TEACHING AND LEARNING PORTFOLIO

by

Thomas E. Grys

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Thomas E. Grys, Ph.D.

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INTRODUCTION AND OVERVIEW

I used to be a normal graduate student, hard at work gathering data that would impress my lab and working toward the goal of “finishing,” whatever that meant. One day I decided to branch out and take a class called Expeditionary Learning, offered by an entity called Delta, because I thought it would help me experience more of UW-Madison and see what was going on around campus. That small step led me into a vast world I never knew existed, where professors, postdoctoral students, and graduate students talked about teaching and learning. I was hooked. It turned out that Delta was the University of Wisconsin-Madison manifestation of a National Science Foundation-funded initiative to enhance the teaching and learning of science, math, technology, and engineering in higher education. Since my career goal was to teach biology at a small, liberal arts college, everything seemed to be coming together. I could begin training myself for my career as I finished my PhD work! The next semester I took a class called Effective Teaching with Technology, another Delta course. The following year I participated in the HHMI-funded Wisconsin Program for Scientific Teaching (WPST). With two other WPST students, I participated in an internship developing instructional materials for a neuromuscular physiology unit at Edgewood College in Madison. The internship experience was the final step in both the WPST and Delta Certificate programs.

Together, the Delta and WPST programs have equipped me with a background in teaching & learning pedagogy, as well as an internship experience in which to try out some of my new skills. In this portfolio I begin with my teaching & learning philosophy. What follows is three parts, each with its own theme. Four appendicies contain additional documents. Part I describes an internship opportunity where two graduate students and I developed a “teachable unit” for neuromuscular biology and implemented it at a local liberal arts institution, Edgewood College. Part II consists of reflections on the three pillars of the Delta program, Teaching-as-research, Learning Communities, and Diversity. Part III is collection of reflections on some classroom tools and techniques. Appendix A contains the neuromuscular biology instructional materials developed and implemented for the internship introduced in Part I. Appendix B is a manuscript describing the instructional materials and data from the implementation at Edgewood College. Appendix C is a summary of Bloom’s Taxonomy, while Appendix D is my *curriculum vitae*.

Teaching & Learning Philosophy: Avoiding the "Max Power" Method

In an episode of "The Simpsons," an irreverent animated cartoon about a dysfunctional family, the father, Homer, decides to change his name to Max Power. Emboldened with confidence by his new name, he proclaims, "There are three ways to do things in this world, the right way, the wrong way, and the Max Power way!" His brash son Bart retorts, "Isn't that just the wrong way?" Homer answers, "Yes! But *faster*!"

Many times, I believe students are allowed to rush through labs and classes in "Max Power" fashion, completing tasks on a checklist instead of learning the material and being able to use it successfully. In my teaching, I incorporate a variety of teaching styles and I challenge students to think critically, so that as a class we *engage* material instead of *cover* material. I also believe the scientific method must be applied to teaching, just as it has been used successfully in other areas of inquiry. When I approach teaching as research, I am constantly gathering data and reflecting on results toward a goal of increasing my understanding of whether and how students are meeting learning objectives.

My objective is to help students become critical thinkers as they acquire a knowledgebase in biology. To accomplish this goal, I use various "protocols" for my scientific teaching, which include five strategies: inspiring students, working with diversity, learning by experience, small group learning, and writing.

Inspiring students sets the stage for learning to happen. By engaging their prior knowledge and extending the course topic to real-world issues and areas related to their discipline, especially for non-majors, I can make the material that I teach more relevant to students' lives. Also, by using a variety of teaching methods, I have a better chance of making connections with a diverse student group.

Working with diversity is a different mindset than "addressing diversity," which suggests that diversity is one step in a process—usually the last one. Students differ in learning style, socioeconomic status, primary language, physical disability, culture, religion, and age, among other dimensions. Under the right circumstances, these differences will transform from obstacles into paths toward flexible and successful learning. By using the variety of student backgrounds and skill levels as an advantage, diversity becomes infused throughout the development, implementation and assessment of lectures and assignments. For example, inquiry-based laboratory exercises allow students to use creativity and insight from their unique life experiences to take ownership of an investigation by developing their own hypotheses or methods.

Learning through experience is a powerful way to enhance understanding and memory. Case studies and lab work demonstrate, and allow the students to practice, the application of methods and information to real-world systems. This type of learning also teaches a broader skill that allows students to think about ways to think critically and apply other types of knowledge to real-world situations, skills useful for effective life-long learning. For example, I mentor undergraduate researchers in our laboratory. I realized that one student, Andrea, was making great strides in thinking critically when she was able to troubleshoot part of a protocol we were developing. It was a satisfying moment for both of us when we both thought about the problem and came up with the same solution.

Small group learning can provide a safe environment for students to ask each other or the instructor the “dumb” questions. It is also a time they can teach and learn from each other—which can sometimes be more effective than an instructor. Well-moderated group work mediates learning and prepares students to communicate well and be effective team workers. I learned a lot in college by studying in groups, and so in graduate school, I took the initiative to start a project group meeting once a week when the number of students in our lab working on my project went from two to four. The meetings were a great time for us to talk about data and troubleshoot techniques at a more detailed level than our general lab meeting. My advisor loved the idea and noticed the results of those meetings. We students became more aware of the various facets of the project and were able to work more efficiently in our individual endeavors.

The writing process takes learning to another level. Deep understanding of a topic is facilitated when students must survey the information they have learned, place it in context, weigh the importance of various facts and opinions, formulate a stance or conclusion, and convey it effectively in words. For example, in biology, formal lab reports provide a mechanism through which students can become more familiar with the language and methods of a discipline. An assignment to write about a technology or a disease for a general audience is another example. Writing is a difficult process, and students who produce quality writing have both achieved and demonstrated deep learning. The process of revision and reflection that occurs during writing helps to solidify logic and relationships of facts and ideas. The result is increased synthesis of what might otherwise be disconnected ideas.

I use a scientific approach to my teaching so that I iteratively improve the effectiveness of the methods outlined above. This includes observation and hypothesizing, experimentation, assessment (data collection), and reflection. In this way, I work to facilitate deep learning by helping students learn how to find the information they seek, connect new concepts with those they know, identify and think analytically about a problem, and practice the communication of scientific information. Instead of the “Max Power” way, where students rush through an activity just to get it done, my students will leave my classroom and lab knowing that they are equipped to investigate the world and *think critically* about problems in any realm they choose.

Vignette: *“My objective is to help students become critical thinkers as they acquire a subject knowledgebase in microbiology…skills useful for effective life-long learning.”* (Teaching Philosophy).

In my third year, I had the opportunity to mentor a talented undergraduate, Matt, for a research project under my direction. He was preparing for medical school, but I told him to be careful, or else he might want to change his mind and apply to graduate school by the time he was done in our lab! In his year and a half in the lab, he made great progress on our project. He is now in medical school at Loyola in Chicago. When he came back for a visit one fall, he told me he was looking for an opportunity to do research at Loyola because he had really enjoyed his experience in our laboratory and wanted to maintain his investigation skills. He said he did not like the memorization that a lot his medical school classes required, and was hoping to find an opportunity to do research and to do some critical thinking. To him, his comments were just updating me with what was going on in his life. To me, his comments validated all the hard work we had put in together in the lab—not only had he made good progress in the way of data, but he had also become a critical thinker and a practitioner of the scientific method. I think those skills will serve him, and his patients, immeasurably in his future medical career.

PART I

The next two essays recount an internship experience where I taught at a local college. The first essay describes the materials and experience, while the second is my reflection on the experience.

Internship Summary: Unlocking students' (action) potential: stimulating students to sense, integrate, and respond in neuromuscular physiology lecture and lab

In the Spring of 2005, I took an instructional materials development course from the Wisconsin Program for Scientific Teaching (WPST). I was part of a group with two other graduate students, and over the course of a semester, we developed instructional materials in neuromuscular physiology. The following spring, we implemented them in a biology class at Edgewood, a small, liberal arts college. The course was a combined lecture/lab setting that met in a laboratory. It met three times a week for two hours. The purpose of our internship project was to put into practice the ideals we had learned in the WPST “Teaching Biology” class, such as inquiry-based learning, diversity, and interactive lecturing. For me, the internship also fulfilled a requirement of the Delta Certificate in Teaching & Learning. Our group developed instructional materials that included a set of lectures that would challenge students with discussions of the material and laboratory exercises that were investigative forays into the subject matter of the lectures. The teaching plan can be found on page 12, but the complete materials are found in Appendix A of this portfolio (page 28).

Students at Edgewood College measure muscle activity during a bicep curl.

We developed several discussion activities (page 36) that broke up the monotony of lecture so that students did not listen to one person talk for more than about 15-20 minutes at a time. The topics for discussion that we chose required students to talk to each other and begin to use the information just discussed by the instructor. These discussions provided an opportunity for the students to engage in the content (when at the beginning of lecture) and help them bring to mind any existing knowledge so that they could connect the subsequent discussions to what they already knew. For example, the students were asked, "What are all the things that happen when a person steps on a tack, and how do they happen?"

The discussions toward the middle and end of lectures encouraged students to begin thinking about the concepts functionally as a system. After a lecture detailing the functional anatomy of nerve cells and the mechanism of action potentials and synapse signaling, we asked the students to explain how botulinum toxin and tetanus toxin could act in similar ways at the molecular level but have opposite effects on muscles. This particular discussion question was a useful mechanism for exploring the neuromuscular anatomy as a functioning system.

The laboratory exercise that we created for the unit was designed so that the students would be able to define and test a hypothesis of their own. Evidence has shown that inquiry-based experiments allow the students to have more ownership of the experiment, and more opportunity for fun and innovation than simply following directions out of a lab manual[1]. The first day the students explored the equipment to figure out how it worked and what its uses and limitations were. For that activity we had designed a worksheet (page 40) worth a few points to give the students some guidance. In the second class period the groups designed their hypotheses, methods to test them, and prepared for the data they would generate. The final class was devoted entirely to the collection of data and the beginning of the analysis. These projects were then written up in a formal laboratory report due one week after the data collection.

For the three-class unit, our overarching concept was:

Properly integrated physiological systems are essential for an animal's ability to successfully sense and respond to its surroundings. Our teaching goals were:

[1] Handelsman, J *et al.* (1997). *Biology Brought to Life: A Guide to Teaching Students How to Think Like Scientists*. New York: McGraw-Hill.

Engage students in discussions during “lecture time” so that students expect to participate and expect to have lecture interspersed with discussions and small-group activities.
Present content in a way that elicits student questions and ideas.
Guide groups to address hypotheses that are interesting, creative, and testable.
Provide constructive and timely feedback of student questions, comments, exams, and reports.

Our learning objectives were:

Be able to think about the action potential, the synapse, and muscle activity as parts of a functioning system.
Understand how muscles contract at the molecular level.
Be able to develop a testable hypothesis, design an experiment, and think critically about one’s own experimental data by drawing conclusions and recognizing the limitations of an experiment.

On the next page is the detailed teaching plan we developed, and the rationales for each activity. Details on the activities, learning objectives, assessments, and rubrics can be found in Appendix A (page 28). A narrative description of the plan and resulting data are in the manuscript in Appendix B (page 58).

A student at Edgewood grips a force-measuring dynamometer and the output is displayed on the screen behind him.

Teaching Plan for Neuromuscular biology Teachable Unit:

Time	**Activity**	**Rationale**
Pre-class email	Pretest	Assess initial student understanding.
Pre-class email	Article about girl who cannot feel pain	Engage students in neuromuscular material and implications of disrupted system.
Class 1 (10 min)	Discussion: Step-on-tack. (See *teaching strategies Day 1*).	Engage pre-existing knowledge, begin thinking of neuromuscular system as functioning unit.
Class 1 (40 min)	Lecture on neurobiology: ion permeability, nerve cell, action potential, synapses (both neuron-neuron and neuron-muscular, while incorporating diseases into these descriptions.	Discuss both general concepts and details of content.
Class 1 (10 min)	Discussion: Tetanus and botulinum toxins. (See *teaching strategies Day 1*).	Synthesize lecture information and provoke students to think of neuromuscular system as functioning unit.
Class 1 (50 min)	Laboratory: explore BIOPAC (begin thinking about an experiment), turn in worksheet. (3 points)	Develop scientific curiosity.
Class 2 (5 min)	Short lecture to introduce to muscles: three muscle types, macro anatomy (fibers, fibrils, all-or-nothing fiber contraction).	Provide base of information for discussion.
Class 2 (10 min)	Motor unit discussion. (*See teaching strategies Day 2 and Fig. 2*).	Challenge students to predict muscle fiber organization and how it relates to function.
Class 2 (20 min)	Lecture on muscles: 3 muscle types, molecular anatomy (actin/myosin, ATP turnover), motor unit recruitment.	Extend motor unit discussion to provide more detail of muscular system.
Class 2 (10 min)	Discussion: two ways to increase muscle force.	Provoke students to think of neuromuscular system as functioning unit.
Class 2 (35 min)	Laboratory: develop and begin experiment, analyze data, make prediction or revise hypothesis.	Foster development of scientific investigation skills.
Class 2 (30 min)	5-minute presentation per group	Provides peer feedback on hypothesis and experimental plan.
Class 3	Laboratory: finish experiment, test prediction or revised hypothesis. Begin data analysis. Lab reports due 1 week from today.	Foster development of scientific investigation skills.
Class 4 (Five days after Class 3)	Exam (on which neuromuscular biology is 1/4 of material, ~15 minutes of exam time).	Assess student understanding.

Internship Reflection on Teaching & Learning Strategies

My two group partners, like myself, had attended liberal arts colleges, and shared the goal of teaching at a small college someday. This was the primary reason we chose to implement our instructional materials at Edgewood College, to practice creating both lecture and laboratory activities and to practice implementing them in a small college setting. The Edgewood animal zoology course allowed us to do this exactly, since it was a combined lecture/laboratory course.

Since I was teaching content outside of my PhD discipline, this experience helped me realize that I am able to readily learn information and teach it to others. I think this is an important skill to practice so that I develop more confidence in informal teaching and outreach type situations. As scientists, we represent all scientists and the scientific method. I think I have become better at presenting content and processes to non-experts, and therefore I am benefiting my community by serving as a resource.

This internship has been a “pilot experiment” in several ways. In the lab, pilot experiments are the first run through a protocol, and often they yield more information about how to do the experiment better next time than about the hypothesis that is being tested. I think this is one of the benefits of the Delta and WPST programs—it allows graduate and postdoctoral students to practice teaching-as-research (TAR) in slow-motion. We were able to feel what teaching was like and it taught us how to (and not to!) practice TAR in the future. Likewise, the internship was an opportunity for me to explore the strategies I discussed in my teaching and learning philosophy.

Two Edgewood students gather data on grip strength.

Diversity at some small liberal arts colleges can appear to be lacking, so we were not sure what we might encounter at Edgewood College. It turned out that our class of 14 students included two members of traditionally underrepresented minority groups, a higher percentage than we had expected. Although diversity involves more than race or culture, it can be more immediately obvious than other factors such as life experiences and learning styles. One way to both harness diversity and facilitate a learning community is to facilitate **small-group** interactions and provide creative outlets. For example, discussion questions posed during lecture can allow students to come up with alternative answers to the sample problem. Open-ended, inquiry-based laboratories like the one we designed in our internship also allow life experiences and different perspectives to come to play. Together in small groups, the students developed a hypothesis, and a method to test it, using the equipment available to them. In our internship implementation, this strategy of directed freedom produced a variety of project topics that allowed students to meet learning objectives for the laboratory exercise in their own way, including: develop and test a hypothesis, design the protocol, collect data, evaluate the hypothesis, and write a laboratory report.

Inspired students are more likely to feel connected and engaged, and thus spend quality time on the task, which is an important part of learning. To generate that atmosphere, we sought to motivate students by engaging their creativity and interest through discussion activities during lecture. Another opportunity for inspiration was during the laboratory investigation, which provided an opportunity for students to take ownership of their project and their learning.

The discussion activities during lecture required students to think about the content and share insights and explanations. These observation and critical thinking skills are crucial to the scientific process. The discussions together with the laboratory fostered **learning through experience.**

Writing the laboratory report required the students to think critically about their project. This included placing the project in context of the lecture content, evaluating whether the data supported the hypothesis, and suggesting experimental questions for the future.

The internship was a satisfying and educational experience. The opportunity to put into practice the skills I learned in class was like riding a roller coaster for the first time. It was a lot of fun, it was over too quickly, and I’m looking forward to doing it again.

PART II: REFLECTIONS ON THE DELTA PILLARS

The Delta program has three pillars, which it considers essential to teaching and learning: diversity, learning communities, and teaching-as-research (which I consider synonymous with the term scientific teaching). These three topics are incorporated in every course, and interns reflect on them during their internships. The teaching strategies I outlined in my teaching and learning philosophy have, in part, developed through my contemplations on the pillars, the Delta and WPST courses, and my internship experience. Although those strategies are my personal beliefs for teaching, I also want to include the following reflections on the common pillars of the Delta community.

Teaching-as-research (TAR):
Using An Iterative Approach To Teaching & Learning

TAR is the application of the scientific method and the rigors thereof to the process and results of teaching. This method implies a high level of awareness, reflection, and evaluation. The instructor must be aware of what is one is teaching, what the students are actually learning, and the correlation of those with the activities in class. When taking this sort of scientific approach to teaching, one needs flexibility and creativity. Flexibility is needed to adapt to different situations that can arise when implementing new methods. Creativity is sometimes necessary to design useful experiments to get good data from a teaching and learning experiment.

In practicing TAR, my strengths may lie in my inexperience. I am open to lots of new ideas and willing to give most anything a try. Also, I feel that because research is my life right now, I am able to transfer skills like critical thinking easily to new domains such as teaching. My areas for improvement include refining the critical thinking process in teaching, so that I am choosing testable hypotheses and manageable projects. Also, I will gain experience that will better equip me for making decisions when solving teaching problems. When I have tried more methods, I will know better what will work and not work in various situations.

The internship experience has been a great opportunity for me to practice my TAR. For example, I was able to practice designing hypotheses and experiments. The level of rigor with which I am used to testing hypotheses is of a different intensity when applied to teaching hypotheses. Animal experiments tend not to be straightforward anyway, so using humans as research subjects means that we must change our expectations and strategies, but not the scientific process.

The internship and seminar altered how I think about data/evidence. There are many sorts of evidence one can collect when assessing students, and each perspective is one sampling technique that gives a bit more of the entire picture of the teaching/learning process. I think the student attitude surveys (for example: see the SALG survey in Appendix A, page 47, and results, page 73) results are an interesting addition to normal test and lab report scores. They give different judgments on teaching/learning than assessments such as exams or reports. This was important in our internship because the students did not do very well on the exams, but they seemed to interact more with the material in class than their normal lecture style. Additionally, since our assessments were a different style than what they are used to, that may partly explain their lower scores. Students tested in a style similar to ours more often in the semester might have done better. Therefore, to see positive evidence in support of our hypothesis, we might have assessed in ways the students were more accustomed to. However, we thought that the exam questions would give the students another opportunity to grapple with the material, which might provide one last opportunity for them to learn. We might find, if we were able to test in this way, that students would retain the information they learned for longer (months/years) than after their normal lecture style. This long-range learning, however, is more difficult to test for, and subject to more variables (subsequent classes students take, etc.).

In summary, once I became aware of how easy it was to change my perspective on teaching to a research-oriented approach, I realized the power it held. After becoming a reflective practitioner of teaching-as-research, I am able to determine if my assessments are testing the content I am teaching, whether students are meeting learning objectives, and how to go about changing my teaching if the answer to either of those questions is negative. With practice I will continue to develop my confidence in teaching, and become a more effective and efficient instructor.

Learning Communities: Everyday Adventures on Campus Through an Expeditionary Learning Class

When I first got an email invitation to join an Expeditionary Learning group, I did not know what it was. What I did know was that my coursework and TA duties were completed for my training program, and I had a little extra time on my hands. I knew that with a university as large as Madison's there is a cornucopia of interesting things going on every week, and I seldom ventured out—for even a nibble. I hoped that this group would help me get out and explore some of what the university had to offer.

What I gained from my participation in the group was a more broad perspective of the types of learning environments on campus. The syllabus that we received seemed very simple. The directions for an expedition might be something like this: *Sometime in the next week, go to a library or museum. Look around & observe. Come back to class the next week*. I thought, how hard could that be? Even though the time commitment was small, I sometimes still found it difficult to complete the expedition because I had gotten used to having no interruptions in my lab work. However, I did manage to complete and reflect on most of the topics and I found the expeditions to be useful and interesting.

Another benefit was that suddenly I was aware of, and connected to, the teaching and learning community on campus. Previously I had little knowledge of any of the aspects of the programs like Delta or WPST. Now that I found myself thinking about graduating at some point and teaching at a small college, I realized I had discovered the community at just the right time. I have since taken "Teaching with Technology," (another Delta course), completed the Wisconsin Program for Scientific Teaching, and completed the requirements for the Delta certificate in teaching & learning. I have no doubt that the Expeditionary Learning path has led me on a journey to better prepare myself for teaching undergraduate biology.

The spirit of Expeditionary Learning will always stay with me. The habit of branching outside my normal discipline's community and reflecting on such experiences will help me refresh my perspective and provide opportunities for collaboration. After the Expeditionary Learning course was over, I attended a lecture in the Department of Physiology entitled, "Vision & Art." It was a fascinating discussion of various artwork, color, luminescence, and the use and purpose of vision in animals and primates. It is adventures like this that remind me that I enjoy more science than just my thesis project; in fact, I enjoy more topics that just science. These expeditions provided insights into teaching and learning or biology that I will be able to use in the future.

Being a part of the Expeditionary Learning group was like opening a door to a world I imagined must exist, but of which I was ignorant. To me, the Delta program performs as a highly effective learning community. By this, I mean that those who participate are a part of something bigger than themselves and will find themselves learning something from almost every interaction they have with Delta. Many entrances to Delta are open, and each door (roundtable dinner, course, lecture, personal contact) is different. Together, these courses and events accommodate a campus with diverse needs. The service of Delta to UW teaching and student learning is, and will be, profound and thorough.

From my experience with the learning community of Delta, I have drawn out several goals for learning communities in which I am involved in the future, both in and out of the classroom. For example, one goal is to provide an array of participation opportunities because not all people are able to commit to a learning community for a long period of time. The benefit of accommodating varied participation is that even those who are short-term members are able to give and receive useful information. Those who are members for a longer time period have in-depth opportunities such as leadership and organizational aspects in the community, not to mention the potential to work on projects such as teaching & learning portfolios, as in the case of Delta.

Scientific investigation is rarely done in isolation. Similarly, scientific teaching should not be, either. Observations, insights, and results of experiments should be shared among colleagues, even (and sometimes especially) across discipline boundaries. This process involves personal reflection, interpersonal interaction and feedback, as well as critical analysis. It is for these reasons that I feel my internship experience was so beneficial—it solidified many notions I have had about learning communities. For instance, I know that I learn best when I am interacting with material and concepts with other people, not in isolation. Thus, I found working in a group to be extremely useful, and our meetings to be very productive (and fun!).

Our group learned the hard way that the composition of some types of learning communities could markedly affect their effectiveness. For instance, we wanted to put students into groups of three in the class where we were implementing our neuromuscular biology materials. The instructor suggested we keep the groups they were already used to (two groups had four students, and one contained five!) We were disappointed, and were later validated in these feelings because observation of group dynamics demonstrated that some group members did not have to participate much in the laboratory activities because there were too many people in the groups.

Although learning communities can be study groups for classes, internship groups, or dinner discussion groups, they are more than just a group of people, as we found out in our internship teaching. What I have learned through my involvement with Delta and WPST, however, is that effective learning communities are an essential part of a successful teaching and learning experience.

Diversity: More than a rainbow

My understanding of diversity has evolved over about 2 years of participation in the Delta and WPST programs. For example, taking a learning styles inventory test in two different semesters gave me insight into what type of learner I am, and how I may have changed (centered, in fact) in several dichotomous ratings over the course of a year. Also, when I took “Effective Teaching with Technology,” I learned about all of the technology available to embrace and harness people’s diversity and learning styles. This heightened my awareness of both the nature and implications of diversity.

I define diversity simply as: *Personal experiences and attributes that define us as individuals and influence how we might learn or teach.* Instead of a rainbow, diversity is perhaps more aptly compared to the periodic table. Like elements, which share characteristics with their neighbors in rows and columns, students share more similarities with some individuals than others, and no two are alike.

The class we taught in the internship at Edgewood College had 14 students. Although this was a small number, the students had a number of diverse characteristics, including, but not limited to, learning styles, socioeconomic status/background, English language skills, age, previous knowledge of subject matter and out-of-class factors, including other classes, jobs, and family and health situations.

The unit we taught was neuromuscular physiology. Some of the students had taken or were concurrently taking an anatomy and physiology (A&P) course, and thus knew a lot of the material already. This is one difference for which we were glad to be aware. When the A&P students answered questions that we posed to the class, we needed to make sure that the other students understood as well. We had planned to have the A&P students dispersed into different small groups to enhance peer teaching, but unfortunately, the groups had been preset several weeks before the unit I taught. Thus, some discussion questions did not challenge a group that contained several A&P students.

Another way I address diversity is by being aware of my language. If there are students for whom English is not a primary language, I am especially careful of using slang or culture-based words and phrases. Regardless of the audience, I make sure to define key words as I use them. Some words we use in class may be shared with other subjects or everyday language, but have specific meaning in the topic at hand. In neuromuscular physiology, an example of this is “big.” If a student or I used “big” to describe a muscle fiber, it could convey several meanings, including, *long, thick, heavy,* or *strong*. Ambiguous words could have adverse effects, such as the formation of misconceptions.

Diversity can be a mechanism for student creation, participation, and inspiration[2]. For instance, for the laboratory portion of the internship, we asked students to construct and test a hypothesis after learning about muscular physiology and exploring Biopac equipment. The Biopac machines can record data from a variety of input attachments, such as a dynamometer, which measures grip strength. For example, in our neuromuscular physiology class, some of the group investigations included measuring muscle strength before and after push-ups, while another determined if watching the muscle force readout affected sustained grip strength. In each investigation, the students learned to use the equipment, and placed their findings in context of the muscle physiology discussed in lecture. Short group presentations allowed the other groups to see the breadth of projects, while allowing each group to verbalize their hypothesis, methods, and results. We could have had all the students follow the same protocol to generate similar data, but that would not be fun nor interesting to them, nor for us to grade similar laboratory reports.

The internship provided me with an opportunity to interact with diverse students in real ways instead of hand waving and philosophizing about diversity in teaching courses. In that sense, I learned how easy and difficult various aspects of diversity are to incorporate in my teaching. One easy way is by using both pictures and text in lecture slides. A more difficult way is to solicit viewpoints of a variety of students. I cannot say where, but somewhere along my internship experience, I began looking at diversity as a tool to be employed, not a problem to be dealt with. Now I do not see diversity as a step in a process, but rather something in which I steep every process. For example, some of the groups contained athletes (who often think about strength and body mechanics), some contained students taking the anatomy and physiology course (who were more advanced), and some students already knew how to use the Biopac machines. The inquiry-based approach to this laboratory experiment allowed all of these diverse characteristics to flourish.

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[2] McLeod, P.L., Lobel, S.A., Cox, T.H. (1996). “Ethnic diversity and creativity in small groups.” *Small Group Research* 27: 248-265.

Vignette: *All the mathematicians turned around and stared at the microbiologist in their midst, wondering why he was here, and why had they not thought of that idea before?*

One week the assignment for Expeditionary Learning was to attend a seminar outside of our discipline. I chose to attend a mathematics seminar entitled, “Rules, Randomness, and Roundness,” part of a series on chaos and complexity. I was familiar with some of the basic concepts of the topic and so was excited to see an academic lecture from people working in the field. One problem the speaker and his research group was addressing was how to estimate a circle on a grid. The approach was to fill in squares on the grid one by one, with each successive square chosen based on a set of rules relating to where the previous square was filled in. The purpose was to investigate the interplay of chaos and order in a simple system. Some rule sets yielded diamonds, squares, or other non-circular objects. A circle was a surprisingly hard figure to create in this system. At the end, I asked a question. I mentioned how in microbiology, we commonly see perfectly circular colonies formed by bacteria on media plates. The colonies are created by a single bacterium reproducing by binary fission. I asked if he could take this idea and apply it to his system by adding squares to the center and having them push out already filled-in squares. All the mathematicians turned around and stared at the microbiologist in their midst, wondering why he was here, and why had they not thought of that idea before?

He said they had not thought of that idea and he mentioned that he would like to talk more with me afterward. I never found out if the idea prompted a new direction in his research group or was just another failed attempt to solve their problem. Either way, the response of everyone in that seminar to my question was enough to solidify my beliefs in the value of learning communities and diversity.

PART III: REFLECTIONS ON TOOLS FOR TEACHING

The essays in this section evolved from reflections for various courses I took from Delta and WPST. They are meant to stand alone, and are works in progress that will continually evolve as I continue to reflect on my teaching.

Assessment, or *What Happened?*

The evaluation used by a particular course should be dependent on the goals of the course, which should be clearly defined and agreed upon by the instructor, department, and students. Different methods of evaluation probe for different outcomes of a course. For instance, a 50-question multiple-choice scantron-type exam in a general biology course suggests that students are required to know a broad range of facts and details. In contrast, the evaluation for a problem-based statistics course might contain several data sets to which students are expected to apply the information they have learned.

Problems can occur when course evaluations don't adequately probe the mastery of expected course outcomes. For example, a general chemistry course might be meant to prepare students for a biochemistry course. But if students are simply tested for recognition-based knowledge via multiple-choice testing, they may not be able to apply and think critically about topics like pH and buffers when necessary. The result is a knowledge deficit that creates confusion and frustration for the students in the second class. I should know, as this situation happened to me in college.

The solution is to create curriculum whereby the desired type of student outcomes (skills & knowledge) are defined, and the courses are set up to build on each other and contribute to different aspects of the desired final product[3]. The evaluations should be created to measure to what extent the students have achieved what each course has been designed to teach.

The process described above requires good communication and teamwork among instructors of a department. Other entities that have important contributions include students (feedback on course design, difficulty, expectations), alumni (feedback on level of preparation they felt in their jobs), and administration (if there is a mandate for such topics as ethics, community service or communication skills). When the evaluation of course content accurately reflects the articulated course goals, then students will be working toward mastering the intended skills & knowledge.

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[3] Wiggins, G., and McTighe, J. (1998). *Understanding by Design*. Alexandria, VA: Prentice Hall Inc.

One of the best ways I have been assessed was during a graduate school class. A large part of the grade was based on a grant proposal we had to write. The proposal was then reviewed, discussed, and ranked (graded) against the others by a group of peers from the class. This method allowed us to also be on the evaluating side and see what it was like to understand and critique the same assignments we had worked so hard on. It gave us great insight into what was important or not, and persuasive or not, when writing grants. It seemed real and was also a lot of fun because it was modeled after the same methods that the NIH (National Institutes of Health) uses to review and rank grant proposals. It also saved the instructor countless hours of reading and reviewing. Instead, he could just guide discussion and provide an unbiased intellectual resource. Meanwhile, the students were actively learning while assessing their peers' work. If I were able to again implement the neuromuscular biology unit we developed during the internship, I would have the groups give feedback on the oral or written lab reports/presentations of the other groups. Reviewing the methodology of their peers could create good opportunities for discussion and learning.

An assessment method that can be quite informative is very short written assignments. We used this strategy during the internship. At the end of the exploration activity of their laboratory session, we had the students write down a question they had about either the laboratory equipment or about lecture content. The answers to these questions allowed us to identify and correct misconceptions or knowledge gaps before moving on. It also provided us with feedback on how concepts are being interpreted/learned by the students. This assessment concept could be adapted and broadened to a number of situations. For instance, the papers or reports could be emailed or posted in a discussion forum (anonymous to the class but not to instructor). Also, students could formulate exam-type questions to probe concepts of the day/week and post them, providing an informal study tools/guide for the class, as well as potential exam questions for the instructor to use. All of this information is of great use to adapt the day's or week's activities to the class's progress.

Effective assessment is a necessity when practicing teaching-as-research. Teaching without good assessment is like doing an experiment with a faulty assay. If the procedure is flawed, or the data are not reliable, then nothing can be learned. Instead, assessments must be well-designed such that students are fairly tested on the content, thereby receiving feedback on their progress, and such that the instructor gathers essential information about where to improve teaching in the future.

Effective Teaching With Technology

One of the courses I took through the Delta program was "Effective Teaching with Technology." The course did not deal with specific software applications, but rather strategies and concerns regarding the use of any sort of technology in the classroom, from calculators to computers to videoconferencing. It is worth pointing out at the outset that some concerns are real and some are only perceived, but either way, they warrant discussion. Most of the factors are related to two questions: Does the technology increase the *value* of time spent learning by students? Does the technology increase the *efficiency* of instruction or time of the instructor?

One of the primary concerns of technology is the associated monetary cost. This can even be the factor that prohibits a discussion of the possibility of its implementation. Thus, it is worth evaluating costs versus benefits related to teaching, learning, and the institution. One type of cost could be a substitution of technology for direct student-student or instructor-student interactions. Although technology can, and in many cases certainly will alter interpersonal interactions, good implementation can lead to increased value of interactions. Bad implementation can lead to student and instructor isolation. Potential benefits of technology include more interactive learning, increased interest of instructor and students, and increased performance of students (or similar performance with an increase of students' perceived performance, suggesting more confidence in skills). In addition, technology can be a very effective way of engaging a diverse student audience. For example, a blind student might use a computerized text reader to keep up with reading for a course.

Also, several aspects of the learning equation must be ready for introduction of technology, including skills of the students, equipment in the learning environment, and mastery of skills by the instructor. Technology skills are a very important subject, since a lack of understanding of the technology tools (by students or instructor) will lead to wasted time, decreased learning and increased frustration[4]. Installation of technology in an institution requires constant upkeep and attention by a skilled staff. Without this maintenance, viruses, compatibility issues,

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[4] Zhu, E. and Kaplan, M. (2002). Technology and Teaching, in *McKeachie's Teaching Tips*. Chapter: Technology and Teaching. Houghton Mifflin.

and constant use by learners can erode a valuable investment over time.

Using technology to evaluate learning can be detrimental or potentially very useful and powerful. Assessment methods must be carefully designed to ensure evaluation of topic skills and knowledge, not technology skills and knowledge. Also, use of technology in assessments can increase the variety of methods used to assess learning, and can certainly enhance organization and ease of grading and record-keeping.

Teaching-as-research is a useful paradigm for teaching with technology. Implementation of technology can be controversial for a number of reasons (discussed above). Therefore, careful evaluation of the results it produces can lead to better use. It is important to compare newer techniques to each other as well as to proven or traditional methods. Research methods are useful for studying different aspects of the learning process and how technology affects them. For instance, a careful analysis can evaluate whether assessments are properly measuring the skills or knowledge intended. Other aspects of teaching and learning can also be probed, including the effectiveness of technology equipment, student attitudes to technologies, and effectiveness of technology usage by instructors. Many times, course technology can simplify the collection of data, leading to easier evaluation of teaching and learning, and thus a more fluid process of teaching evolution.

The process of writing in teaching and learning

In the instructional materials development course taught by the WPST, we read a chapter entitled, "Beyond the Virtual Classroom", which discussed Deep Learning[5]. The article put into words a lot of the ideas I have about what constitutes effective, meaningful learning. For instance, a chart on surface learning vs. depth learning seemed to play to the top and bottom levels of Bloom's taxonomy[6], a multi-tiered ladder of understanding that spans from recognition to synthesis.

The discussion of metacognition was also quite interesting. I agree with the author that articulation is extremely helpful to the learning process, and that writing is an integral part of learning. Not only is it useful to think about what one knows and how he or she knows it, but it is especially useful to write it down.

Writing, more than other forms of communication, forces one to fully articulate ideas and arguments, and challenges one to find the best words possible to most accurately express one's thoughts. In fact, the writing process encompasses more than just articulation. It also requires reflection as well as some self-scaffolding. Although an instructor or learning tool may have helped draw connections from students to a new topic, reflection and articulation can facilitate the enhancement of the scaffold for a learner. This is because the learner begins to fully incorporate the new knowledge, not just to one part of their cognitive scaffold, but by evaluating how the new knowledge might or might not tie into a variety of peripheral or seemingly unrelated existing knowledge.

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[5] Weigel, Van B. (2002). *Deep Learning for a Digital Age: Technology's Untapped Potential to Enrich Higher Education.* San Francisco, CA: Jossey-Bass.

[6] Bloom, B. S. (1956). *Taxonomy of Educational Objectives, Handbook 1: The Cognititve Domain.* New York: David McKay Co Inc. See also Appendix C (page 74)

APPENDIX A

Inquiry-based lectures and laboratory to teach neuromuscular physiology

Edgewood Group Neuromuscular Physiology Teachable Unit

Kate Cooper, Tom Grys, Dave Nelson

Topic

The module is for neuromuscular physiology.

Context

Adaptable to a general biology course or higher-level courses such as zoology or physiology.

Overarching unit concept:

Properly integrated physiological systems are essential for an animal's ability to successfully sense and respond to its surroundings.

Learning Objectives:

Be able to think about the action potential, the synapse, and muscle activity as parts of a functioning system.

Understand how muscles contract at the molecular level.

Be able to develop a testable hypothesis, design an experiment, and think critically about one's own experimental data by drawing conclusions and recognizing the limitations of an experiment.

Teaching Objectives:

Engage students in discussions during "lecture time" so that students expect to participate and expect to have lecture interspersed with discussions and small-group activities.

Present content in a way that elicits student questions and ideas.

Guide groups to address hypotheses that are interesting, creative, and testable.

Provide constructive and timely feedback of student questions, comments, exams, and reports.

Planned assessments: pretest, 1-minute paper, exam questions, a lab report.

Diversity Statement:

Research shows that by incorporating a number of teaching styles (lecture, visuals, discussions, small group activities, and laboratory activities), many students' learning styles will be engaged.

We believe that all students in Biology 352 are capable of learning the material and contributing to the learning of other students

We will strive to keep our language free of slang and other types of phrasing that might impede the understanding of non-American English language speakers.

Teaching Plan

Time	Activity	Rationale
Pre-class email	Pretest	Assess initial student understanding.
Pre-class email	Article about girl who cannot feel pain	Engage students in neuromuscular material and implications of disrupted system.
Class 1 (10 min)	Discussion: Step-on-tack. (See *teaching strategies Day 1*).	Engage pre-existing knowledge, begin thinking of neuromuscular system as functioning unit.
Class 1 (40 min)	Lecture on neurobiology: ion permeability, nerve cell, action potential, synapses (both neuron-neuron and neuron-muscular, while incorporating diseases into these descriptions.	Discuss both general concepts and details of content.
Class 1 (10 min)	Discussion: Tetanus and botulinum toxins. (See *teaching strategies Day 1*).	Synthesize lecture information and provoke students to think of neuromuscular system as functioning unit.
Class 1 (50 min)	Laboratory: explore BIOPAC (begin thinking about an experiment), turn in worksheet. (3 points)	Develop scientific curiosity.
Class 2 (5 min)	Short lecture to introduce to muscles: three muscle types, macro anatomy (fibers, fibrils, all-or-nothing fiber contraction).	Provide base of information for discussion.
Class 2 (10 min)	Motor unit discussion. (*See teaching strategies Day 2 and Fig. 2*).	Challenge students to predict muscle fiber organization and how it relates to function.
Class 2 (20 min)	Lecture on muscles: 3 muscle types, molecular anatomy (actin/myosin, ATP turnover), motor unit recruitment.	Extend motor unit discussion to provide more detail of muscular system.
Class 2 (10 min)	Discussion: two ways to increase muscle force.	Provoke students to think of neuromuscular system as functioning unit.
Class 2 (35 min)	Laboratory: develop and begin experiment, analyze data, make prediction or revise hypothesis.	Foster development of scientific investigation skills.
Class 2 (30 min)	5-minute presentation per group	Provides peer feedback on hypothesis and experimental plan.
Class 3	Laboratory: finish experiment, test prediction or revised hypothesis. Begin data analysis. Lab reports due 1 week from today.	Foster development of scientific investigation skills.
Class 4 (Five days after Class 3)	Exam (on which neuromuscular biology is 1/4 of material, ~15 minutes of exam time).	Assess student understanding.

Teaching Challenges

Challenge: There is a semester's worth of information and we only have 3 days.
Evidence: We are presenting the basic principles of the neuromuscular system of humans, yet that represents a small percentage of the total information that is covered by the chapters that contain the basic principles.
Strategy: We try to ensure that the basic principles we choose and the methods we use make sense to the students so that they can form a basic framework upon which more details can be added if the students learn more about this area in the future.

Challenge: We are developing our project in a class of 10-20 students, while others that use our instructional material may have 40 to 50 students.
Evidence: We are at a small, liberal-arts college, while UW, a state school, has a physiology class where the labs (not to mention the lectures) have 40-50 people.
Strategy: We are trying to ensure that the instructions we create for the lab portion are simple, yet comprehensive, so that the instructor and students all have successful experiences. Small group activities can be employed in classrooms of any size.

Challenge: Getting students to understand the roles of critical components in the neural signaling pathway
Evidence: Students often are confused by the chemistry and molecular details (source: personal knowledge and input from Edgewood instructors).
Approach: Aside from the standard presentation of neural signaling components, we will relate defects in the different signaling components to neuromuscular diseases in humans (ie. ALS, or multiple sclerosis). This will make the material more pertinent, and emphasize the role of each component.

Challenge: Getting students to understand the different steps in action potential signal propagation.
Evidence: This is an active and complex process that does not translate well from static diagrams (source: physiology instructors at Edgewood and UW).
Approach: Utilize a computer-based animation of the action potential process to supplement lecture/textbook material. Ideally we will identify an *interactive* animation that will permit students to study the different stages at their own pace. A demonstration of this would take place in class, but additional viewing of, and interaction with, the animation will take place outside of class.

Challenge: Biopac (machines used in lab) give readout of muscular voltage that could be interpreted as nerve impulses.
Evidence: We thought that was the case at first!
Strategy: Emphasize how muscles use electrical voltage and how it differs from nerves. Explore the relationship between electromyogram data and muscular force using BIOPAC systems.

Girl with rare disease doesn't know pain

Monday, November 1, 2004 Posted: 6:51 AM EST (1151 GMT)

Ashlyn Blocker, 5, must be checked for scrapes and cuts because she cannot feel pain.

In the school cafeteria, teachers put ice in 5-year-old Ashlyn's chili. If her lunch is scalding hot, she'll gulp it down anyway.

On the playground, a teacher's aide watches Ashlyn from within 15 feet, keeping her off the jungle gym and giving chase when she runs. If she takes a hard fall, Ashlyn won't cry.

Ashlyn is among a tiny number of people in the world known to have congenital insensitivity to pain with anhidrosis, or CIPA -- a rare genetic disorder that makes her unable to feel pain.

"Some people would say that's a good thing. But no, it's not," says Tara Blocker, Ashlyn's mother. "Pain's there for a reason. It lets your body know something's wrong and it needs to be fixed. I'd give anything for her to feel pain."

The untreatable disease also makes Ashlyn incapable of sensing extreme temperatures -- hot or cold -- disabling her body's ability to cool itself by sweating. Otherwise, her senses are normal.

Ashlyn can feel the texture of nickels and dimes she sorts into piles on her bedroom floor, the heft of the pink backpack she totes to school and the embrace of a hug. She feels hunger cravings for her favorite after-school snack, pickles and strawberry milk.

That's because the genetic mutation that causes CIPA only disrupts the development of the small nerve fibers that carry sensations of pain, heat and cold to the brain.

"There are all kinds of different nerve cells that help us feel different sensations," says Dr. Felicia Axelrod, a professor of pediatrics and neurology at New York University School of Medicine. "You can have one sense removed, just like you can lose your hearing but still smell things."

Number afflicted unknown

Specialists such as Axelrod don't know how many people suffer from CIPA. As director of a treatment center that specializes in CIPA and related disorders, Axelrod has 35 patients with the disease on file. Only 17 of them are from the United States. Japan has the world's only association for CIPA patients. It has 67 members.

In Patterson, a rural town of 800 people in southeast Georgia, John and Tara Blocker had no idea the disorder existed before they took Ashlyn to the doctor for a bloodshot, swollen left eye when she was 8 months old.

The doctor put drops in Ashlyn's eye to stain any particles that might be irritating it. The infant smiled and bounced in her mother's lap while the dye revealed a massive scratch across her cornea.

"They put the dye in her eye and I remember the look of puzzlement on all their faces," Ashlyn's mother says. "She was not phased by it by any means."

Tests by a geneticist led to Ashlyn's diagnosis. To have the disorder, Ashlyn had to inherit two copies of the mutated gene -- one from each parent.

Ashlyn's father, a telephone technician, and mother, who holds a degree in physical education, were largely on their own in learning to cope with their daughter's strange indifference to injury.

Many things they couldn't anticipate. Ashlyn's baby teeth posed big problems. She would chew her lips bloody in her sleep, bite through her tongue while eating, and once even stuck a finger in her mouth and stripped flesh from it.

Family photos reveal a series of these self-inflicted injuries. One picture shows Ashlyn in her Christmas dress, hair neatly coifed, with a swollen lip, missing teeth, puffy eye and athletic tape wrapped around her hands to protect them. She smiles like a little boxer who won a prize bout.

Her first serious injury came at age 3, when she laid her hand on a hot pressure washer in the back yard. Ashlyn's mother found her staring at her red, blistered palm.

"That was a real reality check for me. At that point I realized we're not going to be able to stop all the bad stuff," Tara Blocker says. "She needs a normal life, with limitations."

So when Ashlyn goes to her kindergarten class at Patterson Elementary School, she gets daily check-ups with school nurse Beth Cloud after recess. Cloud and Ashlyn's mother discussed having her wear a helmet on the playground, but decided it would look too odd.

And when teacher's aide Sue Price puts ice in Ashlyn's chili at lunch, her dozen classmates get ice in theirs too.

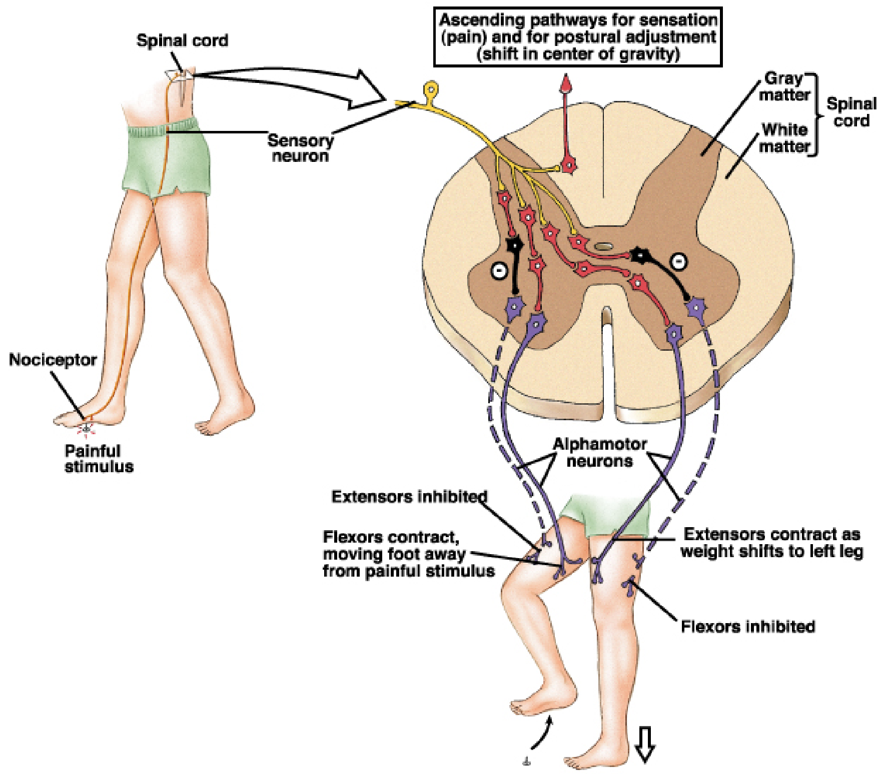
Infections with no outward symptoms also concern them. They heard of a case where a child with CIPA had appendicitis that went untreated until her appendix burst.

"It's a lot to take in. It opens your eyes to things you wouldn't normally think about," says Tara Blocker. "If she sees blood, she knows to stop. There's only so much you can tell a 5-year-old."

Tack Discussion

What happens when a person steps on a tack?

Reference: Silverthron, D., *Human Physiology, An Integrated Approach*, 2nd ed., Prentice Hall.



Clostridium Neurotoxin Discussion: the "Tox Paradox"

Learning objective:
Understand how the structure/organization of neurons and synapses relates their function.

Remind students of tetanus toxin and botox (maybe show pictures), emphasize the opposite effects of toxins.

Write organism names on the board *Clostridium botulinum, Clostridium tetani*

Did you know that although they have opposite effects, they function in similar ways?

Discuss in your groups how these toxins might function to interfere with normal neuromuscular function.

Give time for students to really sort out possibilities.

Explanation: Both toxins inhibit neurotransmitter release by blocking fusion of the vesicles to the membrane at synaptic clefts. The difference is that tetanus toxin does this in inhibitory inter-neurons, which means the motor neuron only receives excitation signals, and constantly activates the muscle fiber it innervates. Botulinum toxin acts at the neuromuscular synapses, blocking any action potentials from exciting the muscle fiber that nerve cell would activate.

More details:

There are 7 different serotypes of BoNT, denoted A-G, but only one type of TeNT.

Interesting note: BoNT/B and TeNT cleave VAMP at the same peptide bond, but cause opposite effects in an animal because the toxins are localized to different neurons

SNARE proteins are the targets for the BoNTs and the TeNT. They are on vesicles that carry neurotransmitters and help the vesicle dock and fuse with the neuron membrane, allowing the neurotransmitters to be released into the synapses. When the SNAREs are cleaved, the vesicles cannot dock or fuse to the membrane, which blocks signaling from that neuron. The SNAREs targeted by BoNTs and TeNT include: VAMP, SNAP-25, and syntaxin.

References and resources:

Pellizzari R., Rossetto O., Schiavo G., Montecucco C. Tetanus and botulinum neurotoxins: mechanism of action and therapeutic uses. *Phil. Trans. R. Soc Lond.* (1999) **354**:259.

Hatheway, CL. Toxigenic Clostridia. (1990). *Clincical Microbiology Reviews* **3**: 66-98.

Genop Healthcare Botox Mechanism of Action http://www.genophc.co.za/Botox.htm February 14, 2005.

www.botox.com

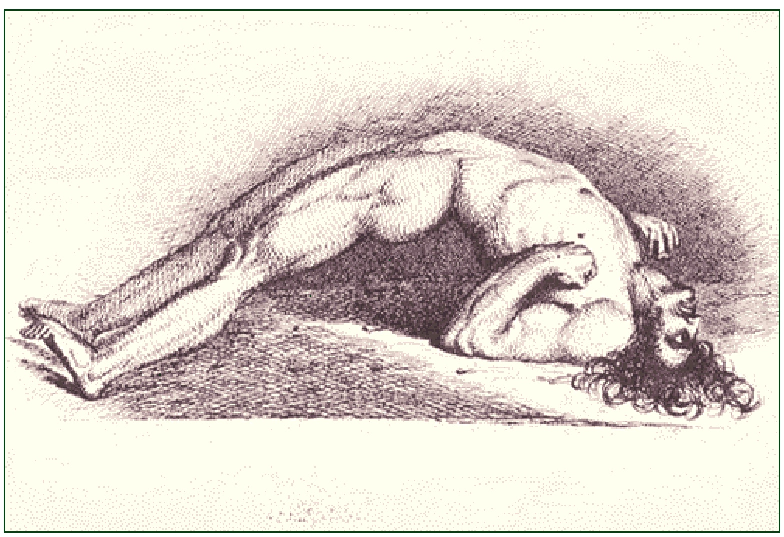
Introductions of these research papers:

- Swaminathan S., Eswaramoorthy, S. Structural analysis of the catalytic and binding sites of *Clostridum botulinum* neurotoxin B. (2000). *Nature Structural Biology* **7**:693.
- Sinha K., *et. al*. Analysis of mutants of tetanus toxin Hc fragment: ganglicoside binding, cell binding, and retrograde axonal transport properties. (2000). *Molecular Microbiology* **37**:1041.

Tetanus picture:
http://microvet.arizona.edu/Courses/MIC420/lecture_notes/clostridia/clostridia_neurotox/human_tetanus.html

Botox picture:
http://www.consultingroom.com/Aesthetics/Treatment/Treatment_Details.asp?Treatment=7

Great botulinum toxin animation:
http://microvet.arizona.edu/Courses/MIC420/lecture_notes/clostridia/clostridia_neurotox/movie/botulinum_movie.html



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Motor Unit Discussion

Animals have many different muscles that contribute to their ability to move and survive. All muscles are composed of fibers, and each fiber is activated by a single motor neuron. One motor neuron, however, can branch and activate a large or small number of muscle fibers. One motor neuron, its branches, and all the muscle fibers it activates define one motor unit.

Compare the differences between a human hand and a leg in terms of their functional requirements and relative strength. Given these differences, describe what you expect the motor units in a hand and a leg to be like. It may help you to draw a chart or diagram of your model. (Hint: don't forget to consider the number of motor units, as well as their characteristics).

Explanation: Motor units in the hand are small but numerous: each nerve activates a small number of muscle fibers, allowing fine control of movement. This differs with leg muscles, where a relatively small number of nerves each activate a large number of muscle fibers, providing an efficient way of stimulating leg movement.

Muscle Strength Discussion

How is muscle strength controlled? What are the various ways neurons could be able to control the force produced by a muscle?

We asked them to remember:
-Neuron activation of a muscle cell is all or nothing
-Muscle cells can only be innervated by one neuron, but one neuron can synapse with more than one muscle cell
-The role of calcium in muscle

Explanations we were looking for:

Increase cross-bridges of actin and myosin by releasing more calcium by more frequent muscle fiber activation

Activate more motor units, increasing total number of fibers being activated

Physiology – BioPac Lab #1

Introduction to BioPac and Electromyogram Exploration

Briefly review muscle action potential
Relate voltage from action potential to electrodes of Biopac
Demonstrate or point out salient features of Biopac software

Goals for today's lab:

- Understand the BioPac System and software
- Determine your forearm muscle strength, endurance, and EMG
- Understand what an electromyogram is
- Begin to explore how a muscle works

Instructions for starting the BioPac system and lab:

1. Attach electrodes to your arm as seen in page 31 of the BioPac book.
2. Open the BioPac Student Lab program and choose the LO2-EMG-2 lesson.
3. Pick a file name.
4. Follow the instructions on the computer for proper hookup of equipment:
    - electrode leads – detect electrical signals at the skin and transmit to system
    - dynamometer – senses the force exerted and sends to system
5. Calibrate according to instructions.

Explore the possibilities of the system and answer the following questions:

(hints: don't forget units on all your answers! The glossary of measurement definitions on page 8 might be helpful. Also, the BioPac book has instructions on how to analyze your data but you can also ask your instructors for help.)

1-What is the maximum force you can generate over approximately two seconds? (an average over that time)
(0.5 points)
This should be a number between 0-100 kg.

2-What was the average electrical voltage (EMG) generated in the muscle during maximum clenching force?
(0.5 points)
This should be in the range of 0.1 to 1 mV

3-How long did it take your muscle to fatigue? (Clench as tight as you can and hold until the force generated falls to 50% of the maximum value)
(0.5 points)
This should be a number in seconds

4-What is the integrated EMG value when your muscles are not clenching? Why do you think this is the case?
(1 point)
(0.5 points): This should be a smaller number than #2, with mV units (0.5 points)
(0.5 points): There is always baseline muscle activity to establish muscle tonus.

5- Perform an experiment to test the hypothesis: **the force generated is proportional to the total electrical voltage no matter how light or strong the clench.** *(Make a table of your data and graph it. Label axes. Does the data support the hypothesis or not?)*

(1.5 points)

(0.5 points): Table
(0.5 points): Graph
(0.5 points): Conclusion

6-What is something you are unsure about regarding the BioPac system or the most confusing part of today's lab?
This is a one-minute paper type exercise to get formative feedback

from them on the lab section.

Pre-test

Below is a pretest we would like you all to fill out. Answer the questions to the best of your ability without looking at your textbooks or other resources. If you don't know the answer, just write "I don't know."

Explain how an action potential is propagated within a neuron and between neurons.

Explain two ways a muscle can increase the force it exerts.

Final Exam Questions and Answers

1.

a) **Draw a functional synapse and label its parts.** (3)

Must show: signaling neuron and effector cell, vesicles, neurotransmitters, vesicles, point of action of drug/toxin, neurotransmitter receptors. Ideally label synaptic cleft. If they choose the m.s. example, then they need to focus on the Schwann cells.

b) **What is the purpose of a neurotransmitter?** (1)

To transfer the action potential from one cell to the next across a junction/synaptic cleft.

c) **Why is it important to degrade and/or recycle neurotransmitters quickly?** (2)

A prolonged signal would cause problems (ie. tetanus, paralysis, mood swings) because signals would be prolonged, and release too much hormones, lock muscles, etc.

Too many action potentials triggered; also, the system loses sensitivity to stimuli (in the sense that with a slow "refresh" rate, responses to new changes in the environment are also slowed)

d) **Give an example of a drug, toxin, or disease and describe its effects on neural signaling at the molecular and physiological level. It may help to demonstrate on your drawing where the drug or toxin acts.** (2)

Botox: interferes with vesicles releasing their neurotransmitters (at motor neuron-muscle fiber synapse), causes flaccid paralysis
Tetox: interferes with vesicles releasing their neurotransmitters (at inhibitor interneuron-motor neuron synapse), causes tetanus paralysis
Prozac: inhibits reuptake of serotonin at neural synapses, effectively increasing the signal/effect of serotonin, used to treat depression.
Multiple sclerosis – demyelination causes slowed signaling, loss of coordination and muscle control
Worse examples (as we didn't go into an real detail)

Parkinson's – too much dopamine; schizophrenia – too little dopamine

2.

a) **Draw an action potential waveform and label the locations of the resting and threshold potentials, and the repolarization, depolarization, and undershoot phases.** (3)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

This example, or anything similar out of a textbook will do. The undershoot is not labeled here, but is the hyperpolarized portion of the wave below –70 mV before slight repolarization to the resting state occurs.

b) **On your drawing, identify which phases the activation of the voltage-gated Na+ and K+ channels are responsible for.** (2)

The Na+ channel activation causes depolarization as sodium ions rush in, the K+ channel activation causes repolarization as potassium ions flood out. The K+ channel is responsible for the undershoot as well, as it closes slowly.

c) If you treated a neuron with a drug that blocked the voltage-gated K+ channel from opening, what would happen to

the membrane potential after the threshold potential had been reached? (1)

Hypothetically, the depolarization phase would still occur, but the membrane would not repolarize and the membrane potential would be maintained at ~ +35-40 mV.

3. Explain two ways a muscle can increase the force it exerts. (6)

Activating more motor units (motor unit recruitment) (1 pt for saying "motor unit" – 2 pts for saying that MORE of these should be activated or recruited. Lose one point if they only say "activate more fibers"and aren't more specific as to how this is controlled by the nervous system.

1)Neurons can increase the frequency of their action potentials, which 2) leads to increased amount of Ca2+ around in the muscle fiber, which 3) (b/c of troponin-tropomyosin interactions) increases the # of myosin heads bound to actin and therefore increases the force that the muscle fiber produces. (1 point for each part – the troponin-tropomyosin detail is optional)

4. *Rigor mortis* is muscle stiffness in dead animals. Describe what is happening to the actin-myosin interactions in the muscle cells, and incorporate the roles of ATP and calcium into your response. (3)

Death makes membranes more leaky, so Ca2+ can leak out into the fiber from the sarcoplasmic reticulum. The Ca2+ starts off the process of muscle fiber contraction (troponin-tropomyosin) because the mysoin head is primed and ready to bind to the actin (bound to ADP). (1pt for this part) ATP is needed for the myosin head to release from the actin so the muscle fiber can relax, since the body is dead, it isn't making ATP and the myosin is unable to release from the actin and the muscle fiber stays contracted – the muscles all remain "clenched." (2 points)

5. Define a motor unit. (2)

A (motor) neuron and all the muscle fibers (cells) that it innervates or activates. 2 points for including both aspects, 1 pt off for missing/confusing one part

Student Assessment of Learning Gains

Available at: http://www.wcer.wisc.edu/salgains/instructor/

Instructions:

Check one value for each question on each scale. If the question is not applicable, check 'NA'. You may add a comment for any item in the text box at the end of the survey.

Q1: How much did each of the following aspects of the class help your learning?
(Scale: NA, No help, A little help, Moderate help, Much help, Very much help)

A. The way in which the material was approached

D. The class activities

1. Class presentations (including lectures)
2. Discussion in class
3. Hands-on class activities
4. Written lab instructions
5. Lab organization
6. Teamwork in labs
7. Lab reports

K. The way this class was taught overall

Q6: Add comments below

Additional Questions:

1. What is your gender?

Female

Male

2. What is the race or ethnicity that you most closely identify with? (choose one)

African American

American Indian or Native American

Asian American

Hispanic American

European American

Foreign National

Other

3. What year are you in college?

First year

Second year

Third year
Fourth year
Fifth or more year

4. What grade do you expect to get in this course?
A
B
C
D
F

5. Why did you take this particular course?

6. Do you feel you were tested on the content we spent time on in lecture and discussions?
mostly
partly
not really

7. What part of class (lecture, discussions, lab, etc.) did you find most useful to your learning?

8. What part of class (lecture, discussions, lab, etc.) did you find most interesting?

9. Do you feel you are able to explain this material to people who don't have a science background? (like your parents)
mostly
sort of
not really

10. Do you feel that you learned more details or more concepts, or something in between?

11. Did you find it useful/enjoyable to create your own investigation with Biopac?

12. Do you think you learned more with the Biopac investigation than you would have with a "canned" or "cookbook" lab activity?
more with Biopac
more with "canned"
about equal

13. Comment here on lecture/discussions/lab/Biopac, etc.

This site was created with funding courtesy of the The ExxonMobil Foundation and the following National Science Foundation-funded projects:

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ModularChemistry (MC2)
The National Institute for Science Education
The AAC&U SENCER Institutes

 Your comments are welcome.

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Personal contact: Dr. Andrew Lokuta, lecture/lab coordinator, Physiology Department, UW-Madison

Personal contact: Drs. Francie Rowe and Nicole Kime, Biology Department, Edgewood College

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Learning Objectives, Assessment, and Rubric

Note: Bold objectives are considered the primary or “top-level” objectives of the unit. Some of these assessments serve redundant purposes (test a common learning object). Thus, different assessments might be used depending on the length of test and other assessments on the exam that may overlap certain assessments.

Learning Objective	Assessment	Excellent	Needs Improvement	Not acceptable
Be able to trace the flow of information throughout the nervous system and describe the three major processes involved in neural signaling: reception, integration, and transmission.	Exam: Have students draw and discuss a graded potential that does not achieve threshold.	Student draws a potential with explanations for each of the 5 major parts. Demonstrates knowledge that an action potential is an all-or-nothing signal.	Student does not have all parts of potential, or has flaws in some parts. Or drawing is great, but discussion is not accurate or contains misconceptions.	Student demonstrates major misconceptions (omits discussion of threshold, etc.).
	Draw a functional synapse and label its parts.	Includes all parts drawn adequately and correctly labeled.	Drawing is incomplete or some labels incorrect	Drawing demonstrates many misconceptions and lacks most labels
	What is the purpose of a neurotransmitter?	Student can describe function	Student’s answer reveals misconceptions along with some correct information	Student presents little to no correct information and/or vast misconceptions
	Why is it important to degrade and/or recycle neurotransmitters quickly?	Student discusses problems of continuous signaling	Student can’t give complete explanation why	Student presents little to no correct information and/or vast misconceptions
	Give an example of a drug, toxin,	Students use a class or other example and discusses the effect and implications of the effect on the neuromuscular system and to the animal.	Student can name a drug and immediate effect but not result on animal.	Student can only name drug

	or disease and describe its effects on neural signaling at the molecular and physiological level. It may help to demonstrate on your drawing where the drug or toxin acts. Lab worksheet: Perform an experiment to test the hypothesis: *the force generated is proportional to the total electrical voltage no matter how light or strong the clench.*	Students have at least four data points plotted on graph of force vs. voltage.	Students have only two or three data points, or incomplete graph	Graph is missing or not set up correctly
Be able to think about action potential, synapse, and muscle activity as a functioning system.	*d)* Exam: ***e)*** **Draw an action potential waveform and label the locations of the resting and threshold**	Drawing is reasonable and correctly labeled.	Drawing contains errors or is mislabeled	Drawing has vast errors and is not labeled well at all.

	potentials, and the repolarization, depolarization, and undershoot phases.			
	On your drawing, identify which phases the activation of the voltage-gated Na+ and K+ channels are responsible for.	Student describes Na+ and K+ ion influx and efflux through channels and relates the movement to different stages of the action potential curve	Student understands the importance/role of an electrochemical gradient and can identify the various components of the system	Student cannot relate ionic movement to voltage generation
	If you treated a neuron with a drug that blocked the voltage-gated K+ channel from opening, what would happen to the membrane potential after the threshold potential had been reached?	Hypothetically, the depolarization phase would still occur, but the membrane would not repolarize and the membrane potential would be maintained at ~ +35-40 mV.	Student grasps that the normal function is inhibited, and posits a reasonable, albeit incomplete answer	Student has little or no correct information or vast misconceptions
	Worksheet: What is the integrated EMG value when your muscles are not	Student realizes that the EMG is never zero, and explain tonus.	Student states that EMG isn't zero, but misses tonus explanation	Student does not realize EMG is not zero

	clenching? Why do you think this is the case?			
Understand how muscles contract at the molecular level.	Exam: *Rigor mortis* is muscle stiffness in dead animals. Describe what is happening to the actin-myosin interactions in the muscle cells, and incorporate the roles of ATP and calcium into your response.	Students discuss how degrading tissue allows release of Ca++ from the sarcoplasmic reticulum, allowing the myosin heads to bind actin, but not release, since there is no ATP present.	Student gets part of the explanation: eg: myosin-actin interaction that can be formed but not disrupted…but can't explain why…	Student re-states question without demonstrating additional knowledge
Be able to define a muscle motor unit and understand how motor units relate to animal movement	Exam: Define a motor unit.	Student has good definition and talks about how some nerves activate many muscle fibers and others activate few.	Student has a bad definition, but has good ideas about movements, or good definition but doesn't relate it well to movement	Student has a few ideas, but lacks an one complete idea.
Be able to distinguish between force and contraction and understand how graduations in contractions are created	Explain two ways a muscle can increase the force it exerts. Explain how a person holding an empty glass in mid-air can maintain the glass in that position as it is filled with milk? Explain what is	Increasing number of motor units activated, and increasing frequency of signals (leads to more calcium, and more cross-bridges Student describes how cross-bridges relate to force. Fibers add cross bridges when milk is added	Student gets one of the two correct, or both mostly correct but demonstrates misconceptions. Student has some concepts correct, but not a complete explanation or includes misconceptions Student incompletely	Student demonstrates misconceptions and gets neither correct Student mentions contraction in this part (misconception), no mention of cross-bridges

	happening in the muscle fibers when the person moves the glass to their lips	Cross bridges move and filaments slide when glass is moved.	describes event or includes misconceptions with true statements	Student does not describe sliding filaments, does not state any correct information
Understand that an EMG (electromyogram) measures electrical activity of the muscles.	Lab worksheet: What does EMG stand for, and what does it measure?	Student correctly defines EMG and what it measures	Student only gets one part right, but doesn't put down "nerve impulse" (big misconception)	Student doesn't get either part right, or has one part right with a big misconception about the measurement
Be able to develop a testable hypothesis, design an experiment, and think critically about one's own experimental data by drawing conclusions and recognizing the limitations of an experiment.	Lab report	Student has clearly stated a testable hypothesis, and collected data from 5+ subject. Student discusses potential flaws in study and how they might be resolved. Student summarizes data well, draws valid conclusions, and makes prediction from data or states another hypothesis. Student uses appropriate data analysis methods, significant figures, and data presentation (graphs, charts). Clear writing style and proper grammar are required.	Student hypothesis is not clear or has data on less than 5 students. Student does some of the things in "excellent" category, but leaves out important discussion of some part of the experiment or data. Student uses correct statistical methods to address hypothesis, but does not effectively present data and conclusions.	Student did not have a real hypothesis. Student fails to adequately review data, discuss method, or talk about future experiments, or has very simplistic scussion about one or two of these topics. Student uses inappropriate statistical methods, draws wrong conclusions, and writes in a vague or low quality manner.

APPENDIX B

This manuscript was written by my internship group. It presents the instructional materials we developed for neuromuscular biology, and presents data obtained from the implementation at Edgewood College.

Inquiry-based lectures and laboratory to teach neuromuscular physiology

Research Article
27,505 characters in main body text only (with spaces) [32,515 total]
Running Title: Inquiry-based neuromuscular physiology
Corresponding Author: Jo Handelsman

Kate Cooper*[ϒ], Thomas Grys*[◙], David Nelson*[✢], Nicole Kime[†], Francie Rowe[†], Sarah Miller[⁂], Jo Handelsman[⁂✯]

[ϒ]*Cellular and Molecular Biology Program, University of Wisconsin, Madison, WI 53706*
[◙]*Medical Microbiology and Immunology, University of Wisconsin, Madison, WI 53706*
[✢]*Department of Genetics, University of Wisconsin, Madison, WI 53706*
[⁂]*Department of Plant Pathology, University of Wisconsin, Madison, WI 53706*
[†] *Department of Natural Science*, *Edgewood College, Madison, WI 53711*
[✯]*Howard Hughes Medical Institute*

*These authors contributed equally to the design, implementation, and evaluation of the instructional materials presented in this report.

Keywords: undergraduate, neuromuscular, physiology, BIOPAC, inquiry

ABSTRACT

Neuromuscular biology is conceptually challenging for students because it integrates multiple scientific disciplines, and requires knowledge at a variety of levels ranging from the molecular and cellular to the physiological. We developed instructional materials for a mid-level undergraduate neuromuscular biology module that encouraged active engagement and input during lecture coupled with inquiry throughout accompanying laboratory work. The lectures blended typical content with small-group discussion questions to solidify core concepts. The laboratory employs the BIOPAC system as a vehicle for scientific inquiry into a topic relating to lecture concepts. Our materials were designed for three meetings of a combined two-hour lecture/lab setting, but the active learning exercises or inquiry-based laboratory can be integrated into an existing course on this subject. We assessed student learning with questions on the unit exam and final exam, a lab report, and an attitudinal (SALG) survey. Most students progressed in their understanding of neuromuscular biology as measured by pre- vs. post-unit test questions and lab reports. Survey results revealed that most students enjoyed the inquiry-based BIOPAC lab and felt they learned as much or more than they would have in a standard “cookbook” laboratory.

Teaching & Learning Challenges

This paper describes a neuromuscular physiology module that has several integrated discussion activities and an associated inquiry-based laboratory activity that incorporates BIOPAC systems (BIOPAC Systems, Inc., Goleta, CA). The BIOPAC system includes integrated hardware and software that facilitate real-time tracking of physiological data from a number of different input devices. This module was designed for mid-level biology students with at least one year of college-level biology. The main concept of the module was: “Properly integrated physiological systems are essential for an animal’s ability to sense and respond to its surroundings.” This emphasized the integrated nature of the neural and muscular systems, and it foreshadowed the subsequent course section on animal behavior.

When designing these materials, we addressed three primary challenges. The first is that the topic is sufficiently complex to be the basis for an entire course, yet we needed to teach the most important concepts in three two-hour classes.

Another challenge is for students to understand the roles of critical components in the neural signaling pathway. Students often are confused by the molecular details because they have not taken chemistry, or have insufficient training in molecular biology, and thus fail to develop a comprehensive understanding of the entire system. For instance, the mechanism of the action potential is arguably the most fundamental concept of neurophysiology, but it is difficult to learn from static diagrams because it is such an active and complex process.

A third challenge is overcoming a misconception about the BIOPAC systems used in the laboratory. These machines are simple, yet powerful tools for collecting real-time physiological data such as muscular force and electrical activity. A common misconception is that the BIOPAC electrodes are measuring nerve impulses, whereas they actually measure voltage changes caused by muscular activity. These challenges provided some guidance for developing our teaching strategies.

Teaching & Learning Objectives

Several major and minor learning objectives were encompassed by the module’s main concept. These objectives provided focus for summative assessments, which included an exam, final exam, and a formal lab report. Formative assessment included a pretest and a short-feedback question on the laboratory worksheet to gauge student perceptions and possible misconceptions. The three primary learning objectives for this course were to:

1. Be able to think about the action potential, the synapse, and muscle activity as parts of a functioning system.
2. Understand how muscles contract at the molecular level.
3. Be able to develop a testable hypothesis, design an experiment, and think critically about one’s own experimental data by drawing conclusions and recognizing the limitations of an experiment.

Our teaching objectives for the instructional materials were to:

1. Actively engage students in critical thinking and discussions during lecture.
2. Elicit student questions and ideas.
3. Guide students in laboratory to generate hypotheses that are creative, relevant to the lecture material, and testable.

4. Provide constructive and timely feedback of student questions, comments, exams, and reports.

Teaching Strategies

Context. The instructional materials were implemented in the Biology 352 (Advanced Biology II: Organismal Zoology) course at a small, liberal arts institution. The students were composed of second through fourth year biology majors, all with at least two semesters of the introductory core biology courses that included ecology, cell biology, energy transfer in living systems, classical and molecular genetics, and evolution. Most students in Biology 352 have also taken Biology 351, the organismal biology course covering plants, fungi, and protists. The course met for two hours, three times a week in a combined lecture/lab setting. The materials described here (Table 1) were implemented in one week of the month-long Animal Physiology unit of the course. Fourteen students took the course in the spring of 2005, evenly divided between women and men. The class included three students of non-Caucasian American background.

'We believe that all students in Biology 352 are capable of learning the material and contributing to the learning of other students when given a supportive and respectful environment. One of our goals was to keep our language free of slang and other language that might impede the understanding of students for whom American-English is not their primary language.

Preparation. Before the first lecture, a pretest was emailed to the students along with a popular-press article about a child who could not sense pain (Associated Press, 2004). The article provided a real-world anchor for the subsequent material about the mechanisms of sensation and response. The pretest offered students the opportunity to see what might be considered important in the upcoming classes and presented instructors with a picture of where the students stood in their knowledge of the concepts.

Day 1. We began with a discussion about what happens when a person steps on a tack and what each overt response reveals about the underlying neuromuscular system. This prompted the students to think for themselves about the functional aspects of the neuromuscular system and then share their ideas with the class. It also provided them a reason to begin thinking about the adaptive value of the nervous system, in terms of being able to respond to external stimuli. A lecture on nerve cells, the action potential, and synapses followed. When possible, examples of nervous system diseases, such as multiple sclerosis, depression, and Parkinson's, were incorporated to highlight the problems that result when a particular component of the system does not function properly.

It has previously been shown that talking about the material in a small group and with the instructors increases meaningful learning in physiology classes (Michael, 2001; Cortright et al., 2005). Thus, to get the students to immediately interact with the new concepts, we used a small-group discussion question about botulinum and tetanus toxins. We told them that although the toxins have a similar molecular mechanism of action, the physiological effects are opposite: flaccid paralysis for botulinum toxin, and rigid paralysis for tetanus toxin. Botox is in the news frequently, and all students have had tetanus shots, so this discussion was relevant for all the students, yet created a beautiful conundrum. The problem invited them to think about the components of a functioning neural signaling system and how they interact. The explanation of the "tox paradox" was derived from comments suggested by the discussion groups. Both toxins inhibit neurotransmitter release by blocking fusion of the vesicles to the membrane at synaptic clefts. The difference is that tetanus toxin targets inhibitory inter-neurons, which means the motor neuron only receives excitation signals, and constantly activates the muscle fiber it innervates. Botulinum toxin acts directly at the neuromuscular synapses, blocking the motor neuron from exciting the muscle fiber (Hatheway, 1990; Pellizzari et al., 1999).

The last 45 minutes of class were spent exploring the BIOPAC systems: how to set them up, what types of data can be collected, and what the limitations are. We provided hand-grip dynamometers, which measure force, and electrodes so that students could measure the following variables: force, time, and integrated electromyogram (EMG) signal. To aid this process, students were required to complete a worksheet and begin thinking about a hypothesis they would test with the BIOPAC machines on Days 2 and 3. This laboratory sequence design echoes the "Crawl, Walk, Run" approach that was advised by the report: *Biology 2010 Transforming Undergraduate Education for Future Research Biologists* (National Research Council, 2002. The rationale is that students best learn science when they are doing science, not following directions.

Day 2. The beginning of the lecture connected topics from Day 1 to Day 2 by reviewing that an action potential signal from the nervous system can result in a muscular system response. After a brief introduction of gross muscular anatomy and the concept of all-or-nothing fiber contraction, we challenged the students with a small-group discussion question that asked them to discuss and sketch motor units from a hand and a leg (Fig. 1). The exercise provoked students to think about the functional aspects of the muscular system and the efficient way in which it is organized. The 5-10 minute discussion also served to give the students a context in which to place the subsequent details and functional aspects of the muscular system. Motor units in the hand are generally small—meaning that each nerve activates a relatively small number of muscle fibers, allowing fine control of movement. This differs with leg muscles, where each nerve typically activates a large number of muscle fibers, providing an efficient way of stimulating enough force for leg movement.

The second half of this class period was allocated to student investigations with the BIOPAC machines. Groups formulated their hypotheses, took sample measurements, and shared their project ideas with the class to get feedback on experimental design. These activities guided students to experiments that would have measurable data and challenged them to begin thinking about how the data would be analyzed after the experiment

Day 3. This day was devoted entirely to student investigations. Groups acquired data from at least 8 subjects and began data analysis.

Assessment Tools

Pretest. A pretest was administered to measure the class knowledge before beginning the unit. The questions directly addressed our learning objectives. Similar questions were included in the unit exam, which provided a mechanism for direct measurement of understanding and skills gained after the unit and the success of meeting the learning objectives for the unit.

Discussion questions. The discussion activities provided a mechanism for formative assessment of the students. The thought processes and solutions of the groups provided a snapshot of how well the students understood and incorporated new knowledge and skills.

Unit exam questions. Subject matter from this lecture and lab module comprised about 25% of the unit exam (Fig. 3). The questions were based on Bloom's taxonomy (Bloom, 1956), whereby students were assessed at multiple levels of understanding and skill. In addition, the questions were arranged and phrased to allow students opportunity to demonstrate knowledge for partial credit if they could not completely answer the question.

Laboratory Reports. The laboratory reports provided a summative assessment opportunity. The students summarized their project, reported their data, and evaluated the results.

Student Assessment of Learning Gains (SALG) survey. A Student Attitudes of Learning Gains (SALG) survey (Seymour, 1997) was administered to the students several days after the final day of lecture to measure student attitudes toward the unit and instructional materials.

Assessment Results

Pretest. The pretest (Fig. 2) revealed many knowledge deficits as well as misconceptions. We instructed the students to answer the questions to the best of their ability, but to write, "I don't know" if they did not have a reasonable guess. Five students answered, "I don't know" to the muscle force question, and two answered "retain water" and "reflex." Only one student clearly stated one of the two answers. In response to the action potential question, eight students answered, "I don't know." Most of the students who did answer the action potential question had some knowledge that there was ions and gradients involved, and one identified acetylcholine as important in the process, yet no answers communicated complete processes.

Discussion questions. For all of the discussion activities, after 5-10 minutes, the students had come up with feasible explanations, showing that they had understood the prior lecture material and were capable of applying that new knowledge to novel situations.

Unit exam questions. Six students were able to accurately draw an action potential curve (Fig. 4A), and ten were able to accurately draw and label the parts of a synapse (Fig. 4B). The muscle force question asked for two answers, and seven students correctly answered at least one of the two. Five students correctly defined a motor unit.

Laboratory Reports. Student groups proposed a variety of topics for investigation. One group tested maximum grip strength before and after one minute of push-ups. Another measured muscular voltage before, during and after bicep curls. The students' project hypotheses were rooted in lecture material, and the experiments provided the students with an opportunity for inquiry and critical thinking. In the lab reports, the student groups used statistics to analyze the data and determine if their hypotheses were correct. In general, the groups' conclusions were valid and based on their results. The lab reports also demonstrated critical thinking about factors that could have affected their data, such as research subjects participating in multiple experiments, and how the treatment may or may not have affected the variable they were measuring.

SALG Survey. Responses to the SALG survey (Fig. 5) suggested that the students generally found the lectures and discussions both interesting and useful. When asked whether they learned more details or more concepts, most students felt they learned both. Only four students (of 13) felt they could "mostly" explain the material to someone without background in this subject. Most, however, (10 of 13 respondents) felt they could at least "partly" explain it.

Half of respondents felt they learned more with the BIOPAC inquiry-based lab than they would have with a "cookbook" lab where the research question and protocol are pre-determined. All but two felt they learned as much or more with it than they would have with a "canned" lab. Overall, 9 of 11 students responding felt the BIOPAC investigation was enjoyable or interesting.

When asked what part of class was most *useful* to their learning, six students responded that the lecture was helpful, and two responded the lab was (one student listed both). One student said discussions, and one said "breaking down the way muscles and neurons working [sic] together—both chemical and physical." When asked what part of class was most *interesting*, two students answered lecture, two said lab, two mentioned both, one said all the material was interesting, and one said "real-life applications."

The students were asked what grade they expected to receive at the end of the course. All of the students expected to receive at least a B, and a third of them expected an A. At the end of the semester-long course, 9 scored a B or better, 2 had a BC, and three had a C or CD.

Evaluation and Analysis

Student Progress. A comparison of the answers students gave on the pre- and post- assessments shows gains in the first two learning objectives. For example, half the class improved on the muscle force question, and by the end of the unit, most could draw a synapse, and almost half could draw and label an action potential curve. Seven students had at least one of two correct answers to the muscle force question. This was compared to one student that had one correct answer to the same question in the pretest. Although only five students correctly defined a motor unit, it was encouraging that these students gave the correct answer again on the final exam for the course two weeks later. The lab reports demonstrated ability in the third learning objective, since all the groups came up with valid hypotheses, tested them, and critically evaluated their experiments.

Discussion activities. The in-class discussions successfully provided an opportunity for students to think about the concepts and material as functioning systems instead of discrete parts. For example, in the toxin discussion, the students' frustrated facial expression followed by chatter in their small groups demonstrated that this was a good discussion-provoking activity. In general, these small-group discussions were productive activities, and students demonstrated that they were able to use details and concepts from the lecture and apply them to new situations.

Assessments. Given the positive results from the discussions, the students should have been well prepared for the unit exam. The results from the unit assessment, however, seemed to show less progress than would have been expected from the responses from the discussions. The lower achievement on the unit exam could be a product of a variety of factors. For instance, the discussions worked to break-up the lecture and promoted student interaction with the material, but it is possible that not all the students in each group understood the answers that the group had formulated.

Another complicating factor in the assessment results is that there were three different student instructors for this module and a somewhat different style of lecture and laboratory than students were used to. Thus, the students may have been unsure how to study for the part of the exam that assessed their learning from this module. For example, none of the module's assessments contained a multiple-choice question, so students adapted to recognition-type assessments would not do well. Some of the students may have thought that because outside instructors were teaching the module, somehow the portion of the exam that covered this module would be easier or worth fewer points. Attendance was good—only one or two students were missing from each class—so it should not have been a major factor affecting the assessment data.

Another possibility is that the students did not study the material from discussions, and instead focused on lecture material. It is known that many students in this class do not purchase the book for the class, and therefore do not supplement the lecture with further reading. Thus, students who miss class or do not pay attention in class have little or no information from which to study. It may be telling that students who did not correctly define a motor unit on the unit exam did not learn the concept before the final exam. Additional implementation of this module will yield more insight into the discrepancy of results between formative and summative assessments. Furthermore, it will provide opportunities to ensure that the assessments are properly aligned with the learning objectives and that the students are aware and prepared for the assessments.

It is interesting to note that nine of the 14 students scored a B or better for the entire class. This number may be a good benchmark to which the summative assessment results may be compared. For example, five of the six students who did well on the action potential question were B or better students. Eight of the nine B students scored well on the synapse question, and six of nine B students scored well on the muscle force question. Thus, students did similarly on our material as on the other course material. Although this serves to validate our material in the context of this class, our objective was to enhance learning for *all* students.

BIOPAC Laboratory. Although the lab activity was too short to allow in-depth exploration of the content discussed in lecture, the SALG data show it was a useful and enjoyable exercise in inquiry for students without resorting to the more typical experiments involving live animal dissection. It provided a creative opportunity for the students because they were able to develop their own experiment, and the subject matter of the inquiry was based in the lecture content. We would recommend the BIOPAC activity for other instructors seeking a mechanism of student inquiry that relates to lecture content. It would not, however, enhance or extend lecture material unless either the students had more time for the laboratory inquiry, or the activity was implemented in a more advanced physiology course.

Lab reports. Several students commented in the SALG survey that the laboratory reports were not a good use of their time. After seeing the laboratory reports, we recommend that a better activity to summarize their findings might be one complete figure with all aspects included—informative title, meaningful axis labels, and a figure legend that includes the hypothesis, brief methods and conclusions. In this way, students would spend more time on what was valued in the learning objectives (i.e., processing of data) and less on what was not (i.e., introduction). Other parts of the laboratory report could be foci during other units of the course.

Implementation. The course in which these materials were implemented had only 14 students enrolled. The result was a small class with a low student to instructor ratio. We envision these materials to be useful in a large lecture format, too, because small group activities can be employed in classrooms of any size (Cooper and Robinson, 2000). These small group discussions should be helpful in making the class feel smaller and more active, effectively bringing the complex content of neuromuscular physiology down from the front wall of the class and into the hands and minds of the students. The instructional materials were designed for mid-level biology students, but could likely be used in a general biology course if the students had a solid understanding of ion chemistry. The types of strategies demonstrated in this study can be applied in a variety of biology courses and to varied student populations.

Surveys. Some students gave negative comments on the final course survey about the class being part of an “experiment.” The SALG survey, however, revealed that most students enjoyed the lab activity discussions. In addition, students showed some confidence in their ability to explain content from the module to someone else. Thus, we feel the data generated from this module and its assessments are valid and the results offer opportunities for discussion.

Conclusions. Based on the evidence from the assessments and observations of students in class, these materials increased student knowledge of neuromuscular physiology and resulted in student participation and enjoyment in the lecture and laboratory. Also, we conclude that the dynamometer tool of the BIOPAC system is a useful tool for inquiry, though less so to teach basic content discussed in this course. Unfortunately, we did not have a comparison group to measure any changes in learning compared to a traditional format. We did, however, establish that students progressed in their knowledge of, and abilities in, the neuromuscular physiology module content. Also, the attitude survey established that students felt they had learned a combination of concepts and details, and that they enjoyed the inquiry-based lab activity. The materials developed here are based on teaching methods with established effectiveness. The laboratory is inquiry-based an interactive, and the lectures are structured around discussion activities. We invite others to adopt and improve these materials in their classrooms and continue to compare efficacy of this approach with traditional methods.

Acknowledgements

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TABLE 1: Teaching plan for the neuromuscular biology unit.

Time	Activity	Rationale
Pre-class email	Pretest	Assess initial student understanding.
Pre-class email	Article about girl who cannot feel pain	Engage students in neuromuscular material and implications of disrupted system.
Class 1 (10 min)	Discussion: Step-on-tack. (See *teaching strategies Day 1*).	Engage pre-existing knowledge, begin thinking of neuromuscular system as functioning unit.
Class 1 (40 min)	Lecture on neurobiology: ion permeability, nerve cell, action potential, synapses (both neuron-neuron and neuron-muscular, while incorporating diseases into these descriptions.	Discuss both general concepts and details of content.
Class 1 (10 min)	Discussion: Tetanus and botulinum toxins. (See *teaching strategies Day 1*).	Synthesize lecture information and provoke students to think of neuromuscular system as functioning unit.
Class 1 (50 min)	Laboratory: explore BIOPAC (begin thinking about an experiment), turn in worksheet. (3 points)	Develop scientific curiosity.
Class 2 (5 min)	Short lecture to introduce to muscles: three muscle types, macro anatomy (fibers, fibrils, all-or-nothing fiber contraction).	Provide base of information for discussion.
Class 2 (10 min)	Motor unit discussion. (*See teaching strategies Day 2 and Fig. 2*).	Challenge students to predict muscle fiber organization and how it relates to function.
Class 2 (20 min)	Lecture on muscles: 3 muscle types, molecular anatomy (actin/myosin, ATP turnover), motor unit recruitment.	Extend motor unit discussion to provide more detail of muscular system.
Class 2 (10 min)	Discussion: two ways to increase muscle force.	Provoke students to think of neuromuscular system as functioning unit.
Class 2 (35 min)	Laboratory: develop and begin experiment, analyze data, make prediction or revise hypothesis.	Foster development of scientific investigation skills.
Class 2 (30 min)	5-minute presentation per group	Provides peer feedback on hypothesis and experimental plan.
Class 3	Laboratory: finish experiment, test prediction or revised hypothesis. Begin data analysis. Lab reports due 1 week from today.	Foster development of scientific investigation skills.
Class 4 (Five days after Class 3)	Exam (on which neuromuscular biology is 1/4 of material, ~15 minutes of exam time).	Assess student understanding.

FIGURE 1: Example of a small-group discussion activity used during lecture.

Motor Unit Discussion

Animals have many different muscles that contribute to their ability to move and survive. All muscles are composed of fibers, and each fiber is activated by a single motor neuron. One motor neuron, however, can branch and activate a large or small number of muscle fibers. One motor neuron, its branches, and all the muscle fibers it activates define one **motor unit**.

Compare the differences between a human hand and a leg in terms of their functional requirements and relative strength. Given these differences, describe what you expect the motor units in a hand and a leg to be like. It may help you to draw a chart or diagram of your model.

FIGURE 2: Pretest assessment. The students were instructed to answer the two questions to the best of their ability, but to answer “I don’t know” if they did not have a reasonable answer.

Pretest (14 students)	**Answered: “I Don’t Know”**	**Examples of Partial Knowledge**	**Examples of Misconceptions**
Explain how an action potential is propagated within a neuron and between neurons.	8	Na^+/K^+ gradients/buildup	Cl^- ions
Explain two ways a muscle can increase the force it exerts.	5	Hypertrophy, use more energy	Retain water, reflex

FIGURE 3: Exam assessment instruments and exam question scores. Below are the questions asked on the unit exam. The exam questions were worth different numbers of points, as indicated by the number in parentheses above the box, representing the total range of points. Each data point represents one student's score, and the horizontal line represents the mean score for that question.

Unit Exam Questions:

1. Compare and contrast the action of hormones* and the action of neurotransmitters
2. Draw an action potential waveform on the axes below. First, label your axes! Then, label the location of the following: resting potential, threshold potential, depolarization phase, repolarization phase, and undershoot phase. Finally, identify which of the phases listed above are caused by the activation of Na+ and K+ channels.
3. Draw and neatly label a functional synapse. Make sure that you include the following parts: axon terminal of the presynaptic cell, postsynaptic cell, vesicles, neurotransmitters, receptors, synaptic cleft.
4. Define a motor unit.
5. Explain two ways that a muscle can increase the force that it exerts.

*note: hormones were discussed the week prior to the neuromuscular physiology module.

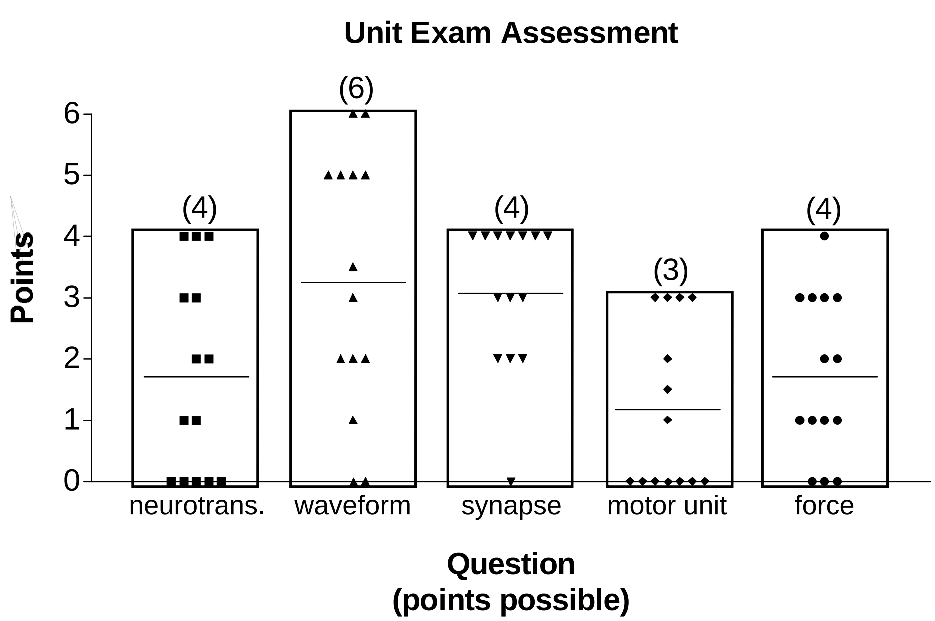
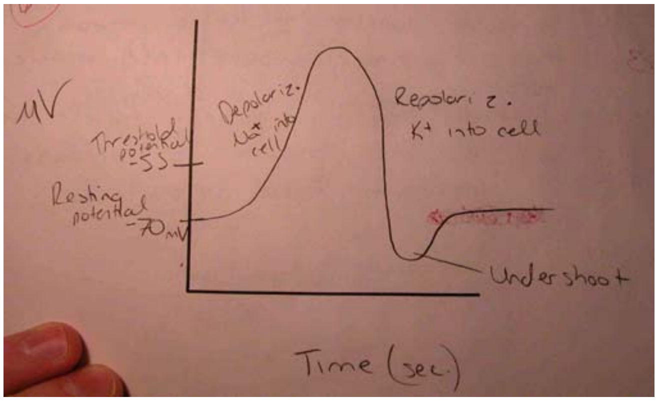
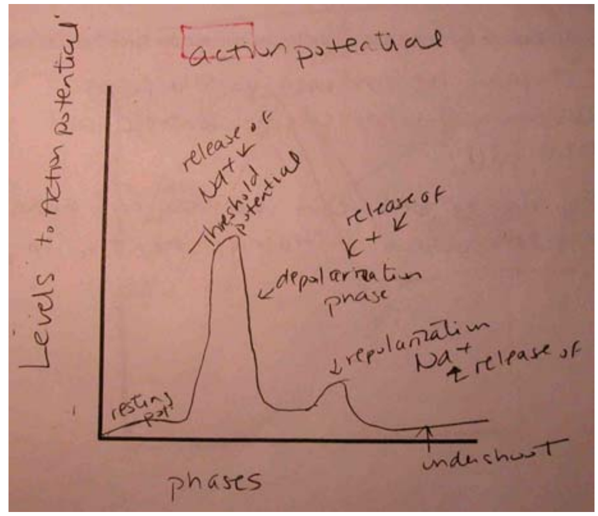
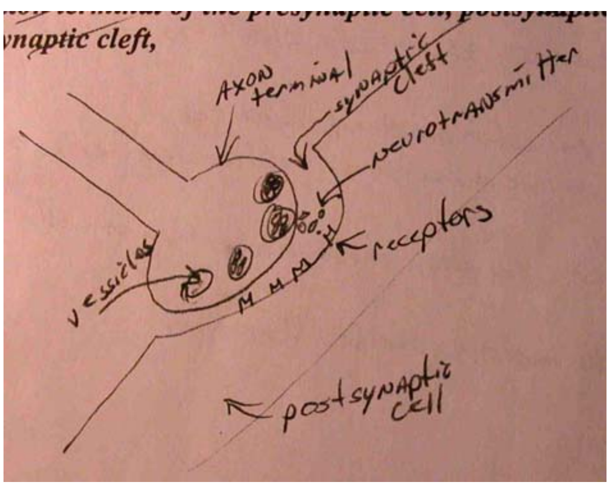


FIGURE 4: Examples of student answers. Below are examples of excellent (left) and poor (right) drawings in response to question 2 (top) and question 3 (bottom) of the unit exam.







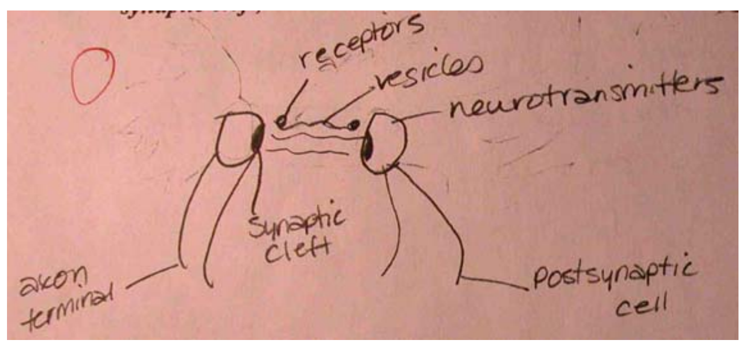
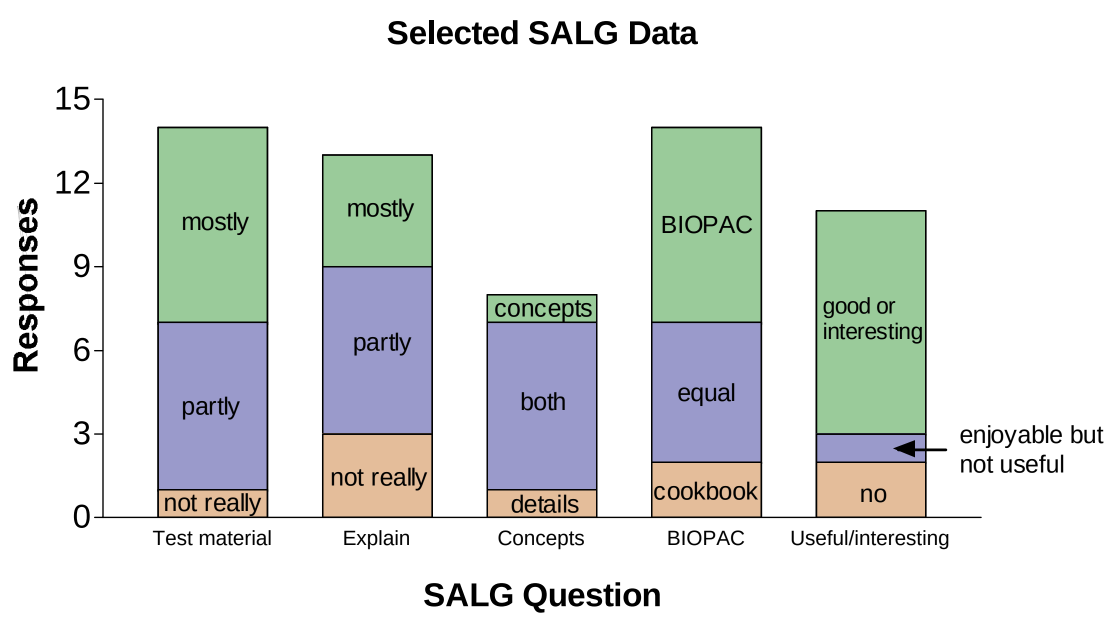


Figure 5. Responses to selected questions from the SALG questionnaire. Below are the questions and in brackets are the answers provided for students. When there was an open textbox, the answers were grouped and graphed by theme.

Do you feel you were tested on the content that we discussed in lecture? [mostly, partly, not really]
Do you feel you are able to explain this material to people who don't have a science background? (like your parents) [mostly, partly, not really]
Do you feel you learned more details or more concepts, or something in between? [open]
Do you think you learned more with the BIOPAC investigation than you would have with a "canned" or "cookbook" lab activity? [BIOPAC, equal, canned]
Did you find it useful/enjoyable to create your own investigation with BIOPAC? [open]



APPENDIX C

Bloom's Taxonomy

Blooms taxonomy is a categorical structure outlining a stepwise increase in complexity and abstraction. It can provide a useful guideline for designing assessment questions that test different levels of understanding and ability. Below, listed in increasing order of complexity are the categories:

Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation

APPENDIX D

Thomas E. Grys, Ph

Curriculum Vitae

Dept. Med. Micro. & Imm.
Room 481 MSC
1300 University Ave.
Madison, WI 53706

tegrys@wisc.edu

1705 Prairie Rd.
Madison, WI 53711
608-235-7461

Objective

Teach and inspire biology students at a liberal arts college

Education

2000 - 2005 **University of Wisconsin-Madison,** *Madison, WI*
Dissertator; Laboratory of Dr. Rod Welch in the Microbiology Doctoral Training Program. The project is an investigation of the role of the StcE protease in pathogenesis of enterohemorrhagic *E. coli* O157:H7.

1996 - 2000 **Gustavus Adolphus College,** *St. Peter, MN*
Graduated in May 2000 *summa cum laude*
BA in Biochemistry and Chemistry. GPA: 3.94

Teaching Experiences

Fall 2004- Present **HHMI Instructional Materials Development Fellow:** Part of a team of three graduate students that are developing instructional materials in neuromuscular physiology. We will be implementing them in the spring at Edgewood College in Biology 352 in collaboration with Drs. Francie Rowe and Nikki Kime. The program is directed by UW Professor Jo Handelsman and funded through a grant from the Howard Hughes Medical Institute.

2003-2004 **Mentor for undergraduate research**. Student: Matthew Siegel, major in Medical Microbiology and Immunology.

Spring 2002 **Procaryotic Microbiology Lab (Bact 304)** *Teaching Assistant.* Instructor: Robin Kurtz. Duties included 10 minute introduction lecture to every lab, correction of tests and lab reports, assisting students during lab.

Fall 2001 **Medical Microbiology Lab (MMI 302)** *Teaching Assistant.* Instructor: Joanne Weber. Duties included one 45 minute lecture, test correction, and assisting students during lab.

Conferences and Panels

May 25, 2005 **CIRTL Forum (Center for the Integration of Research, Teaching, and Learning):** *Panelist*. Part of a four student panel discussing diversity in relation to teaching and learning.

October 29, 2005 **Project Kaleidoscope (PKAL) Leadership Seminar.** *Panelist*. Part of a four-student panel discussing experiences and involvement in the interdisciplinary teaching and learning program, Delta, at UW-Madison.

2002-Present

Teaching/Learning Courses (graduate level)

Instructional Materials Development
Teaching Biology
Teaching With Technology
Expeditionary Learning

2000-2002

Graduate Science Courses

Microbial Pathogenesis
Eukaryotic Pathogenesis
Topics in Immunology
Advanced Microbial Genetics
Cell and Molecular Biology of Pathology
Coenzymes and Cofactors in Enzymology
Statistics for Bioscience
Modern Biological Microscopy

Publications and Abstracts

Thomas E. Grys, Rodney A. Welch. Activity Characterization of the StcE protease of Enterohemorrhagic *Escherichia coli* O157:H7. (submitted).

Thomas E. Grys, Michael J. Rock, Ronald L. Sorkness, Rodney A. Welch. The StcE protease is a potential therapeutic agent to solubilze sputum in patients with Cystic Fibrosis. (To be submitted to Pediatric Pulmonology in Jan. 2005).

Thomas E. Grys, Matthew B. Siegel, Wyndham W. Lathem, Rodney A. Welch. (2005). The StcE Protease Contributes to Intimate Adherence of Enterohemorrhagic *Escherichia coli* O157:H7 to Host Cells. *Infection and Immunity.* 73:1295.

T.E. Grys, M.B. Siegel, R.A. Welch. (2004). The StcE Protease of *Escherichia coli* O157:H7 Contributes to Intimate Adherence to HEp-2 Cells. Abstract presented at the 104th General Meeting of the American Society for Microbiology Conference, New Orleans, LA.

Sriram Ravindran, Thomas E. Grys, Rodney A. Welch, Marc Schapira, and Philip A. Patston. (2004). Inhibition of Plasma Kallikrein by C1-Inhibitor: Role of Endothelial Cells and the Amino Terminal Domain of C1-inhibitor. *Thrombosis and Haemostasis* 92:1277-83.

Lathem W.W., Grys T.E., Witowski, S.E., Torres, A.G., Kaper, J.B., Tarr P.I., Welch, R.A. (2002). StcE, a metalloprotease secreted by *Escherichia coli* O157:H7, specifically cleaves C1 esterase inhibitor. Mol. Micro. 45: 277-288.

Patents

2005 **US 2004/0234530** (pending)**:** *E. coli* O157:H7 C1-INH binding protein and methods of use. R.A. Welch, W.W. Lathem, T.E. Grys

Grants Received

2005 — **Robert Draper Technology Innovation Fund Grant** from the Wisconsin Alumni Research Foundation (WARF). $20,884. *Studies to Enhance Licensability and Invention Protection for StcE, a Potential Therapeutic for Cystic Fibrosis.* Thomas E. Grys, Rodney A. Welch.

Awards received

2000-2003	Fellow of NIH Biotechnology Training Grant, UW-Madison (funding for 3 years)
1999	Scholl Scholar, Mayo Clinic Summer Undergraduate Research Fellow
1997, 1999	Sigma Xi Undergraduate Research Grant
1996	Partners in Scholarship award, Gustavus Adolphus College
1996	Student of the Year Award, Shawano High School
1995	High school soccer Captain, MVP, Charlie Hustle Award, and two-time All-Conference.

Volunteer experience

2004	Co-organizer of first annual Microbiology Career Forum
2003	Co-chair of student-invited speaker seminar series
2001-2003	Student Representative on Steering Committee of Microbiology Doctoral Training Program
1997, 1998, 2000	Habitat for Humanity Spring break work trips
1996-1998	Gustavus Youth Outreach (Christian ministry group)
1995-1996	Strategic Planning Team for Shawano-Gresham School District, one of two student representatives

Interests and activities

Current	Ultimate Frisbee, cross-country skiing
1996-2000	Chapel Choir and St. Ansgar's Chorus, Gustavus Adolphus College
1998-1999	Studied abroad in Durham, England
1998-1999	Gustavus Ultimate Frisbee
1996-2000	Gustavus Adolphus Pep Band

References

Additional references available upon request