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The HAPS-Educator, The Journal of the Human Anatomy and Physiology Society, aims to foster teaching excellence and pedagogical research in anatomy and physiology education. The journal publishes articles under three categories. Educational Research articles discuss pedagogical research projects supported by robust data. Perspectives on Teaching articles discuss a teaching philosophy or modality but do not require supporting data. Current Topics articles provide a state-of-the-art summary of a trending topic area relevant to anatomy and physiology educators. All submitted articles undergo peer-review. Educational Research articles will additionally be reviewed for the quality of the supporting data. All submissions are disseminated to non-HAPS members one year post-publication via the Life Sciences Teaching Resource Community database.

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Information for authors on the terms of submission, the submission procedure, formatting the manuscript, formatting the references, the submission of illustrations, and the peer review process, is available HERE.

Submission Links
Use the Manuscript Submission form for HAPS Educator submissions and the Teaching Tips for A&P (Snippets) form for shorter teaching tips.

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A Message From the Guest Editor

Murray Jensen, PhD

Scott Freeman’s paper titled “Active learning increases student performance in science, engineering, and mathematics” is one of the most cited papers in science education. The paper is a meta-analysis that compares active learning strategies (e.g., paired problem solving, case studies) to traditional lecture. As the title clearly states, students do better in active learning classrooms than in traditional lecture courses.

Most HAPS members lecture in their classrooms – some more than others. But the research is quite clear – we should be lecturing less, and we should be using more active learning strategies with our students. However, creating effective active learning lessons takes time and effort. It takes ideas, trials with students, modifications, more ideas, and more revisions. It is almost impossible for one instructor to generate a complete set of active learning materials for all their courses – they need help from other educators who are also developing materials. That is what this Special Issue of the HAPS Educator is about – sharing peer-reviewed curriculum materials with others who might find them useful in their own classrooms.

Enclosed in this issue of the Educator are fifteen class activities that are intended to “promote good conversation among students,” which is key to active learning. We want to see students talking with each other, posing questions to each other and to the instructor, engaging in doubt and speculation, and generally trying to “make sense” of the many topics and concepts in human anatomy and physiology.

To try a new active learning strategy is risky – it might fail. Yup – you might have a bad day. Students might not engage in good conversations. They might answer all the questions quickly without any doubts or questions. Or there might be so much doubt that it leads to confusion and frustration. “Could you please just tell us the answer,” is a common line from students new to active learning. Picking and choosing an activity that “fits” with the academic abilities of your students is more art than science– it is a “I think this might work with my students” decision. But sometimes you find an activity that works! Students do engage in meaningful conversations, they do speculate, they derive novel questions, they might even have the coveted “a ha” moment. And to see that moment, to see a student finally “get it” – that is as good as it gets for most of us educators; we live for that moment.

(“What do you mean a fetus is not inside the female’s body?!” That is a line that I frequently hear during my “Inside and Outside” the body activity. It is always fun to see students try to make sense of that concept.)

This collection of curriculum materials is not a “one size fits all” thing; not every activity is designed for every type of Anatomy and Physiology classroom. Some activities are long, some short, some are for advanced students, others are for entry-level students. So as you look through this collection you might find only two or three that you want to try out. You might not find any! The key is that this collection is just the beginning. Eventually we hope to have dozens of activities on the HAPS Web site accompanied by answer keys. If all goes well, we will be calling on HAPS members for active learning materials for another Special Issue next year.

This last part is important. If you do try out an activity and it helps your students, please send the author a quick email saying something like “Thanks for the activity! I’ll be using it again next semester.”
A Case of Tense Toes: Clinical Case Study on Calcium Regulation

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Abstract
This case study on calcium regulation provides teaching notes and student handouts. Data on blood calcium, PTH, and vitamin D levels are analyzed and graphed. Regulation of calcium is explored and possible causes of pathology are considered.
doi: 10.21692/haps.2017.032

Key words:  case study, calcium regulation, homeostasis, feedback

Target Audience:  College students, first-year level or High School Seniors

Learning Outcomes:
HAPS:
Content and Process Goal 3:  Recognize and explain the principle of homeostasis and the use of feedback loops to control physiological systems in the human body
Content and Process Goal 5:  Recognize and explain the interrelationships within and between anatomical and physiological systems of the human body.
Content and Process Goal 6:  Synthesize ideas to make a connection between knowledge of anatomy and physiology and real-world situations, including healthy lifestyle decisions and homeostatic imbalances.
Content and Process Goal 8:  Interpret graphs of anatomical and physiological data.
Broader Process Goal 10:  Approach and examine issues related to anatomy and physiology from an evidence-based perspective.

LO Module B:  Predict factors or situations affecting various organ systems that could disrupt homeostasis.
LO Module J:  Identify the source, secretory control, and functional role of parathyroid hormone.

Prior Knowledge:  Basic chemistry, mechanisms of homeostasis, general mechanisms of hormone transport and regulation through negative feedback.

Time Required:  30 to 45 minutes per part; 90 minutes to two hours total.

Faculty Notes:  Students in a first-semester Anatomy and Physiology course work in small groups to complete this case study on calcium homeostasis.  Activities include answering questions about basic physiology, creating graphs, analyzing data, relating the case to homeostasis and feedback, and determining the cause of a homeostatic imbalance, then predicting the course of treatment.

Teaching note 1: I searched for “contracting feet and hands,” as that seemed like something a non-professional might type in.  In addition to finding contractors (amazingly, including one called “Hands & Feet General Contractors”), I saw a link for “hand or foot spasms” at Medline Plus:
Terms that students might list after reading this site include:  spasm, tetany, carpopedal, electrolytes, dystonia, and neuropathy.  For guidance, you might suggest limiting the search to children, or at least not following up on disorders that relate to aging.  You might also point out that both feet are affected.

Teaching note 2:  The narrative should steer students away from searching after hormones related to stress.  The questions in this section should also help guide them toward looking at electrolyte balance.  Possible answers include sodium, potassium, and calcium.  Students should be directed to specify excess, or deficiency, as a cause of muscle spasm.  If students need help, suggest they look up the hormones that regulate electrolytes.

Teaching note 3:  You can either let students discover a reputable online reference for lab values, or provide one.  I use ARUP Laboratories, http://www.aruplab.com.

The relationship between hypocalcemia and muscle spasms is not straightforward, so plan a mini-lecture on the role of calcium in opening sodium channels in the sarcolemma.

Teaching note 4: Answers should include normal negative feedback and homeostatic mechanisms, along with emphasis on the lack of homeostatic control in a case such as this.  The continued on next page
homeostatic imbalance that is created prevents normal feedback mechanisms from operating. You can opt to provide a mini-lecture on the relationship between vitamin D and calcitriol, and/or vitamin D and PTH.

Teaching note 5: Graph:
Each data point is a monthly blood test. The first point for each value is before treatment; the last are after six months of treatment with PTH supplement. Students might need guidance on plotting three values, with different units, within the same graph.

See answer key for sample graph.

Test Questions:
1. Multiple Choice: Which of the following imbalances is related to carpopedal spasm?
   a. calcium level is too low
   b. calcium level is too high
   c. sodium level is too low
   d. sodium level is too high
   e. potassium level is too low.

2. True – False: As PTH level increases, blood calcium level decreases.

3. Explain the anatomy behind the term “carpopedal” in the condition known as carpopedal spasm.

4. Predict the effect of supplementing vitamin D on a 10YO patient’s blood calcium level, given that the current vitamin D value is 17 ng/mL and blood calcium level is 7.3 mg/dL. Use the reference table provided below. Be sure to explain the relationship between vitamin D and blood calcium concentration in your answer.

<table>
<thead>
<tr>
<th>Vitamin D Reference Interval: 0-17 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deficiency: Less than 20 ng/mL</td>
</tr>
<tr>
<td>Optimum level: Greater than or equal to 20 ng/mL*</td>
</tr>
<tr>
<td>18 years and older</td>
</tr>
<tr>
<td>Deficiency: Less than 20 ng/mL</td>
</tr>
<tr>
<td>Insufficiency: 20-29 ng/mL</td>
</tr>
<tr>
<td>Optimum Level: 30-80 ng/mL</td>
</tr>
<tr>
<td>Possible Toxicity: Greater than 150 ng/mL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calcium Reference Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 years: 8.4-10.2 mg/dL</td>
</tr>
<tr>
<td>7-17 years: 8.5-10.7 mg/dL</td>
</tr>
<tr>
<td>18 years and older: 8.4-10.2 mg/dL</td>
</tr>
</tbody>
</table>


Literature cited


About the Author
Betsy Ott is a professor in the Life Sciences Department at Tyler Junior College in Tyler, Texas, where she is the lead professor in Anatomy and Physiology. She has been an active member of HAPS since 1991, serving as president in 2015-16 and hosting a regional conference in 2017. This case study on homeostasis was completed as part of the HAPS Institute course, Writing Case Studies for Teaching Anatomy and Physiology: Pathophysiology and Physiology, offered in 2016 by Dr. Brian Shmaefsky.

Student Materials
Print the next three pages. To make this an interrupted case study, hand out one page at a time, discussing the information on each page before handing out the next one.
**A CASE OF TENSE TOES ACTIVITY**

Part I

Austin is an active 4th grader who lives with his parents, Jenny and Brad. Austin has been having trouble lately with getting ready for school in the morning. The problem came to a head when Austin missed the school bus because he did not have his shoes on yet. Jenny decided to step in, supervising Austin putting on his shoes. “Come on, Austin. You can’t get your shoe on without bending your ankle!”

“I know, Mom! I told you I was having trouble! My foot won’t bend sometimes.” Jenny was surprised to see that Austin looked ready to cry, and sat on the floor to help. She pulled her son into her lap and picked up the shoe. Cradling his foot in her hand, she was more surprised to find it was tensed up - even the toes!

Checking his other foot revealed the same problem. Jenny tried massaging Austin’s feet, while calling to her husband. When Brad came in, he asked Austin, “What’s going on, Buddy? Does it hurt?”

Austin answered, “No, but sometimes my feet do this. And sometimes my hands do, too.”

**Question 1.** While Brad calls the pediatrician, Jenny phones her best friend - YOU. As a pre-nursing student, she knows you can help her understand what is up with Austin. Jenny tells you that Austin’s muscles were tense – you suggest the word “contraction” to help her explain what is going on. A quick Internet search will help Brad and Jenny understand what might be the problem. What search terms might you use? What information turns up when you search?

Brad and Jenny took Austin to the pediatrician, Dr. James, who listened to their description carefully, performed a brief physical exam, and then ordered blood tests. Some of the questions Dr. James asked had to do with Austin’s diet and interests. He seemed glad to hear that Austin plays outside every day and had stable friendships with no problems at school. Jenny assured Dr. James that Austin eats well and that she and Brad make a point of cooking at home most nights. They have Austin try different foods and make sure he eats a balanced diet. Dr. James suggested giving Austin extra time to get ready for school in the morning by getting him up a little earlier, so he does not feel stressed or rushed. He assured Jenny and Brad that he would call them when the test results come in.

Jenny calls you with an update, along with a few questions. She is worried that something serious is causing Austin’s problem and wonders what might cause muscle spasms. She asked what playing outdoors and eating a balanced diet might mean. Since you have been reading up on this after her first phone call, you have some ideas that include possible vitamin and mineral deficiencies. How will you explain to Jenny about the role of minerals in muscle contraction? What hormones control those minerals, and what vitamins are involved? How does playing outdoors figure in?

**Question 2.** An imbalance of what ions might result in muscle spasms? If dietary intake is adequate, what could cause the ions to be out of balance?
Part 2

A few days later, Dr. James called Jenny and Brad. “Austin’s blood work shows a couple of problems that might help explain his spasms. I’m posting his lab results in our patient web portal. Let’s set up an appointment for you to come in and discuss what this means.”

Here are the results of Austin’s blood work:

- Serum Na+ [140 mEq/L]
- Serum K+ [4.2 mEq/L]
- Serum Ca++ [7.3 mg/dL]
- Aldosterone [10 ng/dL]
- PTH [8 pg/mL]
- Vitamin D [17 ng/dL]

Jenny asks you to come over and review the results, and you make sure to bring your laptop, so you can look up any information that you need.

**Question 3. Answer the following questions:**

a. What values in Austin’s blood work are out of the normal range? Are they too high, or too low?

b. Why does hypocalcemia cause muscle spasms?

c. What is a medical ultrasound? How does it work?

d. What structures in the neck might be under suspicion as a cause?

A few days later, Jenny and Brad are with Dr. James to discuss the lab results. “Austin’s parathyroid hormone level, called PTH, is low. In children, this is usually just something that is in the genes. It doesn’t always show up, even in adults with low PTH.”

Brad asks, “What are the treatment options?” Dr. James replies, “There is a new treatment that involves a partial replacement of the PTH, but it is not in wide use yet. For now, we will supplement calcium and vitamin D, and carefully monitor Austin’s levels to make sure they don’t go too high. In the future, the PTH replacement will probably give a better long-term outcome.”

Jenny asks, “What does vitamin D have to do with all this? I remember that his Vitamin D level was low, along with the PTH and calcium.”

**Question 4. How would you explain the relationship between PTH, vitamin D, and calcium to Jenny and Brad? Draw a diagram as part of your answer.”**
Part 3
The follow-up six months later shows that Austin’s blood calcium concentration and vitamin D level are within the normal range. Jenny has taken him in for monthly blood tests during this time; the data table below shows seven months (one pretreatment, and six treatments with calcium and vitamin D supplements).

<table>
<thead>
<tr>
<th>Months of</th>
<th>PTH, pg/mL</th>
<th>Vit D, ng/dL</th>
<th>Ca++, mg/dL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>17</td>
<td>7.3</td>
</tr>
<tr>
<td>1</td>
<td>11.5</td>
<td>19.7</td>
<td>7.5</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>21.4</td>
<td>7.9</td>
</tr>
<tr>
<td>3</td>
<td>15.3</td>
<td>28.8</td>
<td>8.2</td>
</tr>
<tr>
<td>4</td>
<td>17.3</td>
<td>33.4</td>
<td>8.9</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>30.3</td>
<td>8.5</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>35.6</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Question 5. To get a better understanding of the effect of PTH supplementation, graph the data on a single table, with time on the X-axis and three Y-axes overlapping, so that the values of PTH, Vitamin D, and calcium will be compared easily.
Final Questions

1. Explain whether or not the data at the end of six months indicate that Austin’s blood levels of PTH, vitamin D, and calcium have reached normal levels.

2. Explain the relationship between vitamin D and calcitriol, and between calcitriol and PTH.

3. Given that the underlying cause of Austin’s condition was a genetic problem, explain why he will need medical regulation of calcium for the rest of his life.
Application of Homeostasis Feedback Mechanism Terms Using Mini-Cases

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Abstract
Application of information leads to a deeper understanding of concepts than memorization. Case studies have been shown to be effective in helping students reach a deeper level of understanding but they are difficult to implement in content-heavy courses such as anatomy and physiology. As a result, I have experimented with developing mini-cases for use in my Anatomy and Physiology courses. These activities allow students to apply required content to specific real-life biological or medical situations, but take up only a small portion of the class time, so they can be utilized in conjunction with lecture and/or with other types of active learning exercises. The particular mini-cases in this activity are used in my Anatomy and Physiology I class. It allows students to analyze two examples of homeostatic feedback mechanisms (one positive and one negative) to identify the components of each. This activity is completed on the first day of class and it provides a framework for thinking about homeostasis that we revisit throughout the remainder of the Anatomy and Physiology sequence. doi: 10.21692/haps.2017.033

Key words: case study, homeostasis, negative feedback, positive feedback, active learning, anatomy and physiology

Target Audience: This activity is intended for Anatomy and Physiology I students. It is designed to be done on the first day of class.

Learning Outcomes:
HAPS
Module B:
LO2  General types of homeostatic mechanism
LOs 2, 3  Examples of homeostatic mechanism

Learning Outcomes that are not included HAPS
Learning Outcomes:
Application of terminology associated with homeostasis to real-life feedback situations.
Enhancing critical reading and critical analysis/thinking skills.

Prior Knowledge: Students should know the definition of homeostasis, negative feedback, and positive feedback. They should know the structure of homeostatic feedback mechanisms and the definitions of each of the mechanism components.

Time Required: 25-30 minutes (two to three minutes of introduction, 15-20 minutes for student working time, and eight-ten minutes to go over the answers).

About the Author
Shelly Paradies is a Professor in the Biology Department who has been employed at SUNY Orange for 18 years. In addition to teaching Anatomy and Physiology, she has developed and taught Neurobiology lecture and lab as well as a challenging Honors Biology for Today course. Shelly currently serves as a member of SUNY Orange’s Honors Advisory Board and as vice-president of its Shared Governance system. An avid gardener, Shelly initiated an Educational Garden Project that has transformed several green spaces on campus into native habitat gardens. She is also a member of the Board of Directors of her local YMCA.

Lesson Overview: Students often say that they “know” or “understand” what terms mean, but the extent of this knowledge or understanding is typically superficial. They can memorize a definition and give it back for an exam, but until they apply the terms and integrate the definitions into a functional situation, they will not have developed or started to develop true knowledge or understanding.

This set of exercises is designed to help students gain a better understanding of the terminology associated with homeostasis, one of the most important concepts in anatomy and physiology, and one which is integrated into the very fabric of how the human body works. Students are presented with written descriptions of functioning homeostatic control mechanisms presented as short case studies, or mini-cases. The short length of this exercise allows it to be effectively integrated into a class without taking up the entire class

continued on next page
period. Working in pairs or small groups of three or four, the students critically read each mini-case, then answer the questions or complete the statements that follow. These questions/statements are designed to make students apply the definitions of the mechanism components to an actual feedback situation and guide students in identifying the individual components of the feedback mechanism.

Once the students are finished or after a defined time has elapsed, the instructor should go over the exercise with the students. During this portion of the activity, the definitions of the mechanism components are reviewed in the context of the information in the mini-cases, reinforcing them and the roles of both negative and positive feedback.

Because two sets of mini-cases are provided, one can be used in class and the other assigned for homework or provided for extra practice outside of class.
APPLICATION OF HOMEOSTASIS FEEDBACK MECHANISM ACTIVITIES

Homeostasis Cases, Set A

Read through each case. Fill in the blanks/spaces below based on the content of the cases.

Case #1: A woman is breastfeeding her baby. The suckling of the infant at the breast activates receptors in the nipple. Sensory fibers carry signals from these receptors to the hypothalamus/posterior pituitary. This stimulates release of the hormone oxytocin from the hypothalamus/posterior pituitary of this woman's brain. The oxytocin stimulates smooth muscle fibers in the ducts of the breast to contract, squeezing milk into the infant's mouth. The baby nurses more strongly, stimulated by the release of the milk. The oxytocin release and breast stimulation continues for the entire time the infant is nursing.

1. What is the stimulus of this control loop? ______________
2. What is the control center? _________________________
3. What is the effector? _____________________________
4. Oxytocin is playing the role of (receptor / afferent pathway / efferent pathway) in this control mechanism. (Circle one of the terms in bold.)
5. This is an example of ___ (positive/negative) feedback. How can you tell?

Case #2: On a particularly busy day, a student taking Anatomy and Physiology I does not have anything to drink from 9:30 am until 6:30 pm. Osmoreceptors in the brain detect the decreased level of water in the blood. These receptors send a signal to the hypothalamus/posterior pituitary, which stimulates the release of antidiuretic hormone (ADH). This hormone acts on the nephron tubules and collecting ducts in the kidney to increase reabsorption of water, which returns that water to the blood. This retention of water has the additional effect of decreasing urinary output. As the fluid levels in the blood stabilize, the release of ADH ends.

1. What is the variable monitored by this loop? ___________
2. What is the stimulus? _____________________________
3. What is the control center? _________________________
4. What is the effector? ______________________________
5. What is the efferent pathway? _______________________
6. This is an example of ___ (positive / negative) feedback. How could you tell?

Homeostasis Cases, Set B

Read through each case. Fill in the blanks/spaces below based on the content of the cases.

Case #1: Your stomach starts grumbling during your Anatomy and Physiology lecture. As soon as class is over, you decide to hit the snack area. You see your favorite candy bar in one of the snack machines and you cannot resist. Your blood glucose level before eating this snack is 90mg/100ml (normal). As you digest and then absorb the sugar in the candy, the level of glucose in your blood increases to 120mg/100ml. The increased level of glucose is detected by receptors on pancreatic beta cells. These receptors send a signal into the beta cells, informing them of the excessive glucose in the blood. The pancreatic beta cells release insulin. The insulin travels through the blood and stimulates the liver and body cells. The liver and body cells remove the extra glucose from the blood, reducing your blood glucose back to its original level of 90mg/100ml. At this point, release of insulin stops.

1. What is the stimulus of this control loop? ______________
2. What is the control center? _________________________
3. What is the effector? ______________________________
4. In this feedback mechanism, insulin is acting as the (receptor / afferent pathway / efferent pathway). (Circle one of the terms in bold.)
5. This is an example of ___ (positive / negative) feedback. How could you tell?

continued on next page
**Case #2:** A woman is in labor. The size of the fetus combined with the contractions of the uterine muscular layer stretches the uterine wall, stimulating stretch receptors in the cervix. Signals from these receptors are conducted through nerves to the hypothalamus/posterior pituitary. The hypothalamus/posterior pituitary releases oxytocin. The oxytocin travels through the blood and stimulates the smooth muscle layer of the uterus. Oxytocin has two effects on the uterine smooth muscle:

1. It directly stimulates the smooth muscle to contract more frequently and more forcefully.
2. It causes the uterine wall to release prostaglandins, which increase the frequency and force of the contractions even more.

These effects push the fetus more forcefully into the cervix, stimulating the stretch receptors further. The receptors send additional impulses to the hypothalamus/posterior pituitary. The increased activation of the hypothalamus/posterior pituitary stimulates release of additional oxytocin, which further stimulates the uterus. This cycle of activation continues until the fetus is expelled from the uterus.

1. What is the stimulus of this control loop? ______________
2. What is the control center? _________________________
3. What is the effector? ______________________________
4. This is an example of ___ (positive / negative) feedback. How could you tell?
Bioengineering a Heart

Holly Basta PhD1, Sheela Vemu PhD2, Kate Baldwin PhD3

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Abstract

In this classroom activity, students "design" a heart using 3D printed tissues. They evaluated data and predict how their heart might respond to various hormones. They predict how they might get it to start beating and troubleshoot issues that may arise once it is transplanted. This activity is intended to allow students to reflect upon and apply knowledge gained from previous modules, including tissue types, neuron function, sympathetic and parasympathetic nervous system, hormones, and cardiac function and regulation. This activity can be implemented in a lecture or lab setting and takes approximately 30 minutes. doi: 10.21692/haps.2017.034

Key words: heart, cardiovascular, endocrine, nervous, tissues, graphing

This activity was conceived at the Quantitative Undergraduate Biology Education and Synthesis (QUBES) meeting in 2016, where Sheela and Holly participated as a part of the HHMI Faculty Mentoring Network.

Target Audience: Undergraduate or early-career graduate physiology students.

Content Objectives/Learning Goals

Students will be able to…

Integrate knowledge from four different subjects (tissues, nervous system, endocrine system and cardiovascular system) and apply it to a novel case.

Synthesize a plan to test cardiac functionality based on knowledge of cardiac function.

Infer the relationship between blood pressure, heart rate and hormone levels.

Graph real-world data and draw appropriate conclusions.

Align knowledge of microscopic structures (cell, hormones, receptors, etc.) with knowledge of macroscopic structures (heart, nerves).

HAPS objectives:

A.5.2: Give specific examples to show the interrelationship between anatomy and physiology.

B.4.1: Provide specific examples to demonstrate how organ systems respond to maintain homeostasis.

D.3.2: Describe locations in the body where each type of connective tissue can be found.

D.4.1: Classify the different types of muscle tissues based on distinguishing structural characteristics and location in the body.

D.4.2: Describe functions of each type of muscle tissue in the human body and correlate function with structure for each tissue type.

D.5.1: Describe locations in the body where nervous tissue can be found.

G.2.2: Describe the structure, location in the body and function of skeletal, cardiac and smooth muscle.

H.13.2: Contrast the anatomy of the parasympathetic and sympathetic systems, including central nervous system outflow locations, ganglia locations, pre- and post-ganglionic neuron relative lengths, and ganglionic and effector neurotransmitters.

H.13.9: Describe major parasympathetic and/or sympathetic physiological effects on target organs.

J.5.c: Name the target tissue or cells for the hormone and describe the effect(s) of the hormone on the target tissue or cells.

K.6.6: Identify myocardium and describe its histological structure, including the significance of intercalated discs.

K.7.2: Contrast the way action potentials are generated in cardiac pacemaker cells, in cardiac contractile cells and in skeletal muscle cells.

K.7.3: Explain the significance of the plateau phase in the action potential of a cardiac contractile cell.

continued on next page
K.7.5: Compare and contrast the role of nerves in the depolarization of cardiac pacemaker cells, ventricular contractile cells, and skeletal muscle cells.

K.9.1a: List the parts of the conduction system and explain how the system functions.

K.9.1d: Describe the role of the autonomic nervous system in the regulation of cardiac function.

K.14.11c: Explain the role of the sympathetic nervous system in regulation of blood pressure and volume.

K.14.11d: Explain the role of hormones in regulation of blood pressure, including the mechanism by which specific hormones affect preload, heart rate, inotropic state or vascular resistance.

K.16.1: Predict factors or situations affecting the cardiovascular system that could disrupt homeostasis.

Prior Knowledge
The four tissue types, their structures, functions, and where they are found in the body.

The generation and propagation of action potentials in neurons.

The factors that influence blood pressure and blood pressure regulation.

The effects of sympathetic and parasympathetic responses on heart rate and blood pressure.

The electrical events involved in cardiac muscle contraction.

Time required: 20-30 minutes

Implementation Notes for Instructors: This activity is intended to allow students to reflect and apply knowledge gained from previous modules (tissues, nervous system, endocrine system and cardiovascular system), often spanning multiple semesters. Depending on where in your course this activity is implemented, students may need a refresher on some of the background information.

Small groups of two to three students tend to be most effective, with a sharing-out period at the end of the activity.

Literature cited


About the Authors
Holly Basta, PhD is an assistant professor at Rocky Mountain College, a four-year primarily undergraduate institution in Billings, MT. She teaches Human Anatomy and Physiology I and II, Virology, Cancer Biology, Immunology and Medical Careers Courses.

Sheela Vemu, PhD is an assistant professor at Waubonsee Community College in Sugar Grove, IL. Sheela teaches Anatomy and Physiology, Microbiology and Nutrition.

Kate Baldwin, PhD is a freelance scientific visual communicator and illustrator in Madison, WI.

continued on next page
BIOENGINEERING A HEART ACTIVITY

Three-dimensional (3D) printing can theoretically lay down any type of material (or multiple materials at a time) to generate a 3D structure (Figure 1). This technology has the capability to generate full organs that match the complexity of the real thing, opening a world of new possibilities. Imagine a hospital freed from the necessity of human and animal organ donors. These printed organs would not carry over infectious agents from a donor and could be structurally modified to fit each individual. For the heart, researchers have thus far successfully 3D printed functional blood vessels (watch: https://www.youtube.com/watch?v=4iKSrShvH8), beating heart cells, heart valves and muscle tissue. The human heart, however, still possesses multiple levels of complexity that have yet to be replicated. One such level of complexity is the ability of the heart to respond to chemical and electrical signals. Imagine the “fight-or-flight” response, in which heart rate, contractility, stroke volume, etc. increase to provide skeletal muscles with the necessary oxygen for peak performance.

Figure 1. A plastic heart model in the process of being 3D printed (thingiverse.com 2015).

Suppose you are a biomedical engineer trying to replicate a human heart...

1. What cell types would you need to load in your 3D printer?

2. Wouldn’t it be easier and cheaper to make a mechanical heart? What benefits would a biological heart have? Drawbacks?

3. Suppose your 3D printed heart is finished. How would you get it to start beating?

continued on next page
4. What neurotransmitters would you want to test on it before placing it in a human? How would you expect the heart to respond to each? What receptor types do each of these act upon?

5. Chart the effects of acetylcholine on the blood pressure in the left ventricle. Be sure to label your axes. (Data extrapolated from Dobson 1981).

<table>
<thead>
<tr>
<th>ACh Concentration (M)</th>
<th>Pressure (mm Hg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2763</td>
</tr>
<tr>
<td>0</td>
<td>2554</td>
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<tr>
<td>0</td>
<td>263</td>
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<td>2721</td>
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<td>0</td>
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<tr>
<td>1.00E-08</td>
<td>2646</td>
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<tr>
<td>1.00E-08</td>
<td>250</td>
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<tr>
<td>1.00E-08</td>
<td>2649</td>
</tr>
<tr>
<td>1.00E-08</td>
<td>2438</td>
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<td>2528</td>
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<td>1.00E-06</td>
<td>166</td>
</tr>
<tr>
<td>1.00E-06</td>
<td>1361</td>
</tr>
</tbody>
</table>
6. What conclusions can you make from these data?

7. Does ACh binding to its receptors bring about a parasympathetic or a sympathetic response? Does the data you’ve plotted support your answer?

8. How are cardiac muscle cells different from skeletal muscle cells?

9. How are cardiac cell action potentials different from neuron action potentials?

10. Now you know your heart is working, you want to put it into the body. You successfully connect the larger Vagus nerve, but are unsure if the Cardiac nerve is fully connected. How would you test the function of the Cardiac nerve when the person awoke (Figure 2)?

Figure 2. Nervous system control of the heart.
Cancer Immunotherapy

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Abstract
This inquiry-based activity allows students to explore cancer immunotherapy treatments. This deepens student understanding of both cancer and of immune system function. doi: 10.21692/haps.2017.035

Key words: cancer, immunotherapy, immunology, inquiry

Target Audience: College-level Pathophysiology, Immunology, or Introductory Anatomy and Physiology students.

Learning Outcomes:
After completing this activity, students should be able to describe the processes of checkpoint blockade and CAR-T (chimeric antigen receptor T cell) therapy and explain their relevance in cancer treatment.

HAPS:
L.3.1 Describe the roles of various types of leukocytes in innate and adaptive body defenses.
L.4.4 Distinguish among the various types of lymphocytes, including helper T cells, cytotoxic T cells, regulatory (or suppressor) T cells, B cells, plasma cells, and memory cells.
L.6.1 Describe the immunological memory (anamnestic) response.
L.9.2 Describe mechanisms of antibody action and correlate mechanisms with effector functions.
L.10.1 Describe natural and artificial examples of both active and passive immunity.
L.10.2 Provide examples of how applied immunology can be used to diagnose, treat and prevent diseases.
L.12.2 Predict the types of problems that would occur in the body if the lymphatic and immune systems could not maintain homeostasis.

Instructor observations: Because of personal experience or the experience of a loved one, many students find the study of cancer particularly interesting and relevant. Recent developments in cancer immunotherapy have resulted in novel approaches to cancer treatment with which few students are familiar. This guided inquiry activity allows students to take what they know about the immune system and apply that knowledge to specific cancer treatment modalities, deepening their understanding of both cancer treatment and the immune system.

The questions that follow the models compel the student to look closely at the models to understand the processes shown. While working through the activity, students construct their own knowledge of cancer immunotherapy. The Extension Questions give students the opportunity to take what they have learned and apply it to a broader context.

Guidelines for Classroom Implementation: Divide the class into learning teams of three or four students each. Students should examine the models carefully to answer the questions about checkpoint blockade and adoptive cell transfer. The instructor’s role is to facilitate rather than to provide content knowledge or to answer student questions. Instructors guide the students in determining the answers on their own by using the information in the models. After examining the models and discussing the subsequent questions with their team members, students should develop a working knowledge of the methods and rationales for these two types of cancer treatment.

In an Anatomy and Physiology or Physiology course, this activity can be used after covering the immune system to give students the opportunity to apply the knowledge to specific applications. It can be used in a Pathophysiology class to give students a solid understanding of immunotherapy-based cancer treatment modalities.

The Extension Questions are not integral to the activity. Selected Extension Questions can be omitted at the instructor’s discretion depending on student background and interest.

Prior knowledge: Students should be familiar with the function of T cells; the structure and function of antibodies; the role of antigens in the immune system; the role of receptors in immune function; and the role of the immune system in distinguishing self from non-self.

Time Required: 30 to 45 minutes
Background information:
The checkpoint blockade model shows an antibody binding to PD-1. Antibodies that bind to PDL-1 have also been developed and have the same effect.

In normal cells, PD-1 and PDL-1 both play a role in downregulating immune function and promotion of self-tolerance, thus reducing autoimmunity and suppressing immune response to the fetus in pregnancy.

Both therapies can result in autoimmune responses. In checkpoint blockade this occurs when antibodies also bind to healthy cells, targeting them for destruction. In CAR-T therapy, this occurs when the CAR-T cells bind to healthy cells and initiate an immune response.

About the Author
Karen Groh is an Assistant Professor at Good Samaritan College of Nursing and Health Science in Cincinnati, Ohio where she teaches Human Anatomy and Physiology and Pathophysiology.
CANCER IMMUNOTHERAPY ACTIVITY

Background: A patient’s own immune system can be used to fight cancer. Two methods of harnessing a patient’s immune system to fight cancer are checkpoint blockade and CAR-T (chimeric antigen receptor T cell) therapy. Checkpoint blockade is an FDA approved therapy for metastatic melanoma, lung cancer, and urothelial (bladder) cancer. CAR-T therapy is FDA approved for B cell acute lymphoblastic leukemia. Both of these methods are in clinical trials; half of all current clinical trials in cancer treatment involve some form of immune therapy.

Model 1

No Treatment

With Checkpoint Blockade

Binding inhibits T-cell activity
Key to Image

<table>
<thead>
<tr>
<th>Immune System Component</th>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T cell</td>
<td><img src="image" alt="T cell" /></td>
<td>Immune cell</td>
</tr>
<tr>
<td>Cancer Cell</td>
<td><img src="image" alt="Cancer cell" /></td>
<td>Cancer cell</td>
</tr>
<tr>
<td>PD1</td>
<td><img src="image" alt="PD1" /></td>
<td>Receptor on T cell</td>
</tr>
<tr>
<td>T cell receptor</td>
<td><img src="image" alt="T cell receptor" /></td>
<td>Receptor on T cell that binds to MHC</td>
</tr>
<tr>
<td>PDL1</td>
<td><img src="image" alt="PDL1" /></td>
<td>Protein on cancer cell</td>
</tr>
<tr>
<td>MHC (major histocompatibility complex)</td>
<td><img src="image" alt="MHC" /></td>
<td>Protein on cancer cell that presents antigens to T cell</td>
</tr>
<tr>
<td>Cancer antigen</td>
<td><img src="image" alt="Cancer antigen" /></td>
<td>Fragment of protein associated with cancer</td>
</tr>
<tr>
<td>Antibody</td>
<td><img src="image" alt="Antibody" /></td>
<td>Y shaped protein, neutralizes pathogens</td>
</tr>
</tbody>
</table>

1. Label the immune system components on Model 1.

2. What type of immune cell is utilized in checkpoint blockade?

3. What two receptors are found on the immune cell?

4. What are the two cell surface proteins on the cancer cell?

5. What is the role of the MHC protein on the cancer cell?
6. Describe the binding of the T cell to the cancer cell without checkpoint blockade treatment.

7. What effect does binding of PDL1 to PD1 have?

8. What do the antibodies bind to?

9. When the antibodies are present, can PD1 bind to PDL1?

10. How will the presence of the antibodies used in checkpoint blockade treatment affect T cell activity? How will this affect the T cell's ability to destroy the cancer cell?

11. List the steps of checkpoint blockade treatment.
Chimeric Antigen Receptor T Cell (CAR-T) Therapy

CARs are genetically engineered T cell receptors created to allow T cells to recognize and bind to specific antigens.

Model 2

Chimeric Antigen Receptor T Cell (CAR-T) Therapy

CARs are genetically engineered T cell receptors created to allow T cells to recognize and bind to specific antigens.

Model 2

Key to Image

<table>
<thead>
<tr>
<th>Immune System Component</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>T cell</td>
<td>O</td>
</tr>
<tr>
<td>CAR (chimeric antigen receptor, not the same as PD1 from Model 1)</td>
<td>♂♀</td>
</tr>
<tr>
<td>Cancer cell</td>
<td>Cloud</td>
</tr>
<tr>
<td>Protein expressed on cancer cell</td>
<td>♂♀</td>
</tr>
</tbody>
</table>
12. Where do the T cells for CAR-T come from?

13. What is added to the T cells after they are removed from the patient?

14. What happens to the T cells after CAR is added?

15. How does adding CAR to the T cells affect their ability to fight cancer?

16. Summarize the steps of CAR-T cell therapy.
Extension Questions

1. How are checkpoint blockade therapy and CAR-T therapy similar?

2. How are checkpoint blockade therapy and CAR-T therapy different?

3. Compare the way that T cells multiply in a normal immune response with how they multiply in CAR-T.

4. How do you suppose the antibodies used in checkpoint blockade are produced? How might they be delivered to the patient?

5. Multiplication of the T cells after adding the CAR produces new T cells that also have CAR. Explain how this occurs.

6. List two or three non-cancer fighting effects would you expect from checkpoint blockade therapy.

7. List two or three non-cancer fighting effects you would expect from CAR-T therapy.

8. What interventions might help to keep these side effects under control?
9. What effect will CAR-T therapy have on long-term cancer fighting ability? (Hint: Will all the T cells be destroyed immediately after therapy?)

10. How is immunotherapy fundamentally different from other forms of cancer therapy such as chemotherapy, radiation, and surgery?

11. Do you think the side effects of these therapies are better or worse than those for other forms of cancer therapy?
Electric Communication: Part I

Kerry Hull, PhD
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khull@ubishops.ca

Abstract
This inquiry-based activity introduces students to graded potentials and action potentials. A separate activity (Electric Communication, Part 2) discusses voltage-gated sodium and potassium channels in greater detail. doi: 10.21692/haps.2017.036

Key words: neurophysiology; graded potential; action potential; membrane potential; electric communication

Target Audience: I have used this activity in a 3rd year intermediate physiology course, but it could also be used in introductory level courses.

Learning Outcomes:
HAPS: H4 (Neurophysiology)
Process skills: Graph interpretation
Core Concepts: Levels of organization: Students relate changes in channel shape (molecular level) to cellular changes (membrane potential) to organismal events (perception of sensory stimuli). Homeostasis: Model 4 addresses sensors and signals involved in the regulation of blood pressure.

Prior Knowledge: Students should have a basic understanding of the components of negative feedback loops, especially sensors and signals.

Time required: 50 minutes

Instructor observations: Model 4 is the most challenging, because the action potentials and graded potentials in this model do not look the same as those in Models 2 and 3. While completing this model, students often realize for the first time that graded potentials really can differ in magnitude and direction. If students do not recognize the traces in the bottom graph as action potentials, remind them to compare the time scale in Model 3 with that in Model 4.

About the Author
Kerry Hull, PhD teaches anatomy, physiology, advanced physiology, and exercise physiology in the Department of Biology at Bishop's University in Sherbrooke, Quebec.

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ELECTRIC COMMUNICATION: PART 1

WHY: Imagine that you have two pets: a new kitten and a giant Bernese mountain dog. If one of them steps on your foot, you know which one, even with your eyes closed. Why? Because we can distinguish the strength of sensory inputs. This activity is an introduction to how electric signals are created and conveyed down neurons.

Model 1 – Membrane Potential and Electric Gradients

**Questions**

1. Look at the figure. Does the inside of the cell contain an excess of negative ions (anions) or an excess of positive ions (cations)?
   
   Hint: Excess ions accumulate at the membrane.

2. For clarity, it is easier to ignore the paired ions and only consider the unpaired ions, as shown in the right-hand figure. The electric gradient created by these unpaired ions is known as the membrane potential. The membrane potential of this cell is 
   “-25 millivolts (mV)”. Based on the model, is membrane potential measured in the intracellular fluid or in the extracellular fluid?

3. Compare three cells, with different membrane potentials:  
   - Cell #1: -70 mV  
   - Cell #2: +50 mV  
   - Cell #3: +60 mV
   
   a. In which cell is the electric gradient strongest?

   b. Which cell(s) has an excess of positive ions in the cytoplasm?

   c. Which cell(s) has an excess of positive ions in the extracellular fluid?

4. In one or two sentences, explain the difference between a membrane potential of -70 mV and a membrane potential of +60 mV in terms of the strength of the electric gradient and distribution of unpaired ions.
Model 2: Changes in Membrane Potential

Neurons use changes in membrane potential as communication signals.

5. What is the resting membrane potential value in this neuron? Be sure to use the correct units.

6. The letters in Model 2 indicate specific time points.
   a. What is the membrane potential at point c?
   b. What is the membrane potential at point f?

7. **Depolarization** and **hyperpolarization** describe changes in membrane potential away from the resting value. Referring to your answers in questions 5 and 6, describe the change in membrane potential during the depolarization and the hyperpolarization in Model 2. Did the membrane potential become more or less polarized?

   **Depolarization:**

   **Hyperpolarization:**

8. Complete the following sentence, based on Model 2: **Repolarization** describes a change in membrane potential towards / away (circle one) from the resting value.
9. Based on the model, determine if the following membrane values are depolarized, hyperpolarized, or at rest.
   a. 0 mV = **depolarized**
   b. -100 mV =
   c. -75 mV =
   d. -70 mV =

10. **Polarization** refers to the uneven separation of the charges (anions and cations) across the plasma membrane. Using your knowledge of medical terminology, first discuss the meaning of depolarization, repolarization and hyperpolarization, and then write a grammatically complete sentence to define each alteration:

11. A **graded potential** is a change in membrane charge (potential) that can vary in size and duration, and can involve either depolarizing or hyperpolarizing membrane events. Graded potentials are used to convey signals throughout dendrites and the cell body, and to indicate the magnitude of stimulation in sensory receptor organs.
   a. Calculate the magnitude (i.e. change from resting membrane potential) of the two graded potentials illustrated in Model 2. Show the math equation used.

      **Depolarizing graded potential:**

      **Hyperpolarizing graded potential:**

   b. Do both graded potentials have the same time duration? If not, which is longer and which is shorter in length?

12. Graded potentials result from the opening or closing of ion channels, because channels control the movement of ions across the plasma membrane. These channels open or close in response to a specific stimulus, such as a neurotransmitter, an intracellular messenger, or distention (stretch) of the neuronal membrane. For instance, if potassium channels close, fewer potassium ions leave the cell, and the cell depolarizes. Classify these changes as resulting in depolarization (D) or hyperpolarization (H) in a cell that was previously at rest, and defend your answers. (Note: The sodium concentration is higher outside the neuron than inside the neuron, but the potassium concentration is higher inside the neuron than outside the neuron.)
   a. Na+ channels open, permitting Na+ entry
   b. K+ channels open, permitting K+ exit
   c. Cl- channels open, permitting Cl- entry
   d. Ca2+ channels open, permitting Ca2+ entry

   continued on next page
Model 3 – Action Potential
Model 3 shows how the membrane potential changes over time during an action potential, a type of electrical signal used by neurons to transmit signals over long distances, such as from your toe to your brain. Action potentials travel along the axon to the axon terminal to stimulate neurotransmitter release.

13. There are four phases in the action potential shown in Model 3. Label these phases resting, rising phase, falling phase, and hyperpolarization.

14. How does the voltage change (if at all) during each phase of the action potential?
   Resting =
   Rising Phase =
   Falling Phase =
   Hyperpolarization =

15. The protein channels involved in action potentials are different from those involved in graded potentials. Action potential channels open and close in response to changes in membrane potential. Since membrane potential is measured in volts, these channels are known as voltage-gated channels. When voltage-gated sodium channels open, sodium ions enter the cell. When voltage-gated potassium channels open, potassium ions leave the cell. Referring to your answers to question 14, predict if these Na and K voltage-gated ion-channels are open or closed in each phase.

<table>
<thead>
<tr>
<th>Action Potential Phase</th>
<th>Sodium (Na⁺)</th>
<th>Potassium (K⁺)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Resting</td>
<td>closed</td>
<td>closed</td>
</tr>
<tr>
<td>2 Rising Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Falling Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Hyperpolarization</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
16. Examine Model 3. What must be reached in order to initiate an action potential (be specific)?

What happens to the membrane potential if it is not reached?

17. While graded potentials can vary considerably, all action potentials look very similar to each other. Do you think the phrase “all or none” refers to graded potentials or action potentials?

As a group, write a grammatically correct sentence(s) to explain what is meant by the phrase “all or none”.

18. Some textbooks use the term “depolarization” to describe the rising phase. Using your knowledge of medical terminology, explain why “depolarization” is not the most accurate term to describe this phase. (Hint: look at the voltage level at the peak of the action potential).
Model 4: Graded and Action Potentials Work Together To Convey Sensory Information

Specialized neurons called baroreceptors detect changes in blood pressure and convey this information to the brain. The dendrites of these neurons are embedded in the artery wall, which stretches in response to increased pressure, and the axons extend to the brainstem. In the event illustrated in this model, investigators changed the pressure in an artery (Graph 1), and measured the membrane potential in the dendrites (Graph 2) and in the axons (Graph 3) of the sensory neurons. Two trials were run. Data for the two trials are superimposed in Graphs 1 and 2, but separated in Graph 3.

19. Using information in Model 4, write a title for each graph on the line provided.

20. What was the maximum arterial pressure attained in each trial?
   Trial 1 ______
   Trial 2 ______

21. In the middle graph, what differs between the two trials?

22. Does the middle graph illustrate graded potentials or action potentials? Explain.

23. Examine the bottom graph. What differs between the two trials?

24. Does the bottom graph illustrate graded potentials or action potentials? Explain.
25. Based on your answers to this model, write one or two complete sentences comparing how action potentials and graded potentials can convey signals of differing intensity.

Extension Questions
26. Examine the action and graded potentials in Models 2, 3, and 4.
   How are graded and action potentials similar?

   How are graded and action potentials different?

27. Sensory receptors measure a particular variable (e.g. blood pressure) and vary the action potential frequency in order to indicate the level (magnitude, intensity) of that variable. The neurons involved in sensing blood pressure contain stretch-activated Ca²⁺ channels in their dendrites. Based on Model 4, predict as to how these channels, graded potentials, and action potentials enable these neurons to act as sensory receptors for blood pressure.

28. Look back at the Why at the beginning of this activity. Touch is also detected by stretch sensory receptors. Based on what you learned in this model, speculate about how graded and action potentials can convey information that lets you distinguish between the paws of a kitten and a giant dog.
Electric Communication: Part 2

Kerry Hull, PhD
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Abstract
This inquiry-based activity focuses on the voltage-gated sodium and potassium channels involved in action potentials. It is intended to follow Electric Communication Part 1, which introduces graded and action potentials. doi: 10.21692/haps.2017.037

Key words: voltage-gated sodium channel, voltage-gated potassium channel

Target Audience: I have used this activity in a 3rd year intermediate physiology course, but it could also be used in introductory level courses.

Learning Outcomes:
HAPS: H4 (Neurophysiology)
Process skills: Graph interpretation
Core Concepts: Homeostasis: In Model 2, students apply concepts of negative and positive feedback to the regulation of sodium and potassium channels. Flux and gradients: Students relate gradients to ion movement.

Prior Knowledge: Students should have a basic understanding of membrane potential, electrochemical gradients, and the topics covered in “Electric Communication Part 1 (Models 1, 2 and 3). They should also understand the components of feedback loops and the difference between positive and negative feedback.

Time required: 60-80 minutes

Instructor observations: Model 2 helps students understand that sodium channels cannot convert from the inactivated state into the open state without passing through the closed state. Model 3 is the most challenging, and could be omitted for introductory level students. Students may have difficulties relating the different tracings to the two different axes, and sometimes struggle with expressing permeability in relative terms. Instructors may want to pause after question 21 to ensure that students are reading the graph correctly.

About the Author
Kerry Hull, PhD teaches anatomy, physiology, advanced physiology, and exercise physiology in the Department of Biology at Bishop’s University in Sherbrooke, Quebec.
ELECTRIC COMMUNICATION: PART 2

Action potentials are weird and wonderful. They can travel great distances and, thankfully, generally travel in only one direction. This problem set investigates the special features of action potentials in greater detail.

Model 1: Voltage-Gated Sodium and Potassium Channels

The rapid and reproducible membrane potential changes of the action potential reflect the special characteristics of the two types of channels shown in this model.

1. Which type of gate is found in both the Na\(^+\) and the K\(^+\) channels?

2. Which type of gate is found only in the Na\(^+\) channel?

3. A gate is open if it does not obstruct ion movement, and closed if it does obstruct ion movement. Model 1 illustrates the Na\(^+\) channel in its **closed state**. In this state, is the inactivation gate open or closed? What about the activation gate?

4. Gates open or close when part of the channel protein changes shape. In the space below, draw what the Na\(^+\) channel might look like in these states:

<table>
<thead>
<tr>
<th><strong>Open state</strong></th>
<th><strong>Inactivated state</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(with both gates open)</td>
<td>(activation gate open, inactivation gate closed)</td>
</tr>
</tbody>
</table>
5. Questions 3 and 4 describe the possible states of the voltage-gated Na+ channel. Fill in the following table summarizing the characteristics of these three states.

<table>
<thead>
<tr>
<th>State</th>
<th>Activation Gate</th>
<th>Inactivation Gate</th>
<th>Sodium Permeability?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed</td>
<td>Closed</td>
<td>Open</td>
<td>no</td>
</tr>
<tr>
<td>Open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inactivated</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. How many states are possible for the voltage-gated K+ channel? Describe each state.

Model 2: Voltage-Gated Sodium Channels and the Action Potential
Model 1 described the different states of the voltage-gated sodium and potassium channels. This model presents the stimuli that cause each channel to change its state. The table you created in Question 5 will be very useful as you answer the questions below.

7. The activation gate opens in response to the same **stimulus** in both Na+ and K+ channels. What is the stimulus?

8. Write a sentence explaining what causes the Na+ channel to transition from the open state to the inactivated state.

9. What happens to the gates when the Na+ channel transitions from the inactivated to the closed state, and what causes this change?

10. If a Na+ channel is inactivated, can additional depolarization cause it to open? Explain why or why not.

continued on next page
11. If the membrane remains depolarized for a significant length of time, which channel will remain open?

12. Describe the change in membrane potential in response to the opening of each channel type.

13. When the stimulus for opening occurs, the Na⁺ activation gate takes about 0.2 msec to open and the K⁺ activation gate takes about 0.5 msec to open.
   a. Based on your previous knowledge of the phases of the action potential, explain why this time difference is important.
   
   b. If both channels opened at the same time, would there be a change in membrane potential? Explain why or why not. (Hint: Think about electrochemical gradients).

14. “The ____ channel, once stimulated, is refractory to further stimulation until the membrane becomes repolarized and the channel resets itself.” Does this description refer to the Na⁺ channel or the K⁺ channel? Defend your answer, explaining the meaning of “refractory”.

15. Consider your answers to questions 7 and 12 in regards to the Na⁺ channel. Is the relationship between the stimulus and the response an example of positive feedback or negative feedback? Draw a feedback loop (including only the stimulus and the response) to illustrate your answer. (Hint: Not all channels open (or close) at once; each channel has a slightly different threshold.)

16. Repeat question 15 for the K⁺ channel. Manager: Ensure that a different group member identifies the stimulus and the response.

17. If you identified a positive feedback loop in question 15 or 16, what do you think causes the termination of the loop?
Model 3: Membrane Permeability

Model 3 shows the changes in membrane potential and ion permeability over the course of an action potential in a particular region of the neuron. Assume that the stimulus for the action potential occurred at time 0.

18. Trace over the action potential, Na⁺ permeability tracing, and K⁺ permeability tracing using three different colors of highlighters or felt pens. How long after the initial stimulus does the membrane potential return to its resting level?

19. This graph contains two Y-axes, one on the left and one on the right. Which axis is relevant to the action potential tracing, and which axis is relevant to the other two tracings?

20. When the neuron is at rest, is permeability higher for Na⁺ or for K⁺?

21. In this graph, “Relative Membrane Permeability” is in relation to Na⁺ permeability. So, at rest, the membrane is_____ times _____ (more/less) permeable to Na⁺ than it is to K⁺.
22. Does membrane permeability increase first for Na⁺ or for K⁺? Relate your answer to the characteristics of the two channel types from Model 2.

23. Does membrane permeability decrease first for Na⁺ or for K⁺? Relate your answer to the characteristics of the two channel types from Model 2.

24. Fill in the blanks in this sentence with terms from the graph. If needed, look back to question 14 for your definition of “refractory”.

During the ______________ refractory period, no stimulus, no matter how strong, can induce an action potential. During the ______________ refractory period, an action potential can occur, but the stimulus must be stronger than normal.

25. The refractory period reflects, in part, the special characteristics of the voltage-gated Na⁺ channel. Recall from Model 2 that this channel has three different states.
   a. Fill in the blank: Na⁺ channels need to be in the __________ state in order for a new action potential to be initiated.
   
   b. During the absolute refractory period, predict how many Na⁺ channels are in this state. Explain your answer.

   c. During the relative refractory period, predict how many Na⁺ channels are in this state.

26. Notice the change in K⁺ permeability over the course of the action potential. How would K⁺ permeability affect the ability of a neuron to fire an action potential? Explain.

27. Based on your answers to questions 25 and 26, summarize the molecular events responsible for the absolute and relative refractory periods. Use complete sentences.
**Extension Question**

28. Some neurotoxins interfere with neural transmission by acting on these voltage-gated channels. In the boxes below draw tracings for the action potential, Na\(^+\) permeability, and K\(^+\) permeability in cells exposed to the following neurotoxins:

A. tetrodotoxin (TTX): blocks voltage-gated Na\(^+\) channels.

B: mamba snake dendrotoxin: blocks voltage-gated K\(^+\) channels
Flux, Gradient and Resistance

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malm0070@umn.edu

Abstract
This lesson helps students to develop a conceptual understanding of the concept of flow down gradients, or flux, and its relationships to driving force for flow and resistance to flow. After completing this activity, students will be prepared to engage with material related to blood flow, heat transfer, action potentials, osmosis and diffusion, and peristalsis. Students explore the concepts of flux, gradient, and resistance using a drawing of water-filled pipes. After reading about some biological examples of flux, students construct definitions of gradient and resistance, and explore their relationships in biological systems. doi: 10.21692/haps.2017.038

Key words: flux, driving force, resistance

Target Audience: This activity was used as an introductory activity during the first day of class in a core-concept-focused, rather than a system-focused, upper level physiology course for majors. It may also be appropriate for an introductory-level course.

Learning Outcomes:
HAPS: Understanding the concepts of flux, gradient and resistance will help students to achieve the following outcomes:
C.8.1.b – With respect to the following membrane transport processes – simple diffusion, facilitated diffusion, osmosis and filtration, describe the mechanism by which movement of material occurs in each process.
H.4.4 – Differentiate between and concentration gradient and an electrical potential
H.4.5 – Define electrochemical gradient.
H.4.6.b – Explain how passive ion channels cause development of the resting membrane potential in neurons.
K.14.1 – Define blood flow, blood pressure and peripheral resistance.
K.14.2 – State and interpret the equation that relates blood flow to pressure and resistance.
K.14.5 – Interpret relevant graphs to explain the relationships between vessel diameter, cross-sectional area, blood pressure and blood velocity.
K.14.7.c – Describe how net filtration pressure across the capillary wall determines the movement of fluid across the capillary wall.
M.5.2.a – With respect to external respiration, describe oxygen and carbon dioxide concentration gradients and net gas movements.
M.5.2.b – With respect to external respiration, analyze how oxygen and carbon dioxide movements are affected by changes in partial pressure gradient (e.g., at high altitude), surface area, diffusion distance, and solubility and molecular weight of the gases.
M.5.3.a – With respect to internal respiration, describe oxygen and carbon dioxide concentration gradients and net gas movements.
N.5.2 – Define the terms peristalsis, segmentation, migrating myoelectric complex, and mass movement, and discuss the role these activities play in the function of various regions of the alimentary canal.
P.3.3.a – List specific transport mechanisms occurring in different parts of the nephron, including...osmosis, facilitated diffusion, passive electrochemical gradients...
P.3.5 – Compare and contrast reabsorption and tubular secretion, with respect to direction of solute movement, strength of concentration gradients and energy required.
Q.4.1 – Explain the role of electrolytes and non-electrolytes in the determination of osmotic pressure.
Q.4.5 – Describe the forces that affect capillary filtration, including the determinants of each force.

Other Learning Objectives that are not included in HAPS Learning Outcomes:
Students will be able to define the concepts of flux, gradient and resistance, and identify examples of these concepts in biological systems.
Students will be able to recognize the relationships between flux, gradient and resistance, and recognize biological examples of these relationships.

continued on next page
Prior Knowledge: none

Time Required: 20-30 minutes. Upper level students were able to work through this activity rather quickly during class, but introductory students may require more time.

Lesson Overview: Students work in groups of three to complete this activity. Each group should have a reader, a recorder, and a reporter.

The reader reads the models and questions aloud.

The recorder writes down the group's consensus answers to each question.

The reporter reads back the recorded responses to the larger group when asked.

At the start of this activity, I introduced students to these roles, and to the goal of becoming familiar with the concepts of flux, gradient and resistance. Students were tasked with completing Model 1 in five to seven minutes, after which reporters shared their group's responses to questions 4, 5 and 7 with the class. Some students spent too much time trying to derive formulas for the final volumes that accounted for the difference in volumes of the connecting pipes, so I addressed this issue briefly with the students as well. Encouraging them to consider the volume of the pipes to be much less than 10L helps them to focus on the concept of the eventual equilibrium volumes being equal. Students spent another 10 minutes completing Model 2, and recorders shared their groups’ answers to numbers 11 and 13 (descriptions of the concepts of gradient and resistance). They were instructed to listen for similarities and differences in the descriptions from other groups. Finally, they wrote their answers to number 18 on the whiteboards in the classroom, and the class compiled a list of flux examples. Over the next three weeks, the class explored other examples of flux in biological systems, including heat transfer through conduction, blood flow following Poiseuille’s law, and ion flow down electrical gradients.

Example Student Conversation:

“I think the water will move more quickly through the skinny pipe since it will push back on the water more.”

“It’s kind of like a sink drain where the water goes down slower when there’s a clog.”

“What’s the formula for the volume of a cylinder?”

“If the volume is the same in all of them will the gravity pressure be the same, too?” “Yeah, and the air pressure on the other side is the same in all of them as well.”

“But when the valve opens does it depend on the size of the valve or just the water pushing down on it?”

About the Author

Sarah Malmquist is a physiologist who works in the Biology Teaching and Learning Department within the College of Biological Sciences at the University of Minnesota.
FLUX, GRADIENT AND RESISTANCE ACTIVITIES

Model 1: An Illustration of Flux

Each of the examples in the diagram below represents two containers linked by a pipe. The pipe has a valve near the left container. The left container contains 10 L of water, and the right container is empty. When the valve is opened, water will flow from the left side to the right side. The dimensions of each of the containers are the same.

![Diagram of three examples showing water flow through a pipe with variables x and y.]

1. Circle the letter x in all three examples. What does the variable “x” represent?

2. Circle the letter y in all three examples. What does the variable “y” represent?

3. Fill in the table with the starting volumes of each of the containers (at time 0).

<table>
<thead>
<tr>
<th></th>
<th>Left Container</th>
<th>Right Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example C</td>
<td></td>
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</table>

4. Before the valves are opened, does the pressure on the left side of the valve differ between the three examples?

5. Before the valves are opened, does the pressure on the right side of the valve differ between the three examples?
6. The valves are opened and water moves. Fill in the table with the final volumes of each of the containers, after the containers have reached equilibrium.

<table>
<thead>
<tr>
<th></th>
<th>Left Container</th>
<th>Right Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Will A or B reach equilibrium more quickly? Explain your reasoning.

8. Will A or C reach equilibrium more quickly? Explain your reasoning.

9. What two variables are most important for determining the rate of water flow through the connecting pipe between the two containers in each example?
Model 2: Flux, Gradient and Resistance

In the language of physiology, the terms (concepts) 1) flux, 2) gradient, and 3) resistance are used in combination to explain a number of processes within living things. Flux is the rate of movement of a substance between two compartments. In Model 1, flux is the movement of water from the left containers to the right containers through the connecting pipe.

A physiological example of flux is the rate of air movement into the lungs. Resistance is the friction caused by the narrow respiratory passages of the respiratory system (the trachea, bronchi and bronchioles, shown in the image to the left). This resistance counters and slows the movement of air into the lungs. The gradient is the difference in pressure between the outside air and lungs. The lower air pressure inside the lungs, compared to the atmospheric pressure outside, pulls air in, overcoming the resistance caused by the respiratory passages. As a rule, a gradient and resistance together determine flux. These three concepts are also illustrated in Model 1 above.

Answer the following questions using information from Model 1 and the text from Model 2.

10. In Model 1, all three examples started with the same gradient. Describe the gradient that promoted water flow in Model 1.

11. As a group, come up with a one or two sentence description of the generic concept of a gradient that could be used in other contexts, as well as in Model 1.

12. In Model 1, each of the three examples had differing resistance in the connecting pipe just after the valves were opened. Describe the resistance to water flow in Model 1.

13. As a group, come up with a one or two sentence description of the generic concept of resistance that could be used in other contexts, as well as in Model 1.

14. What physical properties (e.g. mass, dimensions, surface tension, density) created the resistance to the movement of water through the connecting pipe in Model 1? Be as specific as possible.
15. The example in model 2 described the movement of air into the lungs. The flow of blood through vessels is another example of flux. Use the cylinder below to draw the processes of flux, resistance and driving force. (Hint: how will you represent the gradient? How will you show resistance? How will you show flux?)

![Cylinder diagram]

16. As a group, write one or two sentences describing how the rate of blood flow through a vessel is determined. Use the terms flux, gradient and resistance in your description.

17. As a group, derive a formula showing the relationship between gradient, resistance, and flux.

18. Blood and air movement in the human body are two physiological examples of flux. As a group, come up with some more examples: two examples from other animals, one example from a plant, and one from bacteria. For each example, describe what exactly is flowing from one compartment to another, the resistance to flow, and the gradient promoting flow.
Empowering Yourself by Reenacting Your Own Immunity Power

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yellowb@gmail.com

Abstract
The goal of this exercise is for students to obtain a core understanding of how a total immune response occurs in the human body. This activity calls for students to review lecture material covered on innate and adaptive defenses in a small group setting; work as a class to collectively agree on a final immunology story based on the small group work and instructor guidance; and perform a short, choreographed “Immunology Play” based on the story created by the class. doi: 10.21692/haps.2017.039

Key words: immune system, cell-mediated immunity, humoral immunity, antibody, lymph node

Target Audience: Human Anatomy and Physiology Students, Immunology Students

Learning Outcomes:

HAPS:
L.12.1 Introduction to innate (nonspecific) defenses & adaptive (specific) defenses
L. 14.3 Describe the roles of various types of leukocytes in innate and adaptive body defenses.
L. 15.4 Analyze ways in which the innate and adaptive body defenses cooperate to enhance the overall resistance to disease.
L. 30.1. Distinguish between humoral and cell-mediated immunity
L. 32.1. Define antigen and antigen receptor.
L. 34.3. With respect to major histocompatibility complex (MHC):
L. 35.a. Define MHC.
L.36 b. Describe where class I and class II MHC and MHC proteins are found.
L. 37. Explain the function of class I and class II MHC in adaptive immunity.
L.38. 4 Discuss the source of antigen receptor diversity.
L. 39.5. Explain the role of antigen-presenting cells (APCs) and provide examples of cells that function as APCs
L. 40. 1. Distinguish among the various types of lymphocytes, including helper T cells, cytotoxic T cells, regulatory (or suppressor) T cells, B cells, plasma cells, and memory cells.
L.41.2. With respect to B cells and T cells:
L. 42. A Define immunocompetence and self-tolerance and distinguish between naive and activated immune cells.

L. 43.b Compare and contrast the sites where the cells originate and achieve their immunocompetence, and the primary location of the immunocompetent cells in the body.
L. 44.c. Compare and contrast the mechanisms of antigen challenge and the clonal selection processes, including effector cells, helper cells, memory cells, and important cytokines.
L. 45.d. Compare & contrast the defense mechanisms and functions.
L. 53. 1. Predict factors or situations affecting the lymphatic and immune systems that could disrupt homeostasis.

Prior knowledge requirements: Students should have already had a lecture on the immune system's innate and adaptive defenses. Previous knowledge of lymphatics, the cardiovascular system and capillary dynamics is a plus.

Time required: ≈75 minutes. If you have a shorter class time, the activity can be broken up.

About the Author
Bridgit Goldman has been teaching college level biology since 1998. She has a PhD in Cellular, Molecular, and Developmental Biology from The Graduate School and University Center of The City University of New York. Since 2007 she has designed, developed and taught all of the lecture and laboratory classes in Human Anatomy and Physiology at Siena College in Loudonville, NY.

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EMPOWERING YOURSELF BY REENACTING YOUR OWN IMMUNITY POWER ACTIVITY

Part I- Small group work: 4-6 students/group (20-30 minutes)

Students form groups and are given a handout to complete. Students answer a subset of questions to reinforce previous knowledge and start to think about how the innate and adaptive immune system defenses work together.

To facilitate small group work, each group decides who will fill the following roles:

- **Reader:** Reads the scenario and the questions to the group.
- **Recorder:** Records the answers agreed upon by the group on the handout.
- **Taskmaster:** Makes sure the group is not getting off topic. Watches the time.
- **Classroom Liaison:** When it is time to share work with the whole class, speaks on behalf of the group.

All members of the group share responsibility for the answers. If there are more than four in a group, the jobs can be shared (ex. take turns reading the questions).

**Example student conversation during group work:**

“What was that thing on the cells to recognize “self”?

“I forgot what an innate defense is.”

“Does an antibody kill an antigen?”

Part II- Class Review and Discussion

To begin, the instructor should draw the same initial drawing from the handout on the board. As you draw, cue the students to finish up their small group work. Then attention should focus on the board. The instructor asks a group to answer the first question. Once one group has answered a question, the floor is opened for other groups to add to, comment on or question the other groups’ answers. This system is repeated until the whole handout is gone over as a class. Throughout this exercise, the instructor’s role is to construct a picture on the board that reflects student answers.

This is an important time as students listen to each other, comment on ideas and misconceptions, gain ideas from one another, make connections and laugh a lot as an action-packed story is pieced together on the board. A typical final big board story picture looks like Figure I below.
Although students and instructor are creating the story together, the instructor should have a clear idea of the story in their mind and prompt students (using the questions) to get there. The instructor can make the story as complex or as simple as was covered in previous lectures. Once the big board story picture is completed to the students’ and instructor’s satisfaction, move to part III. Do not erase the board!

**Part III-The Immune System Play**

The following play is designed for a class size of 30-35 students. See “addendum for large class size” for ideas on how to adapt this for a larger class size.

Suggested Materials:

- Lots of around the room board (or wall) space
- Plenty of sticky notes (more than one color if possible)
- Sharpies
- Bubbles

**SET:** The classroom is labeled by the instructor to designate the body areas relevant for the play. If you do not have enough board space, label the walls with masking tape and a sharpie. Instructor can walk around the room labeling the classroom as the students do their Part I group work. This is an opportunity to listen to the student groups as you make your way around the room.

Board Labels (I usually write them very big) should include:

- Bone Marrow
- Thymus
- Tissue Space
- Lymph Node
- Site of infection

See Figure 2 below for initial classroom set-up.

![Classroom Set-up for Immunity Play](image)

**Figure 2.** Classroom Set-up for Immunity Play

*The arrow on the diagram represents the general flow of movement of the play.*

**CAST OF CHARACTERS:** You will need a sticky note for each character (see the list below). Use the sticky notes and sharpie to write the ‘character’ name to designate the students’ role. I often write these out while they are doing the Part I group activity but you can also write the character roles as you do the first run through of the play. **You will find the starting position for each character written in italics.**

*continued on next page*
Antigen- (1) Waits for entrance in the doorway of the classroom.
This is a starring role so a dynamic student works best. Add six or seven extra sticky notes for this character to designate antigenic determinants (choose a shape, like a black triangle). See Figure 3 below.

![Figure 3](image)

**Figure 3.** Example of how the student playing the ANTIGEN is labeled with both a name and antigenic determinants (black triangles)

Tissue Space Cells- (3) Tissue space.

Dendritic Cell- (1) Tissue Space. Also receives a sticky note that says “MHC II.”

T- Helper Cell (CD4 cell) (1) Bone marrow.

Starring role. Earns the matching antigenic determinant to the antigen that will invade. So, when this student becomes immunocompetent, he/she earns a black triangle shape so that he/she can recognize the presentation from the dendritic cell later in the play. See Figure 4 below representing the activated T-Helper Cell.

![Figure 4](image)

**Figure 4.** Example of how the student playing the Activated T-HELPER CELL should be labeled with sticky notes

Empowering Yourself by Reenacting Your Own Immunity Power

continued on next page
Other T-cells (CD4 cells)- (3) Bone marrow.
B-cells- (3) Bone marrow.
Cytotoxic T cells (Tc) (CD8 cell)- (1) Bone marrow.
T- Memory cell- (2) At least one in the Lymph Node and one seated.
B- Memory cells- (2) At least one in the Lymph Node and one seated.
Cytokines- Seated. (1) Given the bubbles, which will be used to simulate cytokine co-simulation.
Macrophages- (2-3) Seated.
Neutrophils- (2-3) Seated.
Fibroblasts- (1) Seated.
Body Cells- (5-6) Seated and Site of Infection.
Fever- (1) Seated.
Inflammation- (1) Seated.

Now you have labeled your classroom and have your sticky notes and sharpie ready. It is time to ask for volunteers for certain roles, or simply assign them to the students. The student wears the sticky note so that it is visible. It is usually placed on the sternal area, but you can let them decide what is most comfortable.

Once roles are assigned, students should take the appropriate starting position. As students move around through the play (see the arrow which shows the general direction of movement), they travel through imaginary blood vessels or lymph vessels. Students who do not wish to actively participate remain in their seats as “Other Body Cells.” I encourage them to wear a sticky note that reads, “Body Cell,” and another with an MHC I label. Very often these students do choose to become infected by the antigen or take a more active role as the play is repeated because they become more comfortable.

The first time through the instructor, based on the board picture, narrates the play. Do not expect it to be smooth or beautiful the first time. The instructor is learning what a certain group of students can do, and the students are working on doing something outside of their comfort zone in front of their peers. The instructor must remember to laugh and joke with students and be a part of figuring it all out with them. So, the instructor must facilitate the flow of the story, the movement of the students to the right location, and dictate the proper actions and lines of the “character” at the right time. Only after guidance through their story (which remains on the board and can be referenced at any time) will they start to become comfortable in their role.
An example of a typical “Immunology Play”

Below is a sample narration and direction that the instructor might say and give. In a classroom situation, the narrative is said “off the cuff” based on what was created on the board. The instructor must do her/his best to show enthusiasm for the subject matter and get the students to have fun interacting with each other.

Once you have run through the play once and students get the hang of it, run through it again. Depending on the time and class size and dynamic you can continue to narrate for them. Often, with some encouragement, a student can take over the role of narrator. This activity is beautiful to watch because the students are empowered by the story that they have helped to create. It provides a lot of learning, conversation, laughs and overall class bonding.

When you are ready to begin, have students take their starting places as outlined by the cast of character list above in italics.

IMMUNOLOGY PLAY
LOCATION: Inside a human body.
TIME: The present.
SETTING: We are in the bone marrow where immature B and T cells reside.
AT RISE: Five to six Immature B and T CELLS are hunkered down in front of the board labeled “Bone Marrow.”

ACT I, SCENE 1
NARRATOR
Immature B and T CELLS reside in the bone marrow awaiting signals to mature. The signal arrives and these cells begin to emerge from the bone marrow and enter the blood stream.

(Students begin to rise up and walk toward the “Thymus” board label, but do not reach it. They should stop between the “Bone Marrow” and “Thymus” board labels. See diagram above.)

NARRATOR
The future B-CELLS head back to the bone marrow to complete maturation.

(Students with B-CELL sticky notes walk back to the “Bone Marrow” board label)

NARRATOR
It is not clear how B-CELLS mature, but we know that they do, and rise to a mighty power equipped with the ability to one day make antibodies for humoral immunity. In the bone marrow, these cells earn both MHC I and MHC II protein receptors.

(Students are given sticky notes. One reads, “MHC I” and the other reads, “MHC II.”)

NARRATOR
The B-CELLS have passed all of their tests and have now become naïve immunocompetent B-CELLS. They travel through the blood and lymph to end up in a lymph node where they reside as naïve immunocompetent B-CELLS awaiting the antigen challenge.

(B-CELLS students walk through the classroom toward the board labeled, “Lymph Node”. The lymph node was described to students in the previous lecture as a coffee shop where lymphocytes hang out awaiting the antigen challenge. Some students will pretend to drink coffee.)

continued on next page
ACT I, SCENE 2

(Focus turns back to the blood stream where future T-CELLS await their development and training.)

NARRATOR

T-CELLS head to the thymus where they undergo their “basic training” to become either immunocompetent CD4 (T-Helper) cells or CD8 (Cytotoxic T) cells. Understand that T-CELLS that do not comply with body standards are destroyed.

(Students do jumping jacks or some kind of callisthenic exercise to simulate both positive and negative selection (basic training) as the NARRATOR continues).

NARRATOR

It is here that these cells learn to recognize MHC1 (self), but also learn not to attack self. This is key to their role in protecting the human body. In addition, these brave lymphocytes will also learn to recognize a specific antigen (based on genetics and evolution) that they one day hope to encounter and defeat. You can think of these cells as honing one particular martial arts move, designed to destroy one particular pathogen that, if ever encountered by the body, only they will be uniquely equipped to destroy.

(Students strike a martial arts pose to show that they are trained. The Narrator acknowledges them with a nod and by giving each student a badge (sticky note). Each one has a different antigenic determinate on it (different shapes). Make sure that the student who you chose to be the starring T CELL gets the antigenic determinate shape that you gave your antigen (black triangle).

NARRATOR

These newly minted naïve immunocompetent T-cells emerge from the thymus and are deployed to take up residence in the lymph node where they await the antigen challenge.

(Students move to “Lymph Node” board area. As they move, the narrator continues.)

NARRATOR

Remember that these cells are called “naïve” because they have not ever encountered the actual pathogen (antigen) that they are equipped to destroy. However, should the day arise, and the body encounters their specific antigen, and that antigen attempts to take up residence in the body, rest assured, these lymphocytes will be ready!

ACT II

(All students look toward the door of the classroom)

NARRATOR

It is happening. An antigen is invading. This antigen has passed through surface barriers and made its way to the blood stream. The antigen is headed for the tissue space!

(The ANTIGEN enters from the doorway to the classroom wearing his/her character label as well as an additional five to ten sticky notes all over him/her with a designated shape (a black triangle in this scenario). Instructor can try to get student to do an evil laugh as they pass through surface barriers (the doorway to the classroom) and enter the blood stream making their way through the classroom toward the “Tissue Space” board area.)

continued on next page
NARRATOR
The ANTIGEN has reached the Tissue Space. TISSUE SPACE CELLS are scared! The DENDRITIC CELL senses the ANTIGEN’s presence and takes action by reaching out its long cellular extensions. The ANTIGEN engulfs the pathogen and presents one of the antigenic determinants (sticky notes) on its MHC II receptor.

(Pause for this action to finish.)

NARRATOR
Quickly, the DENDRITIC CELL, a powerful Antigen Presenting Cell (APC) travels through the lymph channels to the lymph node to find a lymphocyte that can hopefully recognize the antigenic determinant it is displaying. In other words, the DENDRITIC CELL is looking for a match!

(The DENDRITIC CELL begins travel to the board space that reads, “Lymph Node,” but freezes, midway there with his/her MHC II receptor displaying a black triangle held high. The student should wear a look of determination. Focus turns to the ANTIGEN. The NARRATOR continues the tale.)

NARRATOR
The ANTIGEN does not die in the tissue space, of course, because that would ruin our story. In fact, the ANTIGEN had already multiplied itself and its clones have headed to the Site of Infection!

(More evil laughter from the ANTIGEN as it travels to the “Site of Infection” board area and begins to “infect” or tag the BODY CELLS. Students acting as BODY CELLS who are tagged by the ANTIGEN display a black triangle on their MHC I receptors.)

Infected BODY CELLS
Help! Help!

(These infected cells wildly show the black triangle displayed on their MHC I sticky note. Then they freeze. Focus turns back to the “Lymph Node.”)

NARRATOR
Meanwhile, in the Lymph Node, naïve immunocompetent T and B cells are listening to the war stories of the great T and B Memory cells around them. They hope one day to have stories of themselves to tell.

(DENDRITIC CELL unfreezes and enters the Lymph Node and boldly holds up its black triangle antigenic determinate on its MHC II receptor.)

DENDRITIC CELL
There has been an invasion! Do any of the lymphocytes in here recognize and know the secret black triangle martial arts move to destroy this antigen? Does anybody have a black triangle?

T_h CELL (with black triangle)
That would be me.

NARRATOR
The T_h cell with the black triangle boldly and proudly walks out. Its moment has come!

(Since physical contact of cells is required. The DENDRITIC CELL and the T_h CELL must shake hands to simulate this cell-to-cell contact)
NARRATOR
Contact has been made and thus the $T_H$ CELL has been promoted to active duty in the “Officer Class” of immunity cells. This $T_H$ CELL is granted the power of Macrophage Activating Factor (MAF) and Macrophage Inactivating Factor (MIF) should the occasion arise to use these special forces.

(Previously in lecture I have explained how MAF turns normal macrophages into insatiable phagocytes that even eat sound tissue. I make the analogy that activating MAF is equivalent to the $T_H$ CELL releasing a pack of wild attack dogs. Only the $T_H$ cell can control them (master them) with MIF, and call them off.)

(Give this student MAF and MIF sticky notes)

NARRATOR
For the $T_H$-CELL to use its power in cellular immunity, cytokines must be used.

(Student who is the CYTOKINE (with bubbles) comes to be next to the $T_H$ CELL.)

NARRATOR
Other lymphocytes in the Lymph Node displaying other antigenic determinates remain in the Lymph Node, disappointed that it was not their moment to shine. The activated $T_H$ CELL and CYTOKINES move out to locate the antigen that has invaded.

(The now activated $T_H$ CELL and CYTOKINES travel to the “Site of Infection” board space.)

$T_H$ CELL
Beware foul beast of an antigen! Prepare for your doom!

NARRATOR
The activated $T_H$ CELL, upon seeing the mass infection, mobilizes into action by activating several cell types beginning with NEUTROPHILS, the “foot soldiers” of the immune system.

$T_H$ CELL
The battle is upon us NEUTROPHILS! Prepare yourselves!

(Bubbles are blown to simulate cytokines that cause neutrophils to flood to the Site of Infection. NEUTROPHILS get up from their seats and head to the “Site of Infection.”)

NARRATOR
NEUTROPHILS use their phagocytic abilities to destroy any infectious detritus they encounter. Next, the activated $T_H$ CELL activates CYTOTOXIC T-CELLS. They must dock with the $T_H$ CELL.

(CYTOTOXIC T-CELLS rise from their seats and heads toward the “Site of Infection.” They shake hands with the $T_H$ CELL. Bubbles are blown around them by the CYTOKINE to simulate cytokine co-stimulation.)

NARRATOR
And in the process of cell-to-cell communication, the message to attack cells infected with the black triangle are relayed to the CYTOTOXIC T-CELLS. These cells will use granzymes to destroy infected body cells via apoptosis. The infection is somehow spreading and every cell is now infected! CYTOKINES are used to bring MACROPHAGES to the area.

(MACROPHAGES come to the “Site of Infection.”)

NARRATOR
MAF is released.

$T_H$ CELL
Release the hounds!

continued on next page
And the MACROPHAGES become insatiable phagocytes engulfing and destroying both infected and healthy tissue. They are ravenous!

(MACROPHAGES use their arms to show large engulfing capabilities. All eyes then follow the ANTIGEN as he/she leaves the “Site of Infection” and heads to infect “Other Body Cells” seated in the center of the room that have remained seated during the play. Any infected cell should display the black triangle on their MHC I proteins. The antigen laughs. Focus turns back to the, “Site of Infection.”)

The “Site of Infection” seems to finally be clear and so MIF is released to call off the insatiable phagocytes.

Be calm dogs!

(Focus turns back on the center of the room where “BODY CELLS” reside.)

But lo! This tenacious antigen may have caused other infected areas and may be scouring the humors of the body looking for places to reside. The \( T_h \) CELL continues its fight by calling upon a B CELL to rally humoral immunity.

Enter a B CELL next to the activated \( T_h \) CELL

\( T_h \) cell and B-cell must shake hands to simulate the physical cell-to-cell or cell-mediated contact needed for stimulation. Bubbles are also blown around them to simulate cytokines that are needed for activation to be complete.

Once the B CELL has been activated it makes clones and turns into a PLASMA CELL.

(Add a sticky note to the B CELL that says, “PLASMA CELL.” Also give them a packet of sticky notes (it is very cool if the instructor can cut the sticky note packet into a “Y” shape), preferably of a different color than used for character names. These sticky notes will be the antibodies.)

The PLASMA CELL now pumps out antibodies specific for the black triangle antigen at an amazing rate.

AGGLUTINATE!!
PRECIPITATE!!
ACTIVATE COMPLEMENT!!

(The PLASMA CELL uses its sticky notes to tag infected cells and/or the ANTIGEN, calling out its lines over and over again. But if the student is more subdued the instructor can create sticky notes with those words on them to stick on the antigen and/or infected cells.)

With humoral immunity in full force, macrophages will be called to the area and there is fever and inflammation.

(Students representing FEVER, INFLAMMATION, and MACROPHAGES stand up and can move to the “Site of Infection” and/or the central area of the classroom with “BODY CELLS” that have been infected.)

The final battle is upon us. The \( T_h \) CELL uses cell-mediated immunity and the PLASMA CELL continues to make antibodies for humoral immunity. There is fever, inflammation, and phagocytosis. Both adaptive and innate defenses of the body are employed. Finally, the PLASMA CELL tags the ANTIGEN with lots of antibodies yelling out his actions.

continued on next page
PLASMA CELL
AGGLUTINATE!!!!

(PLASMA CELL tags the ANTIGEN with several sticky notes as he/she says his/her lines. A nearby phagocyte (MACROPHAGE or NEUTROPHIL) engulfs the antibody laden ANTIGEN. The ANTIGEN does his/her best dying interpretation.)

NARRATOR
The ANTIGEN is defeated. The activated T\textsubscript{H} CELLS and B-CELLS create MEMORY CELLS specific for the black triangle antigen and these cells are sent back to the Lymph Node. The T\textsubscript{H} CELL engages FIBROBLASTS to heal damaged tissue. Finally, and importantly, the activated T\textsubscript{H} CELL is deactivated. The immune response is over.

(Pause to allow these actions to happen.)

NARRATOR
Remember that as this immune fight is being fought, the host is not feeling well. But if this antigen should ever dare invade again, the immune system's response will be swift and furious and the host will probably never even know of the antigen's presence.

THE END
Addendum for a Large Class

I have never tried this play with a large classroom size (100-250 students) but I believe it could be very effective. Some suggestions are as follows:

1. Instead of labeling the classroom, have big signs held by students that indicate the area of the body. Each body area could consist of approximately 20-25 students. In this setting, you could have more students immunocompetent in the Lymph Node awaiting the antigen challenge and the Site of Infection would have great potential for a lot of student interaction during the final battle scene.

2. Instead of sticky notes for MHC I receptors, explain to the students that their hands are the MHC I receptors. This will cut down on supplies and allow for the students to display an antigen on their hand should they become infected.

3. One antigen should be the “star,” but seed the classroom within each body area with a few students who would only show themselves as antigens when the Narrator reads or says something like, “In fact, the Antigen had already multiplied itself…” Then have those students stand up to reveal themselves. I think this would give the students an even better idea of how antigens can infiltrate many areas of the body in addition to the main infection site. These antigens can infect local cells within the region that they are sitting in.

4. Assign at least 20-25 students to be Neutrophils and Macrophages. Make another large sign to designate the area where these cells sit. This way, they can be easily found when the T<sub>H</sub> CELL activates them. The activated T<sub>H</sub> CELL can deploy them to many areas of the classroom when the immune response is in full swing.

5. Have the B-Cell not only become a plasma cell, but have him/her make clones by tagging other students to become activated B-cells/Plasma cells. In this way, you will have more plasma cells to make antibodies to travel through the classroom with Y-shaped sticky notes to tag the students playing antigens.

6. In the final battle scene have Antigens and infected body cells die from various methods. See example methods and lines below.

Fever - "I'm too hot!"
Antibodies - "I've been agglutinated! Nooooooo"
Activities for Empowering Yourself by Reenacting your Own Immunity Power

Work together in a small group to answer the following questions in Part I.
Your group should be prepared to share your answers with the class during Part II.
In Part III we will all work together to reenact a story that we create together.

For each group fill in who is the:
   Reader - Will read handout and all questions to the group.
   Recorder - Writes down group answers.
   Task Master - Makes sure you are on task and keeps track of time.
   Classroom Liaison - Will be the spokesperson for your group when we share our answers with the whole class in Part II.
   Other - Contribute to your group with fabulous answers and insight.

To begin to understand how the body will defend itself against pathogens, answer the questions that follow. We will then use your answers to construct a big board story picture with the goal of defeating an evil antigen. Then, we will reenact the final scenario of our creation as an action-packed play with you as the stars!

Part 1: Review your Knowledge of Immunity

1. Where do T cells and B cells originate? ________________

2. Use the arrows labeled 2a. and 2b. to describe what happens to immature B and T-cells traveling in the blood

   ![Diagram of T and B Cells]

3. Once B and T lymphocytes have completed “basic training” and have become immunocompetent, list some places they go to await the antigen challenge?

4. What is the difference between a naïve immunocompetent T-cell and a Memory cell?
5. What is an Antigen Presenting Cell (APC)? Be sure to explain the special receptor found on them that helps them to do their job?

6. TH cells are crucial for an immune response. List some of the major cells the TH cell has the power to activate? Circle the cell type in your list that activates humoral immunity.

7. What is required for a TH cell to activate a B-cell (list at least 3 factors).

8. The Plasma Cell arises from an activated B cell. What “Y” shaped polypeptide will a Plasma Cell pump out in massive quantities that acts as a molecular tag rendering antigens out of commission? _______________________

9. List at least 6 innate defenses of the human body.
   a. _______________________
   b. _______________________
   c. _______________________
   d. _______________________
   e. _______________________
   f. _______________________

10. Choose an innate defense from your list in question 9 and describe how it is enhanced by cell-mediated immunity.

11. Choose an innate defense from your list in questions 9 and describe how it is enhanced by humoral immunity.
Part II Big Board Story Picture

Our drawing will include how our body prepares itself for inevitable contact with antigens of countless varieties, how specific cells recognize antigens, how adaptive forces become mobilized into action, and how these adaptive forces call upon innate defenses so that a total immune response is elicited. We want to show how we ultimately unleash the mighty power of the Immune System if any antigen dares to invade our precious tissue spaces.

The situation:
An evil pathogen, (the antigen), managed to surpass your surface barriers and has entered your blood stream (see the Figure 2 below). This invading antigen is headed for the tissue space where it hopes to occupy and multiply itself! Let’s draw together and defeat the antigen.

![Figure 2. Our big board story picture starts here](image)

Part III The Immune System Play

Homework:
In the next week, your job is to practice this drawing by taking out a blank sheet of paper and re-drawing this story from memory with as much detail as you can. Each time you draw it, check your work with our classroom notes, the PowerPoints, and your textbook. Make corrections, add details, and do it again. Draw it for your friends and family. Tell them the story! Practice, make it better, and practice again! Own your knowledge!
Frank-Starling Law of the Heart

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Abstract
This inquiry-based activity guides students in exploring the Frank-Starling Law of the Heart and the relationship between preload, contractility, and cardiac output. doi: 10.21692/haps.2017.040

Key words: preload, contractility, cardiac output, inquiry, Frank-Starling, heart

Target Audience: This learning activity is suitable for a college-level Introductory Anatomy and Physiology, Physiology, or Pathophysiology course.

Learning Outcomes
After completing this activity, students will be able to:
- Use the Frank-Starling Law of the Heart to describe the relationship between preload and cardiac output.
- Relate the Frank-Starling Law to what is happening in the sarcomeres of the myocardium.
- Describe the relationship between the Frank-Starling Law at rest and during exercise or in heart failure, using the concept of contractility.

HAPS Learning Outcome:
K.11.2.C: Explain the significance of the Frank-Starling Law of the heart.

Prior Knowledge:
A basic understanding of cardiac cycle
The definition of stroke volume
The definition of preload
An understanding of the relationship between stroke volume and cardiac output
The structure and function of a sarcomere
One of the optional extension questions requires knowledge of the renin-angiotensin system and the effect of afterload on cardiac output.

Time Required: 60 minutes

About the Author
Karen Groh is an Assistant Professor at Good Samaritan College of Nursing and Health Science in Cincinnati, Ohio where she teaches Human Anatomy and Physiology and Pathophysiology.

Guidelines for Classroom Implementation
Divide the class into learning teams of three to four students each. Students should examine the models carefully to determine the answers to the questions that follow the models. The instructor’s role is to facilitate. Rather than providing content knowledge or answering questions for the students, instructors guide the students in figuring out the answers by using the information in the models. After examining the models and discussing the subsequent questions with their team members, students should develop a working knowledge of the Frank-Starling Law of the Heart.

Stopping the class after each model and the subsequent questions and processing with the whole class allows students to move forward to the next concept with any misunderstanding from the previous concept clarified.

In an Anatomy and Physiology or Physiology course, this activity can be used after covering heart anatomy and the cardiac cycle. The activity will help students construct knowledge regarding the relationship between preload, contractility, and cardiac output.

The last question (#30) helps students connect what they learned to the pharmacology of ACE (angiotensin converting enzyme) inhibitors. This question may be too challenging for some classes and can be omitted if the instructor chooses.

If the instructor prefers a shorter activity, Model 3 and the question about the length-tension relationship can be omitted without affecting the integrity of the activity.

Instructor Observations: The Frank-Starling Law of the Heart is a challenging concept for most students. Students struggle to articulate the relationship between preload, contractility, and stroke volume. Many students confuse the increase in cardiac output related to increase in preload with the increase in cardiac output related to increased contractility. This inquiry-based activity allows students to examine graphs of these relationships and construct their own knowledge of these concepts.

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FRANK-STARLING LAW OFF THE HEART ACTIVITY

Model 1

1. When you stretch a rubber band a little bit and let it go, what happens to the rubber band?

2. If you stretch a rubber band almost as far as you can, what happens when you let go? How does that compare to your answer to #1?

3. Compare the force of contraction of the rubber band when you stretch it a little bit with when you stretch it as far as you can. Which has a greater force of contraction?

4. If you find a very old rubber band and stretch it, will it snap back as quickly as a new one?

Like a rubber band, the more the myocardium is stretched, the harder it contracts. The end diastolic volume (EDV) of the heart is the amount of blood left in the ventricles just before the ventricles contract. A larger EDV leads to greater stretching of the ventricular myocardium.

5. The end diastolic volume (EDV) of the heart is the amount of blood in the ventricles just before the ventricles contract. Which would cause greater stretching of the myocardium, a low EDV or a high EDV?
Model 2

Consider Model 2 and answer the following questions:

6. Identify the three labels that are given to the variable on the horizontal axis.

7. What are the similarities among the three ways of naming the variable on the horizontal axis?

What are the differences among the three ways of naming the variables on the horizontal axis?

8. Identify the two labels that are given on the variable on the vertical axis.

9. What are the similarities between the two ways of naming the variable on the vertical axis?

What are the differences between the two ways of naming the variables on the vertical axis?

10. As preload increases, what happens to stroke volume in the region marked X on Model 2?

What happens to cardiac output?
11. As preload increases, what happens to stroke volume in the region marked Y?

What happens to cardiac output?


13. How is the heart like a rubber band?
Model 3
Recall the relationship between length and tension in a sarcomere. Sarcomeres produce maximum tension when they can form a maximum number of cross-bridges between actin and myosin.

14. Consider the sarcomeres shown above. Which of them can produce the greatest tension?

15. Now consider sarcomeres located in the myocardium. Which sarcomere above corresponds to a sarcomere in a ventricle with the lowest EDV?

16. Which sarcomere above corresponds to a sarcomere located in a ventricle with the greatest EDV?

17. In Model 2, write the letters A, B, and C next to the regions of the curve where sarcomeres in the myocardium would be arranged as drawn above.
Model 4

Many physiological changes can cause a shift in the Frank Starling curve as shown in Model 2. For example, exercise activates the sympathetic nervous system leading to an increase in contraction strength for a given preload. In heart failure, remodeling of the myocardium leads to cardiac dilation and decreased contraction strength at a given preload.

Model 4 shows three different Frank Starling curves.

18. Write “Exercise” in the box next to the curve in Model 4 that shows the Frank-Starling Law during exercise.

19. If the preload is the same, is the stroke volume greater during exercise or under normal conditions?

   How would this change affect cardiac output?

20. Contractility is the contraction force of the heart for a given preload. Does contractility of the heart increase or decrease during exercise? How do you know this?

21. Using the word contractility, write a sentence that describes the relationship between the Frank-Starling Law during exercise and the Frank-Starling Law when a person is not exercising.
22. Write “Heart Failure” in the box next to the curve in Model 4 that shows the relationship between preload and stroke volume in heart failure.

23. If the preload is the same, is the stroke volume greater under normal conditions or in heart failure?

What happens to contractility in heart failure?

What happens to cardiac output during heart failure?

24. At very high preloads, what happens to stroke volume in heart failure?

What happens to cardiac output?

25. Write a sentence that describes the relationship between the Frank-Starling Law in a patient with heart failure and a patient without heart failure:

26. How is the heart of a patient with heart failure like an old rubber band?
Extension Questions:

27. During tachycardia (heart rate greater than 100 beats per minute), there is insufficient time between diastole and systole for the ventricles to fill. Using your knowledge of the Frank-Starling Law of the Heart, explain how tachycardia affects stroke volume. Use the word preload in your answer.

28. Why does your heart pound during a scary movie? Use the word contractility in your answer.

29. Besides exercise and heart failure, name some other factors which would cause a shift of the Frank-Starling curve and state whether they would cause the curve to shift up or down.

30. In addition to its other effects, angiotensin II binds to the myocardium and triggers ventricular remodeling that leads to hypertrophy (enlargement and thickening of the walls of the heart) and weakness of the heart. ACE (angiotensin converting enzyme) inhibitors prevent conversion of angiotensin I to angiotensin II. Describe ways that ACE inhibitors improve or maintain cardiac output under each of the following categories:

   Afterload

   Contractility

Draw curves below showing the relationship between cardiac output and preload, with and without ACE inhibitors.
Homeostasis Speed Dating

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Abstract
Homeostasis is a foundational theme in all Human Anatomy and Physiology courses. However, it is often particularly challenging for students to grasp. This activity asks students to evaluate six different physiological scenarios and answer a set of questions for each one. These questions help students identify the various parts of a communication pathway (stimulus, sensor, input message, integrator, output message, target, effect) and then determine if there is any kind of positive or negative feedback taking place. Finally, students are asked to determine whether or not the scenario is an example of homeostasis. The activity specifically addresses the common misconception that all communication pathways (and negative feedback loops) are homeostatic. By using a “speed dating” model, this activity provides a particularly engaging and social way to explore the complexity of homeostatic pathways. doi: 10.21692/haps.2017.041

Key words: homeostasis, communication pathway, feedback loop, speed dating model

Target Audience: This activity is intended for introductory human physiology students or anatomy and physiology students. The students’ previous experience will determine the depth you can expect from conversations. In a physiology-only course, the activity will probably take place in the beginning of the semester, and can serve as an inquiry-based introduction to complex physiological interactions. In an anatomy-only course, it might be more appropriate at the end of the units covering the nervous and/or endocrine systems.

Learning Outcomes:
HAPS:
B.2.3: Explain why negative feedback is the most commonly used mechanism to maintain homeostasis in the body.
B.3.1: Provide an example of a negative feedback loop that utilizes the nervous system to relay information …
B.3.2: Provide an example of a negative feedback loop that utilizes the endocrine system to relay information.
B.3.3: Provide an example of a positive feedback loop in the body.

Prior Knowledge:
HAPS:
B.1: Definition of homeostasis
B.2.1: List the components of a feedback loop and explain the function of each.

Time Requirements: 60-90 minutes, depending on how much prep and discussion is needed.

Literature cited

About the Author
Wendy Riggs is an Associate Professor of Biological Sciences at College of the Redwoods, a two year community college in Eureka, California. She teaches Human Anatomy, Human Physiology, and General Biology to mostly pre-health professions students. She is active on the HAPS email discussion group (list-serv) and has been the HAPS Communications Committee Chair since 2014.

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HOMEOSTASIS SPEED DATING ACTIVITY

Implementation Notes: This activity requires students to think deeply about communication pathways in the body. It challenges students to draw on their anatomy background to identify the parts of six communication pathways and determine whether or not the pathway is homeostatic. The activity requires students to “speed date” the scenarios, which increases engagement and focus while they evaluate the six scenarios.

When studying the human body, the concept of “homeostasis” is foundational for truly understanding the complex interactions between multiple body systems. However, research suggests textbooks (and instructors) often have very vague and misleading ways to deal with the concept, usually early in the term, and then never again.

This activity was developed with input from several HAPS members (particularly Olga Minich from Stephen F Austin State University, who contributed the scenarios), and is designed to help students organize their existing knowledge about homeostasis and communication pathways. It should help students reframe their understanding of this thematic concept that will be revisited over and over again throughout the course. The activity utilizes a “speed dating” model to increase engagement with the content and facilitate social interactions and teamwork between students.

Preparation

1. Print one copy of the “Homeostasis Speed Dating Scenarios” handout.
2. Place ONE scenario at each of 6 stations.
3. Clearly NUMBER each station (one through six), so students can quickly get to the scenario they are currently working on.
4. Print one copy of the “Speed dating groups.” This includes 24 unique speed-dating strips. Each strip informs students of the ORDER in which they will VISIT the six scenario stations (or tables). Cut the strips so that each student receives one strip.

Student Materials

Each student will need:

1. One copy of the “Homeostasis Speed Dating Lab Handout”
2. One speed dating strip (cut from the “Speed dating groups’ sheet)

Facilitating the Activity

1. Write “Round One” on the board, so students know which station they should be working on. Then ask students to sit at the station listed under “Round One” on their speed dating strips.
2. Walk through the example in the lab handout, so students have an idea of how they are supposed to evaluate each scenario.
3. Remind students that they are not expected to know details about each scenario, but they should have enough information from the description to answer all the questions in the handout.
4. Also remind students that they should embrace a GROWTH MINDSET and approach the activity knowing they will be pushed to discover their own misconceptions about homeostasis and communication pathways, and that those misconceptions will be addressed by their classmates and their instructor as the activity progresses.
5. When everyone is settled, tell the students to begin working on the scenario at their table. Each group should work together to fill in the information on the lab sheet.
6. Allow eight to ten minutes for students to complete Round One. Monitor the discussions and adjust the time if needed. Early rounds tend to take longer than later rounds, as students get the hang of the activity.
7. With about one minute remaining, warn students that they should finish up the station they are working on. Encourage them to highlight confusing parts so they can discuss this with their group mates at the next tables, if there is time.
8. At the end of Round One, ask students to move to the station listed under Round Two on their speed dating strips.
9. Repeat steps five through eight until all rounds are complete. Wander the room to monitor the conversations and provide guidance as necessary.
10. When the students have visited every station, have them return to their original seats and give them time to talk with their nearby classmates about the “tricky things.”
11. Debrief. This can take many forms. For example, students could have whiteboards at each table and they could sketch the pathway at their final station. These sketches could guide the instructor’s summary conversation.

continued on next page
Because of the setup of the speed dating strips, the activity works best in groups of 24 or fewer (which creates teams of four at each station). If the class is much bigger than 24, consider dividing the class into TEAMS of 24 and have SETS of six stations for the students to visit.

**Homeostasis Speed Dating Groups**
Print one copy of the following document (one sided) for each group for 24 students. Cut into strips and distribute, one/student.
Homeostasis Speed Dating Groups

Print one copy of this document (one sided) for each group for 24 students. Cut into strips and distribute, one/student.

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Homeostasis Speed Dating Groups

Print one copy of this document (one sided) for each group for 24 students. Place one scenario at each numbered table.

**Scenario 1**
When intense physical activity increases the level of carbon dioxide in the blood to dangerous levels, the carotid bodies in the carotid arteries sense the change in carbon dioxide and send a message to the brain. The brain responds by stimulating the chest muscles to increase lung ventilation. This lowers the blood carbon dioxide level.

**Scenario 2**
When you are suddenly exposed to the bright light, the photosensitive cells in your retina respond and a message is sent to the midbrain. The midbrain responds by stimulating the muscles of your iris to contract, decreasing your pupil size. This reduces the amount of light entering the eye.

**Scenario 3**
Regulation of blood pressure in humans is very important. If baroreceptors in the carotid artery detect increased BP, they relay the message to the medulla oblongata. The medulla then signals the heart to slow down the rate of contraction. As a result, blood pressure falls back to its normal level.

**Scenario 4**
When a baby starts suckling at the breast of its mother, nerve endings in the nipple detect the suckling and send impulses to the hypothalamus. The posterior pituitary then releases a chemical signal (oxytocin) that targets the breast tissue, and initiates milk let-down. The release of milk causes more suckling at the breast and the cycle continues until the baby is full.

**Scenario 5**
After a meal, glucose is absorbed by the small intestine into the blood. High glucose levels are detected by the β-cells of the pancreas, which respond by releasing a chemical messenger (insulin) into the blood. Insulin signals the liver to remove glucose from the blood and store it. Blood glucose concentration thus returns to the normal level.

**Scenario 6**
When a blood vessel is damaged, collagen from the underlying connective tissue is exposed. Collagen activates platelets, which attach to the site of damage and release signaling chemicals. The chemicals attract more platelets to the area. New platelets recruit even more platelets. Platelets continue to pile up and release chemicals until a platelet plug is formed, large enough to seal the damaged area.

continued on next page
Lab Worksheet: Homeostasis Speed Dating

Instructions
Each table has one scenario. You will have eight minutes to evaluate the scenario and fill in the chart with your group mates. At the end of the eight minutes, you will receive a NEW table assignment (and a new group) and will work on the next scenario. (Scenarios courtesy of Olga Minich, Stephen F Austin State University.)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>EXAMPLE</th>
<th>Table 1</th>
<th>Table 2</th>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A person’s body temperature fluctuates within a range which centers around 98.6°F.</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
<td></td>
</tr>
</tbody>
</table>

What is the:

| Stimulus? | Increased body temperature |
| Sensor/sensory receptor? | Thermoreceptors in hypothalamus |
| Input message/afferent path? | Visceral sensory neuron |
| Integrator/controller? | Hypothalamus |
| Output message/efferent path? | Visceral motor neurons |
| Target/efferator? | Smooth muscle in blood vessels |
| Response? | Vasodilation |

Is there a “regulated variable?” Yes. Body temp (because it is held within a range!)

If so, is this variable a characteristic of ECF? Yes!

If so, is there a homeostatic range? 98-100°F

Does the response affect the stimulus? How? Yes. Vasodilation increases heat loss, decreasing body temp. Negative FB.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Table 4</th>
<th>Table 5</th>
<th>Table 6</th>
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<tr>
<td>What is the:</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
<td>Is this an example of a communication pathway that maintains homeostasis?</td>
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<tr>
<td>Stimulus?</td>
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<tr>
<td>Sensor/sensory receptor?</td>
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<td>Input message/afferent path?</td>
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<td>Integrator/controller?</td>
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<td>Output message/efferent path?</td>
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<td>Target/effector?</td>
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<tr>
<td>Response?</td>
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<tr>
<td>Is there a “regulated variable?”</td>
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<td>If so, is this variable a characteristic of ECF?</td>
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<tr>
<td>If so, is there a homeostatic range?</td>
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<tr>
<td>Does the response affect the stimulus? How?</td>
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Homeostasis Speed Dating

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Lab Questions
Helpful resource: http://advan.physiology.org/content/39/4/259

1. Draw the pathways described in all 6 scenarios. Label all parts of the pathways and indicate whether or not they are homeostatic.

2. Are all negative feedback loops homeostatic?

3. How did your experience taking Human Anatomy help you understand this lab today?

4. What were some surprising insights, or “ahah” moments you experienced as a result of this lab?
Inside and Outside of the Body

Murray Jensen, PhD
University of Minnesota, College of Biological Sciences, Biology Teaching and Learning, 3-154 MCB
420 Washington Ave SE, Mpls MN 55455
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Abstract

This lesson helps students develop a conceptual understanding of what is inside and outside of the body and sets the stage for lessons related to absorption, excretion, protection, and other phenomena that involve movement across membranes (e.g., oxygen movement within alveoli), or a break in a protective barrier (e.g., dangers of infection after breaking the skin). This topic is so basic to anatomy and physiology that many textbooks do not cover it. However, understanding what is inside and outside of the body, and how items move from one side to the other, is central to a robust understanding of anatomy and physiology. doi: 10.21692/haps.2017.042

Key Words: Inside the body, outside the body, movement across membranes

Target Audience: The target audience for this activity is students taking introductory anatomy and physiology.

Note: In physiology courses, this concept is typically found in Chapter 1 of the text and is discussed during the first week of class. In introductory anatomy and physiology courses the concept is often not found in the book and the whole concept is often omitted. However, a basic understanding of the “inside and outside” concept can lead to a deeper understanding of the digestive and respiratory systems, and even the integumentary system.

Learning Outcomes:

HAPS: Fundamental Content & Process Goals: #5
Recognize and explain the interrelationships within and between anatomical and physiological systems of the human body.

Learning Objectives Not found in HAPS Learning Outcomes

1. Students will be able to identify when a substance (e.g., molecules, bacteria, toxins) is inside or outside the body.
2. Students will be able to apply this inside/outside concept to normal physiology and pathophysiology.

Prior Knowledge: None required. This activity can be used on the first day of class in almost all anatomy and physiology courses.

Time requirements: 20 to 40 minutes

Lesson Overview for Instructors

The intent of this activity is to introduce the concept of “inside and outside” the body. For most introductory students this concept is odd (for example, food in the stomach is considered outside the body) but learnable. Students should examine the model closely to see that the “skin” is not continuous, but rather has breaks or openings for the urinary system, digestive system, etc. The instructor should not give away answers in this activity, but rather encourage students to look very closely at the model or answer student questions with still more questions. After inspecting the model, and discussing ideas with their group members, students should be able to develop a working understanding of “inside and outside” the body.

This activity can be used in a couple different sections of the course schedule. For some, it is a concept appropriate for the first week of class and for others it can be used as an introduction to the respiratory or digestive system.

This lesson following the POGIL (Process Oriented Guided Inquiry Learning) format and therefore implementation works best if students are assigned to groups of two or three and each member of the group is assigned a specific role. For this, and most other POGIL activities, the following student roles are recommended:

(The following roles are standard for most POGIL lessons.)

Reader: The reader reads the text of the activity out loud (directions, questions, etc.) so all members of the group can hear and follow along.

Note: Reading “model one” will be difficult because it is a graphic. Have students “describe what they see” in model one as opposed to “reading” model one.

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Recorder: The recorder makes the final decision as to what is written down for the final answer(s). The goal of the recorder is to determine the final language of each answer and to provide the official text of the answer. I have each student in a group write down answers to every question. Group members often have different ideas as to what a final answer should be.

Taskmaster: The taskmaster is in charge of making sure the group completes the activity on time and keeps the group members focused. The person may frequently say, “Are we sure about this?” “Are we ready to move on?” Or even, “Put away your phone - we need to get back on task.” The taskmaster is often called upon to be the spokesperson for the group at the end of the class and report answers to the class.

Examples of student conversation
“Food that inside your stomach is inside your body, right? It’s, like, way in there.”

“Should we go back and change our answer to question 8? That doesn’t seem right anymore.”

About the Author
Murray Jensen is an Associate Professor in the College of Biological Sciences at the University of Minnesota. Murray’s research focuses on teaching and learning in entry-level anatomy and physiology courses.
INSIDE AND OUTSIDE THE BODY ACTIVITY

Why?
If you swallow a piece of gum, it stays in your body for seven years – right? Well, no. That's just wrong. In this activity, you'll learn something else about that gum in your body.

Model 1: Cavities and Tubes in Humans

1. There are two lines on the left side of Model One, label the top one “outside body” and label the lower one “inside body.”

2. What structure (organ) creates the primary outer barrier that separates the inside from the outside of the human body?

3. As a group, find and label the following organs: lungs, kidneys, uterus, and intestines. Write directly on Model One.

4. Using your pencil, track the pathway that a molecule of undigested food (waste) would follow. The pathway starts at the beginning of the digestive tract.

Does this molecule ever enter the body? YES NO
5. Use Model One, your answer to question four, and the first answer provided in the table below to determine if the listed item is inside or outside the body. (Complete the table by putting an “X” in the correct column).

<table>
<thead>
<tr>
<th>Inside the body</th>
<th>Outside the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air in lungs</td>
<td>X</td>
</tr>
<tr>
<td>Food</td>
<td></td>
</tr>
<tr>
<td>Urine in bladder</td>
<td></td>
</tr>
<tr>
<td>Blood in circulatory system</td>
<td></td>
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<tr>
<td>A fetus developing in uterus</td>
<td></td>
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<tr>
<td>A wad of gum that you swallowed and is now in your stomach.</td>
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</tr>
</tbody>
</table>

6. If you swallow a piece of gum and it eventually passes out of the body in your feces, was it ever “in” your body? Explain.

7. Blood is inside the body, but it sometimes comes outside. What must happen for blood to move from the inside to the outside of the body?

8. As a group, provide a detailed explanation on how to determine if an item is inside or outside the body. (Hint: Examine the model.)
Extension Questions

9. A five-year old swallows a marble. As a group, discuss whether this is or is not a medical emergency. Will surgery be needed to remove the marble? Explain.

10. Patients with third-degree burns (the most serious) are highly susceptible to infection. Using your understanding of inside and outside the body, explain why third-degree burns are so dangerous, and predict what precautions a hospital would take to prevent infections in burn patients.

11. A biology student decides that he loves mitochondria so much that he gets a tattoo to represent this passion. Is the tattoo inside or outside the student’s body? Explain your reasoning.

12. In Model One, there are some very tiny arrows (look, for example, at the lungs). As a group, predict the meaning of these arrows.
An Exercise in Understanding The Basic Physics Governing Blood Flow

Amber E. Schlater PhD, Kelly Durick Eder PhD, and Lindsay Pacey, MS
Department of Biology, The College of Saint Scholastica, 1200 Kenwood Avenue, Duluth, MN 55811
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Abstract
The purpose of this laboratory exercise is to give students an understanding of how our blood flow rate changes as it moves through parts of our circulatory system by emptying water out of a carboy. Student understanding of bulk flow and Poiseuille's law is put to the test through a series of activities that require them to alter the rate of water flow through a tube. The ultimate goal is to give students an opportunity to physically manipulate the variables associated with bulk flow and Poiseuille's law.

Key words: circulation, bulk flow, Poiseuille's Law

Target Audience: Sophomore-level undergraduate Anatomy and Physiology Students

Learning Outcomes:
HAPS
K.1: Describe the major functions of the cardiovascular system.
K.12.1: Compare and contrast the structure of arteries and veins and arterioles and venules.
K.12.2.b: Correlate the anatomical structure of each type of blood vessel with its function.
K.14.1: Define blood flow, blood pressure, and peripheral resistance.
K.14.2: State and interpret the equation that relates blood flow to pressure and resistance.
K.14.9: Discuss how muscular compression and the respiratory pump aid venous return.

Prior Knowledge Required: Students should have had a basic introduction to circulation, bulk flow physics, and Poiseuille's law.

Time Required: 60-90 minutes

Guidelines for classroom implementation:
The purpose of this laboratory exercise is to give students an understanding of how our blood flow rate changes as it moves through parts of our circulatory system by emptying water out of a carboy. Student understanding of bulk flow (Flow = Pressure/Resistance) and Poiseuille's law (R = (8η*length)/(π*radius^4)) is put to the test through a series of activities that require them to alter the rate of water flow through a tube. Students will be prompted to alter the flow rate of water using tubing of varying diameter and length. Troubleshooting and failure are encouraged as a part of the learning process. The ultimate goal is to give students an opportunity to physically manipulate the variables associated with bulk flow and Poiseuille's law.

Students work in groups of three or four. While specific roles are not necessary, it may help to encourage groups to assign a note taker; this way, they are more likely to record all trials and errors and maximize their retention. Each group will be given medium-length, medium-width clear vinyl tubing, two water jugs/carboys (one to be placed on top of a lab bench/table and one to be placed on the floor), separate empty containers, an aquarium pump, a timer, and a box of “modifiers”.

The modifiers are:
Tube “tee” fitting (for splitting one tube into two)
Tube couplers (for using tubing of different sizes)
Short, medium, and long tubes with a small diameter
Short, medium, long tubes with a large diameter

Special note for instructors: be sure to have towels on hand!
Instructor observations (student conversations or misconceptions revealed by activity):

“I thought smaller tubing would have made flow speed up, because of capillary action.”

“The relationship between the length of the tube and flow was confusing to me, but I feel like I have a better understanding of that now.”

“So, muscles around our veins help blood return to the heart?”

“I thought I kind of understood blood flow when I looked at those equations in the book. Now I am definitely sure I get it.”

About the Authors

Amber Schlater earned a PhD in Zoology at Colorado State University and studied hypoxia in deer mice (Peromyscus maniculatus) during a postdoctoral fellowship at McMaster University.

Kelly Durick Eder earned a PhD in Microbiology and Immunology at the University of North Dakota and studied host-microbe interactions during a postdoctoral fellowship at St. Jude Children's Research Hospital.

Lindsay Pacey earned an MS in Clinical Anatomy at Creighton University and is currently working on an MEd.

Together, Dr. Schlater, Dr. Eder, and Lindsay Pacey team-teach Human Anatomy and Physiology I and II to 250 sophomore-level biology and pre-health professional students.
AN EXERCISE IN UNDERSTANDING THE BASIC PHYSICS GOVERNING BLOOD FLOW

Introduction
The circulatory system is a series of arteries, arterioles, capillaries, venules, and veins joined by the heart to create a complex, closed loop. Blood moves throughout the loop because the beating heart, which sets the stage for circulation, pushes it along. The mechanics behind how fast blood flows can be described by the following two equations:

**Bulk Flow:** \( \text{Flow} = \frac{\Delta \text{Pressure}}{\text{Resistance}} \)

**Poiseuille's law:** \( \text{Resistance} = \frac{8 \times \eta \times \text{length}}{\pi \times \text{radius}^4} \)
(\( \eta = \text{viscosity} \))

This laboratory activity will require you to put your understanding of these equations and bulk flow physics to the test. You will be required to move water out of a carboy (a large water jug) and into a bucket using the tubing provided. Then you will alter the rate at which the water flows by making various modifications to your tubing.

Upon completion of this exercise, you should have an understanding of the following objectives:

Have an understanding of how the **length** of a tube affects bulk flow.

Have an understanding of how the **diameter** of a tube affects bulk flow.

Make hypotheses about how change in fluid viscosity can affect bulk flow.

Be able to make connections to blood flow in your vasculature. For example: which parts of your vasculature are smaller? Larger? How might blood flow change upon reaching these various points in your vasculature?

**Materials**
- Two carboys
- Two filling bowls
- Clear tubing
- Modifier box
- Timer

continued on next page
Set-up

Fill each carboy with four liters of water. Keep one carboy (carboy #1) on top of your lab bench, and place the other on the floor (carboy #2). Then, place the two empty filling bowls on the floor next to (or beneath) each water jug (see Figure 1).

1. Using the medium-sized tube (without any modifiers), measure the time that it takes to fill an empty container from each carboy. Record your observations, making sure to label units. Was water flow the same for both water jugs? If not, what may account for the difference?

Time to empty Carboy #1: _____________________

Time to empty Carboy #2: _____________________

2. Open the box of modifiers. For both water jugs, modify the tubing three different ways so that the flow is faster. Then, modify the tubing three different ways so that the flow is slower (see Figure 2 for examples of modified tubing). Record your observations.

Fast Modifier #1: ______________________
Notes:

Fast Modifier #2: ______________________
Notes:

Fast Modifier #3: ______________________
Notes:

Slow Modifier #1: ______________________
Notes:

Slow Modifier #2: ______________________
Notes:

Slow Modifier #3: ______________________
Notes:
3. Predict what would happen to flow rate if you had honey flowing through the tube instead of water.

4. Relate your observations back to bulk flow and Poiseuille’s law. Where do your data support specific variables of these equations? How does this relate back to parts of the circulatory system? How was equipment in this activity different from your circulatory system?

5. What are other modifiers or tools that you could use to speed up the flow of water against gravity? Relate this to mechanisms in place for venous blood return.

**Figure 1.** Diagram of initial setup.

**Figure 2.** Examples of modified tubing.
nDNA Fingerprinting: Understand the Multiple Uses of Repeat Variants in the Human DNA Sequence

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Abstract
This activity is best for students at an intermediate level, such as the second or third year of BSc Biology. I typically give this activity at the end of the chapter on the genomic organization of human DNA in a cell biology course. In this activity, we will virtually produce DNA fingerprints of students in the classroom, using four highly polymorphic loci. At the end of this activity, students should have a deep understanding of polymorphic DNA as a way to find identity and heredity. doi: 10.21692/haps.2017.044

Key words: DNA, polymorphisms, heredity, meiosis, allèle

Target Audience: This activity is best for students at an intermediate level, such as the second or third year of BSc Biology. This activity is typically given at the end of the chapter on the genomic organization of human DNA in BIO201 (Cell and Molecular Biology), but it could also be suitable for BIO208 (Genetics), as long as it is introduced after pre-requisite courses where the basics are covered.

Learning outcomes:
HAPS:
S.1. Describe events that lead to genetic variability of gametes
S.3. Describe examples of prenatal and postnatal genetic testing

Additional outcomes:
Reinforce knowledge about the various types of DNA sequences in the human genome.
Reinforce the understanding of PCR and electrophoresis.
Understand and apply the concept of homo/heterozygosity.
Apply the concepts of alleles / distribution of chromosomes at the molecular level.
Understand the genetic relationships between related individuals.
Help students discover potential pitfalls of the method.
Ultimately, students should, at the end of this activity and after answering the questions, have a deep understanding of polymorphic DNA as a way to find identity and heredity.

Prior knowledge:
Structure of DNA, types of DNA sequences in the human genome (unique / moderately repeated / repeated sequences), genomic organization, mitosis and meiosis.
While it may not be fully understood, students should have learned the concepts of homozygous and heterozygous, as well as the concepts of alleles and chromosomes.
Genetic variability / polymorphisms.
Students should have seen the basic techniques of polymerase chain reaction (PCR) and electrophoresis.

Time required and guidelines:
Time required before activity: preparation 30 minutes:
Prepare 4 boxes / envelopes / bags, each labelled with the identification one of the loci under study. Prepare little pieces of paper with numbers, and distribute the papers as follows:
Box CSF1PO, place several papers with a number: for this locus, numbers will be 5, 6, 7… etc up to 16. Put several copies of each, randomly.
Box THO1 containing papers with numbers 17, 19 and 21, several copies of each.
Box VWA filled with papers with numbers 0 to 8, each in several copies.
Box FGA, filled with papers with numbers 4, 8, 12 and 16, each in several copies.
Prepare a grid on a large piece of paper, or on the board, where students will be able to report their results. Alternatively, it can be an individual grid provided on the report sheet.

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**Time during class:** 1 hour:

Distribute the question sheet. Allow students to read for **two minutes**.

Form groups of four to five students, so they can help each other, but each student works on their own data and fills their own worksheet, for questions 1 to 7.

Have students pick two papers for each locus and report their numbers in the table of the question sheet (students often think that they have to pick only two papers. They must take **two papers for each locus**, so they should end up with 8 papers. If you do not have enough papers (large classroom) you can ask them to put the papers back in the box once they have reported the numbers. Students have **five minutes** for this activity. If the class is large, you can reduce the time by having multiple boxes.

Have students calculate the size of predicted fragments obtained from amplification of their four loci – Allow **five minutes** for this step.

Ask students to report on the common grid (board or paper), as well as on their own grid. Allow **five minutes** for this activity.

Have students answer questions 1 to 7 – allow **15 minutes** for this activity.

Students report their results to the classroom. Identify the culprit, if any, in this classroom. Allow **ten minutes** for this activity.

Briefly discuss the activity with students and ask them what they have learned from this activity.

**Time after class:** for in-class discussions

Allow **two to three days** to have students answer additional questions (8 to 20)

Ask them to work in teams of four or five and identify roles:

- **A technical expert** who will be able to explain the procedure.
- **A spokesperson** who will report in front of the classroom and may receive help from the technical expert.
- **A task manager** who makes sure that questions are being answered and calls the teacher in case of unsolved questions.
- **Group members** who contribute to the discussions.

Ideally at the next class, allow **20 to 30 minutes** to discuss questions and answers with each team's spokesperson and with the help of technical experts.

You may wish to ask your students to go further and explore FBI DNA databases and perform researches of sequences and such.

This can be a good start to introduce a new topic such as the blood clotting cascade (starting with the VWA polymorphic locus), or cell cycle / cancer with the polymorphic CSF1P0 locus studied here.

Resource page for CODIS loci: [http://strbase.nist.gov/fbicore.htm](http://strbase.nist.gov/fbicore.htm)

**Important note:** in this activity the sequences and numbers of repeats have been modified in order to render the activity understandable for students. Remember that the real CODIS sequences have in fact many more alleles, and that the product sizes are kept different between various loci because of the use of primers that amplify flanking sequences of various sizes. Without these flanking sequences, it would be impossible to discriminate products from the amplification of the four loci because they roughly have the same size and number of alleles. In this activity we want students to understand the principles but this particular technicality will not help understanding and might instead lose students into unnecessary technical considerations.

**Student feedback and discussions:**

- Discussions I had with the students at this point were very positive as most of them had previously seen DNA fingerprinting band patterns, and they knew that you had to look for the presence of same / different bands. But they told me that they had never in fact realized what it really meant, what these bands were. A lot of them had never realized that each band is in fact a « pair of bands » coming from same locus with 2 different alleles. They had never realized that they could be homozygous for a given locus. A lot of them believed that if you had, for instance 7 repeats in a sequence, you would have 7 bands.

- A lot of students also believed that each individual is unique in the numbers of repeats, and were surprised that their neighbour student could have a same number of repeats in a given sequence. With the activity, they understood that it is the combination of variable (but non unique) numbers of repeats, found each in 2 same or different copies in a given individual, and on a multiple number of loci (here 4 but normally 13) that makes a unique pattern.

- The fact that students see the concepts of homozygosity / heterozygosity / alleles without linking them to a trait made them understand this concept at a deeper level.

- We also had very interesting discussion after they had completed the additional questions, about unicity, variability and stability of DNA sequences; we discussed the advantages and inconvenience of greater variability vs greater stability of the DNA. We discussed the use of variable DNA sequences as a mean to « track » the transmission of more stable sequences like genes.

- We discussed polymorphisms within genes after I showed them that some of the polymorphisms employed here are in fact located in genes encoding critical proteins

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(for instance Von Willerbrand factor) and ended up discussing the variability in blood clotting capacities potentially explained by polymorphic VWA genetic sequence. Students realized that it is wrong to speak of « the » sequence of a gene and realized that each coding sequence in the human genome displays a substantial level of variability.

**Common misconceptions about DNA fingerprinting:**

- Wrong or incomplete understanding of what a polymorphism is
- DNA fingerprinting is a kind of pattern of DNA fragments that is unique to everyone. Half of it is shared with parents. It is however difficult for students to say why this pattern is unique.
- If we share bands we are probably linked
- Students unable to say what the bands represent apart « pieces of DNA »
- Students unable to apply concepts of homo/ heterozygosity to the concept of DNA fingerprints

**Background:**

DNA fingerprinting is an identification technique that uses specific characteristics of human DNA sequences to identify unique individuals. The human genome, in the context of individual identification, regroups all the pieces of DNA found in the nucleus and in the mitochondria of a human cell. In humans, DNA has a very specific organization. While it is entirely made of the same four nucleotides A, T, C and G, the way those nucleotides are aligned changes along a single piece of DNA. Three types of alignments (called sequences) are known in humans:

1. **Unique sequences**, which are alignments that are found only once per haploid genome. They are complex sequences. If you had to remember one of these, it would be very difficult because it would just be a very long succession of letters in random order. These unique sequences are usually genes, sequences that code for proteins. While they are unique in a single cell, their exact copy is found in every cell of a human being, and because they code for proteins, they are usually found in exact copy in other human beings expressing the same proteins. Thus, they are unique but also very conserved among individuals; therefore they are not very useful to discriminate one individual from another.

2. **Moderately repeated sequences** are alignments of nucleotides that are usually shorter than genes and repeated several times in the genome of a same individual. They usually serve as regulatory sequences, gene promoters or even gene families where there are several repetitions of the same gene with little variations. Again, these sequences, even though they do show some variations within their group, are found to be the same in every human being. Likewise, these sequences are probably not the best targets to identify unique individuals.

3. **Highly repeated sequences** are very short sequences (between two and ten nucleotides) repeated several times. While the location and composition are the same in every human being, the number of times the sequence is repeated varies among individuals. They are very good targets to identify people because we know exactly where they are in the genome, we know exactly the nucleotides they are made of and the number of repeats is easy to detect because it will affect the size of the DNA portion containing the repeat. One repeated region (locus) may be found with the same number of repeats in more than one human being. However, if we look at two repeated regions, there is much less chance that two unrelated individuals will have the same number of repeats in the two given regions. Then if we look at even more regions and compare the number of repeats in each of these regions, it is almost impossible that all their repeats are identical. A total of 20 regions have been validated by the FBI to serve for identification purposes. In fact routine examinations are restricted to a short list of 13 loci and only if ambiguities remain will they analyze all 20 sites. They span a huge variety of chromosomes and they are called CODIS (Combined DNA Index System).

The technique used to detect the number of repeats in each CODIS is a simple **Polymerase Chain Reaction**, followed by a gel **electrophoresis**. In short, investigators use very small pieces of DNA that are complementary to the sequences located before and after the CODIS. We call them primers. Enzymes are used to identically copy the region found between those primers. Several rounds of amplification later, we obtain enough copies of the DNA piece found between primers that we can visualize it on an agarose gel. In a typical investigation, as many as 20 CODIS can be amplified at the same time (multiplex amplification), all with different sizes. Each of them is amplified in enough copies to produce a band visible on a gel. If an electric current is applied through the gel, DNA pieces will migrate towards the positive end. This technique is called **Electrophoresis**. The pieces of DNA will, however, migrate at different speeds; the smallest going faster and biggest going slower. If we let them migrate long enough, there will be a succession of bands, each of which corresponds to a collection of DNA pieces of the same size, each piece corresponding a CODIS with a given number of repeats. The pattern created by all the bands corresponding to the several CODIS tested represents the number of repeats in each of them, for a given individual. If two different individuals share the same number of repeats in a CODIS, it is statistically extremely improbable that they will share the same number of repeats in all 13 or 20 CODIS. Thus, a given pattern is unique to a given individual.

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**Note:** For purposes of simplicity, the numbers of repeats have been limited in the following activity. Here ([http://strbase.nist.gov/str_fact.htm](http://strbase.nist.gov/str_fact.htm)), you can find a list of all the CODIS that have been validated by the FBI. You can click on any part of the CODIS to find the primers used to give valid results, the number of repeats possibly found in the human population, and the size of the DNA pieces expected if you run a PCR on this CODIS. Validated CODIS and primers usually produce fragments between 100 and 400 nucleotides, which is the range in which the resolution is greatest and allows visualization of differences between fragments that differ by only one nucleotide. For this activity, please use the information provided in the text below.

**About the Author**

Estelle Chamoux is a Professor in the Biology department of Bishop's University. She has always used active learning techniques and real-life case studies, however, it is only recently that she has documented these activities and evaluated them for use in an active-learning classroom.
nDNA FINGERPRINTING ACTIVITY

Context
Gum has been found stuck under one of the tables of the classroom. This is really disgusting and there is no way the university will allow this behavior to go on. We need to find the culprit. Suspicions center on biology students and mathematics students, both of whom had class just before the gum was found. DNA extraction has been performed on the gum and the DNA fingerprints of the chewer have been determined. We now need to analyze the DNA of all students in the classroom in order to determine if the culprit is a biology or a mathematics student.

Activity
In this activity, we will virtually produce DNA fingerprints in all students of the classroom, using four highly polymorphic loci. These four loci are among the thirteen CODIS (Combined DNA Index System) repeat variants used routinely by the FBI in forensic investigation (see picture below).

![Figure 1](http://strbase.nist.gov/fbicore.htm)

**Figure 1** Picture representing the genomic distribution of the 13 loci selected by the FBI for DNA fingerprinting
(Source http://strbase.nist.gov/fbicore.htm)

**CSF1PO** is located on chromosome five; it is a four-nucleotide repeat, sequence TAGA. It can be repeated, in humans, between five and sixteen times.

**THO1** is an eight-nucleotide repeat, sequence TCTGTCTA. Three alleles are known in humans with 17, 19, or 21 repeats.

The third locus, **VWA**, is again a four-nucleotide repeat, sequence CTTT. In the human genome, variants from zero to eight repeats have been identified.

Finally, **FGA**, a 18 nucleotide repeat has been found repeated 4, 8, 12 or 16 times in the human genome.

continued on next page
Questions

1. Create your CODIS pattern. Pick two papers from each box identified with the name of a locus.
   a. In the table below, record the number of repeats indicated on each of these papers. The number of repeats picked corresponds to one allele for each locus (don’t mix loci!). You need to pick two alleles for each of the four loci.
   b. Predict the size of each fragment corresponding to the loci analyzed in your DNA sample (the two alleles might have a different size). Report this in the table below.

Table 1: Record in this table the number of repeats picked for each allele of each locus, report in “# of repeats”. Calculate the size of each fragment, report in the column “Predicted size”

<table>
<thead>
<tr>
<th>Locus</th>
<th># of repeats</th>
<th>Predicted size</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSF1PO allele 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSF1PO allele 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THO1 – allele 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THO1 – allele 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VWA – allele 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VWA – allele 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FGA – allele 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FGA – allele 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Up to how many bands will you obtain if you submit your DNA fragments to electrophoresis? Is it possible that you obtain fewer bands?

3. On the provided grid, which would correspond to an agarose gel where DNA fragments are being migrated? Draw your own DNA fingerprints. Report this drawing on the table in the classroom.

Figure 2 Grid representing an agarose gel. Use the grid to show the bands corresponding to your personal fragments. Report to the whole classroom. Compare your pattern of DNA fingerprints with that of the culprit.
4. On the grid/gel, are your fragments ordered from smallest to largest or from largest to smallest? Why?

5. Are there any alleles for which the sample is homozygous? How should this appear on the gel?

6. Compare your DNA profile with that of the culprit. Are you this person? Is anyone in the classroom the person we're looking for?
Additional questions

7. It is said above that THO1 has three alleles in humans. Can you write the sequences of these three alleles?

8. How many alleles does the FGA locus have?

9. Analysis reveals a student obtains a single fragment of 16 nucleotides for VWA, while his parents have the following pattern for this four-nucleotides locus: mother 0/8 repeats (alleles with 0/32 nucleotides), father 1/7 repeats (alleles with 4/28 nucleotides). What is the most likely explanation; justify the answer of your choice. Choose the reason why you reject answers from the following list:

   a. This is normal, both parents provided half of their nucleotides, therefore they each gave 16 nucleotides. The student is now homozygous.

   b. There has been a mistake in the procedure.

   c. It is normal as the repeats are distributed randomly, so the student could very well have received 4 repeats for each copy of the locus.

   d. This child was adopted.

10. A dad is heterozygous with 8 and 12 repeats for the locus FGA. The mom is homozygous with four repeats. While the first child of the couple is found to be heterozygous with four and eight repeats, their second child, born with several inborn disorders, is homozygous with 12 repeats. What would be the best explanation for this observation?

11. How can you explain that both the mother and the father of an individual are heterozygous for a given locus and that their child is homozygous?

12. How many possible combinations of alleles can you make for the locus CSFPO1?
13. How many possible patterns of fingerprints exist if you consider the four loci under study here? If we consider that there are 60 students in the Biology group and 52 students in the Mathematics group, what are the chances to obtain the same results for two different students?

14. Because the numbers of repeats are different among individuals, does it mean that some have more DNA than others? Hence more genes?

15. We know that some diseases are linked to unstable repeat numbers, where the number of repeats changes from one generation to the next. How is this possible?

16. Considering again question 13, do you think this could affect the results of DNA fingerprinting results? Why or why not?

17. Discuss the concept of stability of the loci and the concept of variability of the tandem repeats. In other words, how can highly polymorphic loci help to trace identity (uniqueness of an individual) and relatedness (stability between relatives) of individuals?

18. Considering two second-degree parents (grand-parents and grand-child for instance). Is it possible that the grandchild has a fragment that is not found in any of the grandparents?

19. In the classroom, there is a debate: give your opinion and defend your choice between a and b:
   a. Not finding a fragment that was present in both parents is a proof of non-relatedness
   b. Finding a fragment that wasn't present in any of the parents is a proof of non-relatedness?
Short-Term Cardiovascular Control

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Abstract
The control of blood pressure through the baroreceptor reflex is commonly discussed in both the cardiovascular system unit and as an example of homeostasis. Yet the application of this model to actual data is often more challenging than predicted. This guided inquiry activity allows students to apply relevant data to the homeostatic changes that occur during lower limb exercise as a way to refine their understanding of this feedback loop. doi: 10.21692/haps.2017.045

Key words: baroreceptor, homeostasis, feedback loop, exercise

Target Audience: For advanced physiology students

Content Objectives/Learning Goals:
Students will be able to:

a. Apply the relationships between MAP, HR, SV and VR in the context of rest and during exertion (exercise).
b. Identify HR as an effector in the control of MAP and not a controlled variable.
c. Identify that just because a variable/value does not change, that it is not necessarily homeostatically controlled.

Prior Knowledge:

a. Definition of homeostasis.
b. Components of a homeostatic feedback loop (sensors, integrator, effectors, regulated variable(s)).
c. Relationship between mean arterial pressure (MAP), heart rate (HR), stroke volume (SV) and vascular resistance (VR).

Time required: This is an advanced activity that is predicted to take approximately one hour but will vary based on the level of students and the number of times the facilitator intervenes in the activity. It will also vary based on modifications by the facilitator.

Implementation Notes for Instructors:
This is a more advanced activity that is best used to summarize how changes in blood pressure are regulated in the short term and to apply the concept of homeostatic feedback loops to this control. An additional goal is for students to identify that HR is not a homeostatically controlled variable – a common misconception; and that even if a “measured” variable stays constant, it may not be homeostatically controlled (Modell 2015). Instructors may wish to have regular team reports throughout the activity to assess student’s application and understanding of topics.

The activity generally works best in groups of three to four students and specific roles may be assigned to aid in completion of the activity. For example:

Manager – keeps the team on task
Reader – reads the questions to the group.
Recorder – records “official” team answers
Reporter – reports team answers when requested by the instructor

Instructors are encouraged to read through the entire activity and make adjustments based on their particular needs before making copies for their students. Questions can be changed for modified to best suit the course.

The source used to create the data table in model one (see image credits below) contains additional time points, indicating an increase in blood pressure over three minutes of exercise, which could be added and used to portray a central resetting of the blood pressure set point, which is supported by some sources.

Facilitators may or may not want to include the data related to femoral artery cross-sectional area in their activity, depending on whether or not they want to stress that just because some experimental variables do not change, they are not always homeostatically controlled variables. Removal of such data would require a change to a couple of the questions.

Model two could be replaced with an image from a textbook or other proprietary source that you use for your course, as long as it is not shared outside of your own students.

continued on next page
Literature cited

About the Author
Ron Gerrits is a Professor of biomedical engineering at Milwaukee School of Engineering (MSOE). He earned his BS degree in biomedical engineering from MSOE in 1994 and his Ph.D. in Physiology from the Medical College of Wisconsin (MCW) in 1999. That same year he returned to MSOE to become the coordinator of the health science courses. Since that time he has taught a variety of courses, including cell biology, microbiology, nutrition, physiology, pathophysiology and pharmacology, to nursing, biomedical engineering and perfusion students. He is active in the Biology Scholars program, the Human Anatomy and Physiology Society, Project Lead the Way, and various summer programs for high school students.

Full data table (see implementation notes) is:

<table>
<thead>
<tr>
<th>Experimental variables</th>
<th>Rest</th>
<th>10 s</th>
<th>20 s</th>
<th>30 s</th>
<th>60 s</th>
<th>120 s</th>
<th>180 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (beats/min)</td>
<td>76</td>
<td>82</td>
<td>82</td>
<td>86</td>
<td>86</td>
<td>96</td>
<td>108</td>
</tr>
<tr>
<td>Mean BP (mmHg)</td>
<td>91</td>
<td>90</td>
<td>93</td>
<td>92</td>
<td>93</td>
<td>101</td>
<td>103</td>
</tr>
<tr>
<td>Femoral artery blood flow (l/min)</td>
<td>0.29</td>
<td>1.54</td>
<td>1.5</td>
<td>1.59</td>
<td>1.69</td>
<td>2.12</td>
<td>2.85</td>
</tr>
<tr>
<td>Leg Vascular Conductance (ml/min/mmHg)</td>
<td>2.9</td>
<td>10.5</td>
<td>9.9</td>
<td>10.4</td>
<td>11.2</td>
<td>13.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Cross sectional area of the femoral artery (mm2)</td>
<td>17.2</td>
<td>17.4</td>
<td>16.3</td>
<td>16.3</td>
<td>16.7</td>
<td>16.3</td>
<td>16</td>
</tr>
</tbody>
</table>

Model and Image Credits

Model 2: Murray Jensen (own work) and may be used or modified for educational purposes.

Figure 1: Ron Gerrits (own work) and may be used or modified for educational purposes.

Example student conversations:
“Heart rate is a regulated variable, I know I have read that somewhere”

“If you remind me how conductance relates to resistance of a blood vessel?”

Answer Key
It is best to generate your own answer key based on expectations for your course. However, an answer key can also be found on the HAPS website.
Control Short-Term Cardiovascular Function

Student Version

Model 1. Research Data. In order to obtain data related to cardiovascular function during exercise, the following was collected from 10 healthy male volunteers at rest and at various time points (in seconds) after the initiation of short bouts of upright stationary bicycle exercise. Data is presented as mean values from the group.

<table>
<thead>
<tr>
<th>Experimental variables</th>
<th>Rest</th>
<th>10 s</th>
<th>20 s</th>
<th>30 s</th>
<th>60 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (beats/min)</td>
<td>76</td>
<td>82</td>
<td>82</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Mean BP (mmHg)</td>
<td>91</td>
<td>90</td>
<td>93</td>
<td>92</td>
<td>93</td>
</tr>
<tr>
<td>Femoral artery blood flow (l/min) in one leg</td>
<td>0.29</td>
<td>1.54</td>
<td>1.5</td>
<td>1.59</td>
<td>1.69</td>
</tr>
<tr>
<td>Leg Vascular Conductance (ml/min/mmHg)</td>
<td>2.9</td>
<td>10.5</td>
<td>9.9</td>
<td>10.4</td>
<td>11.2</td>
</tr>
<tr>
<td>Cross sectional area of the femoral artery (mm²)</td>
<td>17.2</td>
<td>17.4</td>
<td>16.3</td>
<td>16.3</td>
<td>16.7</td>
</tr>
</tbody>
</table>

1. Over what time period (in minutes) was data collected during exercise?

2. Complete the following table using the data from model 1.

<table>
<thead>
<tr>
<th>Change in value from rest to last measurement during exercise (show calculation)</th>
<th>HR</th>
<th>Mean BP</th>
<th>Femoral artery blood flow</th>
<th>Leg vascular conductance</th>
<th>Cross sectional area of femoral artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent change in value from rest to last measurement during exercise (show calculation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Rank the experimental variables from those that changed the least to those that changed the most on a percentage basis.

4. Which (if any) of the experimental variables would you predict to be homeostatically controlled variables? Provide reasoning for your answer(s). Continue on back if necessary.
Model 2: Structural Components Involved in a Feedback Loop that Helps Control Short-Term Cardiovascular Function

5. Label those structures in model two that are involved in the short-term control of cardiovascular function (label as many as you can). Write directly on the model.

6. List the structures that you labeled on the model. Briefly describe the function of each.

7. Below is a general model of a homeostatic feedback loop. Categorize the structures/ functions from the previous question into components of the loop. Are there any structures/ functions listed in the previous question that are not part of the loop?

8. What information travels from the structures in Model 2 to the brainstem? Does any of this information come directly from the heart?
9. There is both sympathetic and parasympathetic innervation to the heart. How does stimulation from these two types of innervation effect heart rate, stroke volume and blood pressure (if at all)? What are the mechanisms by which such changes are effected?

10. Develop a two or three sentence explanation how heart rate is controlled.

11. Develop a two or three sentence explanation as to how blood pressure is controlled.

12. Which of the following statement(s) is/are true (could be either, both or neither)?
   a. HR is a homeostatically controlled variable.
   b. BP is a homeostatically controlled variable.

13. Justify your answer(s) to the previous question. It may be helpful to refer to the models and diagram in question 7.
**Extension/Challenge Questions:**

14. Referring back to model one, what happens to blood flow into the legs during bicycle exercise? Explain/predict what happens to cardiac output during this same time.

15. Assuming a resting cardiac output of five L/min and that any additional increase in CO with exercise is supplied to the legs, what happens to stroke volume between rest and 60s?

16. Write an equation that shows the relationship between mean blood pressure and cardiac output. Hint: The equation needs to contain at least one other variable.

17. What happens to vascular resistance in the legs during bicycle exercise? Comment on how the data for both leg vascular conductance and femoral artery cross-sectional area either support, or do not support your conclusion about vascular resistance in the legs. Explain any discrepancies.

18. Would you define the femoral artery cross-sectional area as a homeostatically controlled variable? Why or why not?
19. Using the following figure as a starting point, redraw it to show the response to exercise illustrated in Model 1. It may be helpful to realize that this data was not measured continuously, but at specific time points. Consider the original perturbation to be exercise that induces a large change in leg vascular conductance (as supported by data in Model 1).
“Winging It” Chicken Wing Dissection

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Abstract

The concept of muscle contraction working in concert with joints to produce a specific movement is often an abstract concept. Through this chicken wing dissection students can investigate bone anatomy, joint structure, movement production, and histological tissues. This dissection is a cost effective, efficient way to incorporate a lab activity that can summate a significant amount of information given in Anatomy and Physiology I. doi: 10.21692/haps.2017.046

Key words: origin, insertion, movement, long Bone

Target Audience: Undergraduate Level Anatomy and Physiology I or Advanced High School Students

Learning Outcomes:

HAPS:
F.3.1 Identify the structural components of a long bone, with emphasis on region of longitudinal growth.
F.8.3 Describe and demonstrate the generalized movements of synovial joints.
G.8 Identify the origin, insertion, and action of the major skeletal muscles and demonstrate these muscle actions.

Prior Knowledge: This activity is best done following a lecture on joints and gross muscle anatomy. As prerequisite knowledge students need to know general histology, bone anatomy, and a basic knowledge of gross muscle anatomy. This activity can also be used to review former topics including histological components of skin as a means of connecting those concepts to the thought of the different structures working as a unit. Knowledge of the sliding filament model is not required.

Time Required: 30-45 Minutes

Guidelines for Classroom Implementation:

Note safety concerns associated with the use of raw chicken in the student work sheet. I personally do not use gloves because I do not see the need for it as long as everyone is conscientious about washing their hands.

This lab usually costs less than $40 to run with a class of 70 students. Chicken wings are readily available from any grocery store. I use one chicken wing to four students. Choose the fresh (not frozen) whole chicken wings. Do not get the drumette and wingette cut pieces.

Check with your school and see if any animal research is done. We have a turtle research team and they asked me to save all of the scraps from the lab and place them in the freezer for baiting traps. This allows us to put the waste to good use and use our departmental money more efficiently.

The skin does not remove well on the posterior side of the elbow and below the wrist. Removing the skin below the wrist is not worth the time spent, in my opinion.

If you do not have needle holders or hemostats that can push down and lock, a hammer and a sandwich bag can be used. I have used a sandwich bag, but the needle holders work better. If a sandwich bag is used, take the students outside for this part and tell them NOT to beat the bone to a pulp with the hammer, one or two strikes with the hammer should be sufficient.

For our general education assessments we are required to assess the physical principles of a biological topic. I use an extended response questionnaire to satisfy that student-learning outcome.

continued on next page
**Instructor Observations:** Seeing is understanding. This activity allows students to see what I have been teaching from the beginning. Even some of the brightest students have never thought about how muscles cause movement. This activity is a great way to demonstrate movement production.

The tissues of the body should have been covered prior to doing this activity. Areolar connective tissue is a tissue students struggle to understand in terms of location and structure. During this activity I specifically point out the areolar connective tissue to give students a better understanding of its structure, function, and location.

Dense regular connective tissue makes up the tendons. Students can actually see the fibers in the raw chicken wing. This is a light bulb moment for students.

I encourage students to create movement in several different ways. They can manipulate the wing to move at the wrist and the elbow. This allows them to understand the complexity of muscular contraction/relaxation that generates even the simplest motion with the arm. Appreciating complexity is important. My students also enjoy “raising their hand” with their chicken wing to get my attention and waving at each other from across the room.

Bones are vascularized. There is usually a nutrient artery entering the diaphysis of the bone, allowing students to see the vascularization of the tissue.

Bone marrow is subdivided into red and yellow marrow. Students associate yellow marrow with adipose tissue, but they do not usually realize the amount of vascularization that is found in the tissue.

Direct and indirect muscle attachment can be seen in the specimen. Usually this is a concept that is not fully understood, but can be clarified through this activity.

**Safety Information**

This lab involves the use of raw chicken. This increases the risk of coming into contact with *Salmonella enterica* bacteria, which may cause illness. All students should wash their hands after all chicken has been thrown away and clean up everything that could have been touched while the chicken was being handled. Use the bleach spray to clean the table.

This lab also involves sharp instruments. Use common sense and be careful. In the event of an injury please notify the instructor immediately.

**About the Author**

Wendy Gean is an instructor of biology at Freed-Hardeman University in Henderson, Tennessee. Mrs. Gean taught high school for five years. During which time she earned her Masters degree is from Mississippi State University in General Biology. She then moved to higher education and is in her fifth year of teaching at the collegiate level.
Dissection Directions and Objectives For Students

As you observe the chicken wing reflect on prior lab units and think about the types of tissue that make up each structure. Think about how structures and functions coordinate. Begin to remove the skin at the “shoulder” and move toward the “elbow.” This will include using your fingers to separate the superficial tissues from the muscle. Once the elbow is reached you will notice that removing the skin will be more difficult. One helpful maneuver is inserting your scissors while they are still closed, then open them to break the connective tissue. Find the loose (areolar connective tissue) that connects skin and muscle. This tissue is a clear layer that must be separated to remove the skin.

Isolate a piece of skin and examine the dermis and the pale yellow subcutaneous adipose tissue that remains with the skin. The skin can be cut with scissors to see the layers more easily.

You will note the muscle appears to be beige in color. Remember that each muscle is covered in a series of layers of connective tissues that are not visible to the naked eye.

**Dissection Question 1.** If you are looking at the *biceps brachii* muscle as a whole it is covered in layers of connective tissue. What is the name of the most superficial layer? Describe it.

Tendons are formed where muscle meets bone. They should be iridescent. Notice their fibrous consistency. Tendons are composed of dense regular connective tissue. Compare the tissue to what you saw as dense irregular tissue that made up the dermis.

**Dissection Question 2.** Describe the difference in the connective tissue of the dermis and the tendon. Include the direction of the fibers.

Using your probe or fingers pull on the muscles or tendons to mimic the shortening of a muscle. Try to make your wing move at the two different joints, the elbow and the wrist. Notice the motions produced.

**Dissection Question 3.** In the space below draw the elbow joint you are seeing. Include the humerus, ulna, radius, *biceps brachii*, and *triceps brachii*. 
**Dissection Question 4.** What type of motion does contracting the biceps produce?

**Dissection Question 5.** What type of motion does contracting the triceps produce?

Break the elbow joint. You will have to force the joint beyond its normal range of motion. You will find tendon attachments around the joint and articular cartilage in the joint. You may find some ligaments that connect the bones.

**Dissection Question 6.** What is the color of the articular cartilage? What does the color suggest about the articular cartilage blood supply?

**Dissection Question 7.** If you pull the connective tissue found around the bone all of the muscles, tendons, and other structures are stripped from the bone. What is the connective tissue covering the bone that contains the attachments called?

Clean off a bone. Attempt to find the nutrient artery entering the diaphysis. Use the needle holders to apply pressure to the diaphysis, then the epiphysis, until they crack. You will notice blood. Remember that bone is a highly vascularized tissue. You can also find the epiphysis and diaphysis contain different types of bone and marrow.

**Dissection Question 8.** What type(s) of bone are in the epiphysis? Draw an illustration below to show the arrangement and label it.

**Dissection Question 9.** What type(s) of bone are in the diaphysis? Draw an illustration below to show the arrangement and label it. Include the medullary cavity.

You may investigate your chicken wing further as desired, but keep it all in the tray and do not flick it around the table. You may try to find direct/indirect muscle attachments, blood vessels, nerves, ligaments, etc.
Clean Up Instructions:

1. Pick up all of your chicken and your instruments. PUT ALL THE CHICKEN IN THE LARGE ZIP LOCK BAGS…NOT THE TRASH CAN OR DOWN THE SINK.
2. Wash all instruments and the dissecting pan. Put the instruments back into the pan and return the trays to your lab tables.
3. Clean your table with bleach spray and paper towels.

Complete exercises below

Name:_________________________________________ Lab Section: _______________

Be able to identify the following items on your chicken wing.

- Articular Cartilage
- Diaphysis
- Epiphysis
- Compact Bone
- Areolar Connective Tissue
- Adipose Tissue
- Creation of motion at the wrist
- Creation of motion at the elbow

- Tendon
- Skeletal Muscle
- Spongy Bone
- Medullary Cavity
- Yellow Marrow
- Red Marrow

In this image (right) label the following:

1. Origin
2. Insertion
3. Biceps brachii
4. If the nutrient artery is coming into the diaphysis of the bone, then this is associated with the primary ossification center or the secondary ossification center?

5. Provide an example of the antagonist to the biceps brachii from the lab activity. What evidence do you have to support your claim?

6. When you broke the elbow joint, what motion was required to do so? Explain.

7. For each of the following please label the types of motion seen in the images.

(a) ___________ at the elbow
(b) ___________ at the knee
(c) ___________ of the upper limb
(d) ___________ of the lower limb
(e) ___________ of the upper limb
(f) ___________ of the foot
(g) ___________ of the head
(h) ___________ of the forearm
8. Compare and contrast the anatomy and physiology of the red and yellow marrow?

9. Why is the yellow marrow also red in your specimen?

10. An individual is having joint pain from 20+ years of competitive tennis play. He decides to take a chondroitin/glucosamine supplement daily. He does not note any change for at least 6 months. What property of the articular cartilage affecting the use of chondroitin/glucosamine supplements, and any other drug, and why does that impact the length of time needed to see results? How does this relate to the slow healing of articular cartilage?
Extended Response Section

In a paragraph that consists of three to five sentences explain how muscles, bones, and joints create motion. Explain how a lever (simple machine) is used to produce motion. You will need to focus on the physical principles of how the muscle causes motion. Include the terms origin, insertion, and force. No extended response answers should match exactly.
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Cindy Wingert
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