypothesis was confirmed by the Likert-type scale survey data from the experimental group (Table 1), which showed that most students enjoyed using the apps and mobile devices in the lab, had a positive learning experience, felt that this modality motivated them to learn the subject matter and was more effective as a learning tool than the lab manual. Our results here are consistent with other studies, which find that students like using tablets and other mobile devices in the classroom, and report greater student engagement with the material as well as a potentially “enhanced learning experience” (Morris et al. 2016, Quant et al. 2016, Raney 2015, Wilkinson and Barter 2016).

It is clear that histology and anatomy apps have the potential of adding greatly to the A&P lab experience. Anatomy apps allow students to view and identify the structures three-dimensionally, to learn the location and orientation of structures in the body, and to interact actively by rotating the structures and by removing and replacing body layers. Histology apps present a large screen image of each tissue...
that can be moved around and magnified in the same manner as a slide under the microscope, but without worrying about focusing, lighting, field of view, etc. Information added to the image can help the student identify cells types and tissue layers. The use of digital imagery increases the opportunity for group-work; for students to gather around a tablet screen to discuss what they are seeing. Digital imagery also makes it easier for a lab instructor to engage with students and to have more of a discussion about what they are seeing than is possible when students are looking through microscopes.

Increased integration of mobile devices and apps into the A&P lab may reduce the tendency of students to become distracted by their own digital devices. As Figure 4 shows, students use smart phones in class for multiple purposes, only some of which relate to the course itself. Thus, introducing a course-related digital device and app into the classroom would at least provide a competitive alternative (Bice et al. 2016). Using digital technology in the lab also makes it easier for students to access information. In an earlier unpublished study, we measured throughput, the amount of information that students could enter on their lab worksheets within a measured amount of time. Students using digital technology were able to access and enter approximately 50% more information about the muscles (actions, synergists, antagonists) on their worksheets than students using the traditional lab manual. Although increased throughput does not necessarily translate into learning and information retention, it may be useful as a first step in that direction.

As a cautionary note, findings such as those reported above must be examined for the confounding influence of either a "novelty" or "Hawthorne" effect. That is, students in the experimental group might be reporting a positive learning experience merely because they were doing something novel, such as using mobile devices and apps, or were participants in a study (Wilkinson and Barter 2016). Additionally, the "glow of technology" may create a favorable reaction among the participating students (Girlando and Eduljee 2016). However, regardless of the underlying reason for the students’ metacognitive assessment that the mobile devices and apps had a positive effect, students were undeniably more successful in focusing their attention on their lab work when it involved interacting with their histology or anatomy app.

Our secondary hypothesis, that the digital technology would increase student learning and information retention, was not confirmed. Although a small preliminary study that we conducted indicated a 10% higher average lab test score among students who used the digital technology, in the present study the analysis of quantitative test data did not yield statistically significant results, and is not reported here. Many authors (Perez et al. 2011, Raney 2015, Scibora and Mead 2015) indicate how difficult it is to extract meaningful data from experiments designed to measure the impact of mobile devices in the classroom. We anticipate continuing our investigations with a larger student sample size and increased access by the experimental group to the mobile devices and apps. These modifications in the experimental design should provide a better environment to test the pedagogical effectiveness of this modality.

Figure 4. Students use smart phones in the classroom for both academic (blue) and non-academic (red) purposes. Respondents may list multiple uses: the X-axis indicates the percentage of respondents reporting each use. N = 180.
Two additional issues will need to be addressed as our research goes forward. First, although the histology app that we were using had a convenient layout, many tissue examples, and was easy to view at lower magnifications, when the tissues were viewed at maximum magnification the app did not always provide sufficient resolution to distinguish cell characteristics. In our future work, we will explore other options, including virtual microscopy resources available on the web.

Second, we underestimated the difficulty that some students would have in mastering the apps. Although the worksheets contained detailed instructions for the apps, some students struggled with the software, which adversely affected their lab work. The problem was compounded by the fact that the students had only limited access to the apps, three hours spent with the histology app, spread over two lab periods, and four and a half hours spent with the anatomy app, spread over three lab periods. Other researchers have also reported that students may have difficulty in mastering anatomy apps (Morris et al. 2016).

One solution would involve formal app training sessions, but that would use up valuable lab time. Alternatively, students could be given increased access to the apps, so that they could familiarize themselves with the apps outside of the lab. This would also enhance their learning. Rainey (2015) found a correlation between student performance and the amount of access to a mobile device and apps. Students with “unlimited access” outperformed students with “limited access,” and in turn the “limited access” students outperformed the control group of students who had “no access.” Of course, such a solution would require either that the institution provide the apps (and perhaps the mobile devices), or that the students purchase the apps for their own mobile devices, e.g. a “Bring Your Own Device” (BYOD) solution, which might provide the best results. Indeed, students appear ready to buy such apps. In our survey of the experimental student cohort, 75% said that they would be willing to buy an anatomy app for their own mobile device.

Conclusion

Our data support the conclusion that mobile devices and content-specific apps increase student enthusiasm and engagement in the A&P 1 lab. Metacognitive assessment of the students revealed a perception that using the apps and mobile devices in the lab was enjoyable, provided a positive learning experience, motivated them to learn the subject matter, and was more effective as a learning tool than the lab manual. Further research is needed to clarify the extent to which students’ positive response to digital technology translates into gains in learning, understanding, and information retention.

The students were not fully committed just yet to replacing the A&P lab manual with digital technology. This suggests that the apps are most useful as a tool, and not as an entire strategy, to present information in the classroom and lab.

In anatomy, mobile devices and apps are best suited as a supplement to traditional modes of presentation and learning, e.g. recitations, models and preserved specimens. However, there are indications that histology mobile apps or online resources with improved design and high-resolution imagery may well supplant the traditional use of the microscope.

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The Pedagogical Value of Mobile Devices and Content-Specific Application Software in the A&P Laboratory


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Sorting Activities as a Means to Engage Anatomy and Physiology Undergraduates in Vocabulary Acquisition in Laboratory Settings: A Sample Lesson: Muscle Anatomy and Histology

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Abstract
For many students, the amount of specialized vocabulary required in an Anatomy and Physiology course presents an overwhelming challenge. In fact, Sturges and Maurer’s (2013:4) work “revealed that the language of the class and content overload are among the most important factors that make this class difficult.” The goal of this lesson was to incorporate tools demonstrated in other learning environments (K-12) to facilitate student retention of specialized vocabulary, namely sorting activities, and apply them to a laboratory lesson covering the anatomy and histology of muscle tissue. Observations from four laboratory sessions using this lesson indicate that this active learning strategy to support vocabulary acquisition successfully engaged university level students and students’ verbal responses indicated that they enjoyed the experience and found it challenging.

Key Words: Anatomy and Physiology, Laboratory, Engagement, Vocabulary, Sorting Activities.

Introduction
Our university, like many other universities, has observed that Anatomy and Physiology courses have one of the highest rates of dropout, failure and withdrawal (DFW) (Harris et al. 2004, Sturges and Maurer 2013, Sturges et al. 2016). Students come into the class perceiving the material to be difficult (Sturges and Maurer 2013). Additionally many enrollees are under-prepared since there are no pre-requisites or standing requirements to take this course at our University. As a result instructors spend a great deal of time thinking about how to mitigate these difficulties and alleviate student struggle in this class.

Sturges and Maurer’s (2013:4) work “revealed that the language of the class and content overload are among the most important factors that make this class difficult.” There is demonstrated a need for hands-on, concrete, and applicable approaches in Anatomy and Physiology courses, particularly with respect to vocabulary load and acquisition (Lunsford and Kerzog 1997, Sturges and Maurer 2013). Vocabulary is typically presented via lecture. However, many students do not retain the vocabulary of the content when it is presented using traditional lecture methods and as result, they fall behind. This is in part due to cognitive overload experienced by students during lecture sessions where they are expected to follow explanations that are laden with content specific vocabulary. As Sturges and Maurer (2013:4) found, students express this feeling of frustration in statements such as “the teacher expects too much… I would like it better if the teacher could explain everything more in simpler terms… and there is a lot of information that is completely new… it needs to be explained as if we were beginners.” Engaging students in activities in a laboratory setting that develops word knowledge and promotes divergent thinking and inductive reasoning may be one solution. Therefore, the goal of this lesson was to incorporate tools demonstrated in other learning environments (K-12) to facilitate student recognition, increase retention of specialized vocabulary, and reinforce the application of the vocabulary to the anatomy and histology of muscle tissue.

Anatomy and Physiology Lesson Redesign
The lesson was designed to focus less on rote memorization of the content and more on active learning. Active learning involves students in doing things and thinking about the things that they are doing (Bonwell and Eison 1991). Wilke (2003) argued that active learning promotes higher-level learning which advances the view that science is not a set of facts to memorize but instead it is a process that shifts the responsibility of learning from instructor-centered to student-centered. In this way, lessons using active learning add value to the learning experience.

Furthermore, the intent of the lesson was to move away from the traditional laboratory session. At our university, a custom lab manual presents students with an atlas of what they are expected to learn each week with very little background or context. There may be up to five graduate teaching assistants and five different laboratory instructors for this course. Each provides a different level of context surrounding the material presented during their laboratory session. What is consistent is the content that students are required to learn; including–up to 100 new vocabulary terms that are presented via anatomical models and histology slides. This traditional laboratory provides limited time for review and assessment of learning.

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Sorting Activities

Explicit instruction strategies that support vocabulary acquisition are important in science (Blachowicz and Fisher 2002). In order to engage students with new vocabulary instructors should encourage the use of words in real life contexts, relate words to vocabulary that students already know, and expose students to multiple usage of the words (Gunning 1998). It has been argued that word sorting activity is a vocabulary strategy that can do all of these. (e.g. Carrier 2011, Hill and Miller 2013).

Sorts are classification tasks that are designed to help students develop vocabulary acquisition and understanding (Blachowicz and Fisher 2002). Sorting activities are not a new idea (Olle 1994) and have been used in the K-12 setting, specifically in music, to help younger students learn new vocabulary, and more prevalently in literacy classes to promote language development. There is no evidence from a search of the literature that indicates that this strategy has been utilized in higher education settings with undergraduate students studying Anatomy and Physiology.

Word sorts are a vocabulary development strategy used by cooperative groups to facilitate students’ discourse. Students receive a set of cards labeled with content specific vocabulary and decide how to group the words based on their own personal reasoning. As they work they see the correct spelling of the word written on the card and hear the word spoken as they decide upon placement. Vocabulary is reinforced as the cards are manually sorted and re-sorted. This can, according to Olle (1994), enable the acquisition of vocabulary and allow the development of knowledge about individual words first through trial and error and then through more intentional speed and accuracy. The collaboration provided by the activities provides hands-on and visual experiences with new words as well as engaging students with text and with other learners. Overall, word and other sorting activities can help learners with the internalization, generalization, and the transferring of the content into long-term memory storage.

Lesson Plan

The lesson plan used is provided here, and will be explained in detail.

Course: Anatomy and Physiology I Lab
Grade Level: Undergraduate
Topic: Skeletal Muscle: Histology and Muscle Anatomy

Content: Muscles are one of the four types of major body tissues. There are three types of muscle tissue. In skeletal muscle, striations are obvious; the cells are long, cylindrical, and multinucleate. Skeletal muscle is well vascularized and controlled by the somatic (voluntary) nervous system. The other two types of muscle tissue are cardiac and smooth muscle. Cardiac muscle is short, complex, and also striated, but it is controlled by the autonomic nervous system. Smooth muscle has spindle shaped cells and is not striated or multinucleated. It is also controlled by the autonomic nervous system.

| Goals | Students will be able to:
| --- | --- |
| 1. List the different types of muscles
2. Understand and compare the features of the three types of muscle.
3. Identify new terms and their definitions.
4. Distinguish between the different groups of muscles, identify their locations, points of origin, and points of insertion, and provide examples of their action. |

| Objectives | After completing this section, the students will state the differences among the three types of muscles and identify muscle tissue (and the Neuromuscular Junction (NMJ)) using microscope slides and NMJ models. They will classify the muscles into groups based on their points of origin, insertion or modes of actions with about 90% accuracy. |

| Materials | Laminated skeletal muscle picture displays, slides of skeletal muscle tissue, microscopes, lists of names of muscles and points of insertion and origin, markers, sticky notes. |

| Introduction | Exercise 11: Skeletal Muscle Histology and Anatomy. Students will view a short PowerPoint presentation and be briefed on what they will be studying, the objectives and format of the lessons, as well as expected outcomes. |

| Development | Students will be given the pictures for the types of muscles and the list of terms that will help them identify the muscle types. Working in groups, students will sort the terms and match them to the correct picture, providing justification for their reasoning. Any terms that students feel should be added or not used, may be included or removed respectively as long as justification is given. Students will reinforce learning by looking at the tissues and NMJ slides under the microscope and make connections between the pictures and the slides. Students will continue working in groups for the second activity. They will organize the muscles given into categories and provide an explanation for their arrangements. Students will view arrangements of other groups and ask questions regarding differences and similarities noticed. |

| Assessment | Each group will develop a short quiz for the others. Groups will be given a chance to respond to quiz questions. |

| Closure | Analogies identify relationships between pairs of seemingly unrelated concepts and is an extended comparison between two things usually thought of as unlike (for e.g., an engineering student might explain something relatively unknown -loading a tanker- by using her knowledge of something known-filling pop bottles). To assess understanding of muscles and human Anatomy and Physiology each student group will generate their own analogy comparing muscles and the body to a seemingly unrelated concept or idea. Further they will be asked to identify three parallels within the analogy they develop. The analogy and parallels will be used as an exit-ticket at the end of the class. |

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Lesson Plan in Action - Using Sorting Activities

Four Anatomy and Physiology lab classes were exposed to several sorting activities within the lesson on the topic: The Histology of Human Tissue and Muscles of the Human Anatomy. This project was approved by the Institutional Review Board at our University (IRB#16-1205), and informed consent was obtained from all participants. The three sorting activities included Picture sorts, Words sorts and Concept word sorts. The lesson introduction included a short discussion on the purpose of the muscles of the human body using a picture of a bicycle as an analogy to stimulate the discussion and access student prior knowledge on the function, location, and features of the different types of muscles.

Following this discussion, the first sorting activity, Picture sorts, was implemented. Student groups were provided with laminated pictures of different types of muscles. The groups were instructed to sort the pictures and use words that would differentiate or show similarities among the different types. This activity used an explore–then–explain strategy in order to promote an in-depth conceptual understanding of the histology and muscle anatomy. This approach discouraged the ‘cramming’ that students find to be easy but does not promote retention. Ausubel (1968) has acknowledged that changes in knowledge that constitute rote memorization or an ability to regurgitate propositions verbatim do not exemplify learning or understanding. In the picture-sorting activity students arranged, wrote down words that identified, described and differentiated the features of the different types of muscles, then shared information and defended their arrangements with the other groups. The discourse that followed exposed the class to other students’ ideas. This activity was reinforced with whole group discussion followed by a review of histology slides of the three types of muscles, a skeletal muscle slide with neuromuscular junctions using the light microscopes, and models of muscle fiber. This activity concluded with a discussion of the new vocabulary terms and the modifications made to their initial picture sorts. Figure 1 below shows examples of student picture sorting activities.

Figure 1. Student generated display of picture sorts

does not
Activity two included an open-word-sorts activity that required students to arrange the vocabulary terms used since the beginning of the lesson, which were associated with muscles and muscle types. Students were encouraged to add vocabulary terms that they thought were necessary. Students then explained and defended their arrangements as well as provided reasons for adding words to the arrangement.

Critical thinking was promoted and served as a means of rehearsal and reinforcement of new vocabulary words. Furthermore, the collaboration provided students with both hands-on and visual experiences with new specialized vocabulary words so that they were engaged in strategic interactions with the material as well as with other learners. In addition, this activity allowed students to engage in a creative activity where they could be free to express themselves and still learn. Examples of student word sorts are seen in figure two below. This activity was also reinforced with a review of microscope slides and students were allowed to revise the vocabulary terms that they had learned and associate them with the histology slides that they were viewing via the microscope.

The final sorting activity was an open-concept sort. Students were provided with the names of muscles written on laminated word strips. Each group worked to sort the muscles into an arrangement that demonstrated the relationship between muscles and their origin, insertion and action. Students were also allowed to add additional vocabulary terms as needed. Upon completion, students were asked to provide reasoning for their sort and encouraged to view the sorts of other groups and ask questions.

Engaging in this word concept activity allowed students to produce organizational visuals and become more familiar with the vocabulary terms, which gave meaning to the experience. Bazeli (1997) explained that such experiences make learning more personal and memorable. In addition, this provided an efficient way for students to represent their personal learning. Figure three below shows examples of student concept-word sorts.

Figure 2. Student generated display for word sorts

Figure 3. Student generated display for concept word sorts
Student Experiences
Field notes taken while students were engaged in the sorting activities indicated a high level of student interest and active participation. One indicator of enthusiasm and engagement was the manner in which students utilized the entire lab table for placement of arrangements. The body language of participants also indicated their interest level. Students were seen standing and leaning over tabletops as well as clambering over the desks to discuss and position words in what they considered the right category. This was a marked difference in the typical laboratory behavior in that students were not sitting idly or engaged in off-task discussions; they were not texting or chatting on social media, or browsing the web with cellphones or other handheld devices. Students were actively engaged in productive discourse, defending their claims by providing reasoning for their sorting and classifications, as well as their choice of additional words. It was also observed that students were confident in explaining and defending their arrangements and category placements. As students added words to the word groups, they wrote them down on sticky notes and stuck the sticky notes where they thought that they belonged. Several students appeared proud of their accomplishments and wanted to make sure the laboratory instructor noticed their arrangements. Of particular note were the groups that designed their sorts to reflect day-to-day objects and/or personal experiences, such as a sunflower in spring, a stick figure, or traffic congestion on the way to school. The fact that students made the activity personal indicated that they were not mentally distracted or isolating themselves from the lesson.

In general the verbal responses given by students indicated enjoyment of the word-sort experience and the majority of students agreed that although it was new and finding the categories were challenging at first, in the end they were able to grasp more of the vocabulary words. This was a positive indicator of the learning. An overall conclusion is that students were very satisfied with the activity and felt that they had learned more by participating actively than they would have otherwise. Several students commented that the activity was the manner in which students utilized the entire lab table for placement of arrangements. The body language of participants also indicated their interest level. Students were seen standing and leaning over tabletops as well as clambering over the desks to discuss and position words in what they considered the right category. This was a marked difference in the typical laboratory behavior in that students were not sitting idly or engaged in off-task discussions; they were not texting or chatting on social media, or browsing the web with cellphones or other handheld devices. Students were actively engaged in productive discourse, defending their claims by providing reasoning for their sorting and classifications, as well as their choice of additional words. It was also observed that students were confident in explaining and defending their arrangements and category placements. As students added words to the word groups, they wrote them down on sticky notes and stuck the sticky notes where they thought that they belonged. Several students appeared proud of their accomplishments and wanted to make sure the laboratory instructor noticed their arrangements. Of particular note were the groups that designed their sorts to reflect day-to-day objects and/or personal experiences, such as a sunflower in spring, a stick figure, or traffic congestion on the way to school. The fact that students made the activity personal indicated that they were not mentally distracted or isolating themselves from the lesson.

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Implications for Practice and Conclusions
This active learning strategy of using sorting activities appeared to increase student interest in a lesson that would otherwise have been overwhelming due to the extensive amount of content. Although the lesson activities discussed here do not provide conclusive evidence for the wholesale use of word sorts in post-secondary science education, they do contribute to the growing body of knowledge in the support of these strategies. The teaching of Anatomy and Physiology laboratory still remains a challenge for instructors; the use of word sorts has demonstrated that such active learning strategies can produce desirable results in terms of student engagement and support of specialized vocabulary acquisition.

Important questions remain unanswered regarding the utility of sorts for other topics in the A&P syllabus. We believe these questions afford several fruitful avenues for future thinking and research. At the least, sorting activities seem to capture two main aspects of learning (interests and engagement) that are essential for academic achievement. Therefore, we believe that these activities provide an engaging alternative to traditional laboratory instruction and may well produce long-term positive results for helping students master the content of anatomy and physiology laboratories in higher education.

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