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The Perfect Team—Our Heart and Lungs

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Introduction

Every teenager should be able to tell you that they have a heart and two lungs and that these organs circulate blood and take in air, respectively. But how many can explain *why* and *how* these organs perform these functions, or *what happens* over time when we mistreat them? I continue to be shocked when I find how little my students know about their bodies, their health, and how nutrition and lifestyle choices affect them. Teenagers thrive on instant gratification and they typically fail to think of the long-term ramifications of their actions. The fact that the body tolerates a great deal of abuse, especially in youth, makes it difficult to realize the cumulative effects that small, short-term choices have the organs.

While we often take for granted the consistent and automatic patterns of the heart and lungs, we would die in a matter of minutes without either organ. This three-week unit explores the basic structures and functions of the organs and their associated tissues from both a cellular and whole-organism approach. The objective is to create learning that is relevant and communicable on the essential (yet fragile) nature of these organs. The unit will incorporate technology and hands-on learning and culminate in a student-centered project emphasizing the importance of spreading health awareness to peers, family, and the community.

This unit is designed for my senior-level International Baccalaureate biochemical biology class, but can be adapted for any course covering human health or physiology. I teach at a neighborhood (non-selective enrollment) high school on the southwest side of Chicago. According to Chicago Public School's High School Report Card, 94.4% of my students qualify for free or reduced lunch, and 95.9% are racial minorities (the large majority of whom are Hispanic) [1] . Many of my students, including the advanced seniors this unit is tailored for, struggle with literacy, effective and appropriate communication, and traditional teaching and learning styles. Most of these students will pursue post-secondary education in some capacity, so I feel that it is critical to address these issues while still presenting them with challenging material and preparing them for college-style classes. This concept is reflected in this unit, which balances technical and detailed content with hands-on, technological, and inquiry-based components.

The content of the unit contains a narrative covering the necessary background information for lectures and formative assessments, a series of supplemental labs to be performed throughout the unit, an outline for a culminating portfolio project, and numerous web and print resources to be used in the classroom.

Rationale

The International Baccalaureate (IB) biology course follows a strict and well-defined set of standards but also has the flexibility to provide relevant and meaningful connections to students. I teach physiology in the half year of the two-year curriculum, so this particular unit will be taught to seniors that have already had biochemistry, cellular biology, and genetics. By the end of the unit, students should understand and be able to explain the structure and function of both the circulatory and respiratory systems, evaluate their interdependence, and effectively communicate the importance of making healthy choices.

The health and communication aspects of this unit are absolutely vital. Too many people receive their physiology and nutrition information from the media, which frequently contradicts itself or conveys an incomplete message. Americans, especially those in disadvantaged and less-educated communities, are lacking in science-supported understanding of their bodies. Not only will students become more empowered when they are the ones communicating the information in this unit, but their families and communities will receive a voice for health awareness.

Heart disease remains the number one cause of mortality among adults in the United States, responsible for more than 600,000 deaths per year [2] . Because 12% of adults are currently diagnosed with heart disease, it is quite likely that my students have at least one family member affected with some aspect of it. Sadly, many preventable factors contribute to the development of heart disease, such as smoking and maintaining a healthy weight. Lung conditions are also widespread and are on the rise. More than 25 million Americans suffer from asthma and another 14.8 million have chronic bronchitis or emphysema [3] . While there are certainly genetic factors involved, some of these cases also result from poor lifestyle choices and lack of health education.

For students to successfully take ownership of their health, they must understand the impact they have on their physical condition and how the choices they make affect their bodies on a tissue and cellular level. The goal of this unit is to provide this information from a content standpoint, and to teach it in a way that encourages students to empower themselves and to communicate this message to other young people.

Strategies

Since students have some idea about how their body works, I will begin with a basic discussion to determine current student knowledge and misconceptions. What is the heart? The lung? Why do we have them? What do we know about how they work? How does their structure relate to their function? This could be an open discussion in class, a homework assignment for an online discussion board, such as Edmodo (see Appendix A— Technology Resources), or a more guided discussion based on private student feedback (through paper surveys or an online media such as a Google form).

The unit will then formally begin with a lecture-based introduction to the heart and circulatory system, followed by the lungs and the respiratory system, as outlined in the background information section below. I strongly encourage questions during lectures and facilitate discussion from these questions and my own prompts to create active and engaged learning. This will be supplemented with a series of labs and the unit will conclude with a final portfolio project focusing specifically on student empowerment and communication.

I am fortunate enough to have a class set of iPads and will use them frequently for research, blogging, and heart and lung current events. Appendix A (Technology Resources) explains the particular sites and programs that I will use to supplement the unit.

Background Information

System Structure and Function

Need for Circulatory and Ventilation Systems

Each metabolically active cell in the body needs a steady supply of oxygen. Because only a tiny fraction of these cells lie in close enough proximity to the body surface to obtain oxygen directly, a ventilation system is necessary to bring oxygen into the body, and a circulatory system is required to distribute it to all cells.

Even at rest, our tissues have incredible demands for nutrients and energy sources. Blood nourishes the tissues, providing various materials needed for energy and building molecules. It also transports products made in different glands and organs, and circulates cells involved in immune response. Additionally, blood collects wastes such as carbon dioxide and excess nitrogen (urea) and takes them to organs responsible for their removal [4]. Our often-underappreciated heart has the endless task of distributing this vital fluid; each minute it pumps approximately five liters of blood throughout the body. The heart is situated at the center of the circulatory system, a series of vessels so finely spread throughout the body that each metabolically active cell is within 100 micrometers of one of its branches [5]. Blood vessels exist in a number of sizes with a variety of specific functions, all with the general purpose of distributing and collecting blood to each of the cells in the body.

The Heart

The heart is a four-chambered muscle set up as a pair of pumps. The left side collects blood from the lungs and sends it out through the body; the right collects this blood back from the body and sends it to the lungs. Each side of the heart has an atrium, a thin-walled collection chamber and a ventricle, a thicker-walled pump [6]. Both sides of the heart contract simultaneously and follow the same pattern. The beginning point is arbitrary since the process is cyclical.

Blood returning to the heart from the pulmonary vein (left side) and venae cavae (right side) collects in the atria and flows into the ventricles through the open atrioventrical valves. The atria contract, then the ventricles, increasing the flow into the ventricles until the pressure in the ventricles exceeds that in the atria and the atrioventricular valve between them shuts. This, combined with the continued contraction, causes the pressure within the ventricle to exceed that in the aorta and pulmonary artery. The semilunar valves then open, blood is ejected from the ventricles to the arteries, and the valves close again after the ventricles relax and pressure drops [7]. Blood again flows into the atria and the cycle continues. To simplify, both atria contract, then both ventricles, and blood flows out of the heart. When the body is at rest, each contraction lasts about one second, resulting in a measurable pulse of 60-70 "waves" (beats) per minute [8] .

The Circulatory System

The heart lies at the center of a remarkable set of plumbing, extending to every organ, tissue, and extremity in the body. Blood from the left side of the heart moves through the systemic circulatory system and diffusion occurs across capillaries in body tissues such as organs, muscles, and the brain. Blood also flows through the coronary arteries located directly on the heart itself, providing the cardiovascular tissue with necessary oxygen and nutrients. The blood exiting the right side of the heart moves through the pulmonary circulatory system and gas and nutrient exchange occurs in capillaries in the lungs.

Arteries carry blood away from the heart; the pulmonary artery carries blood to the lungs and the aorta carries blood to the systemic circulatory system [9] . These large arteries branch into successively smaller channels, then to smaller branches called arterioles, then eventually to capillary beds, where molecular exchange occurs. Arteries are characterized by their relatively large diameter, thick layer of smooth muscle, high-pressure flow, and lack of valves [10] . As blood flows through the arterial system to the capillary beds, the total cross-area for flow increases while blood velocity and pressure decrease proportionally [11] . Because they have the highest total cross-sectional area, the blood flows through the capillary beds slowly and diffusion occurs on a single-cell level. Small veins called venules receive the low-pressure blood from capillary beds and it flows into progressively larger veins until reaching the heart. Unlike arteries, veins have larger diameters with thin walls, contain low-pressure flow, and have a series of valves to keep blood circulating back towards the heart. Deoxygenated blood from the lungs flows back in to the heart through the pulmonary vein, blood from the body through the venae cavae [12] . A blood cell traversing the entire system would go through both the pulmonary and systemic systems; its journey would take approximately one minute [13] .

Heart Rate Regulation

The majority of the heart is composed of cardiac muscle; the cells in this tissue are unique because they possess the ability to spontaneously contract and relay electrical signals without nervous system input. This myogenic muscle contraction allows the heart to beat every minute of every day of our lives, beginning just twenty-two days after fertilization and continuing until death [14] . There is a particularly active cluster of cells located in the tissue in the right atrium called the sinoatrial (SA) node, which serves as the pacemaker of the heart. These cells generate action potentials, which are transmitted simultaneously through the atrial tissue and cause its contraction. This electrical signal continues through the myocardium to the atrioventricular (AV) node, and, after a brief delay, it is sent through the ventricles, triggering a contraction that ejects a volume of blood through the pulmonary and systemic systems [15] .

Components of Blood

Since it is responsible for moving cells and molecules throughout the body, blood is a fluid with many components. The liquid portion of blood, plasma, composes approximately 55% of the fluid, and cellular components (erythrocytes, leucocytes, and platelets) make up the rest [16] . Erythrocytes, or red blood cells, make up the majority of the cellular portion. They have the demanding task of carrying oxygen from the lungs to the body's tissues, as oxygen itself is not very soluble in plasma. Leucocytes, white blood cells involved in the immune response, are also present in blood, as well as platelets, cell fragments that form clots to stop bleeding at the site of injury [17] .

Blood is responsible for moving a number of molecules in addition to oxygen. When oxygen is used in the process of internal respiration (discussed in a later section) to produce chemical energy, carbon dioxide is created as a waste product. This waste is collected and removed by the circulatory system, as well as other forms of waste, such as urea (excess nitrogen). Blood also transports nutrients necessary for energy and building tissues, such as amino acids, glucose, and lipids. Additionally, blood moves molecules made in specific tissue cells throughout the body. Hormones, for example, are produced in particular glands but are needed in target cells that may be far removed from the gland, and antibodies must be distributed throughout the body or to specific areas when there is an immune response. Blood also has a role in temperature regulation; the arterioles can expand and contract to gain and release heat [18] .

The Lung

The ventilation system consists of two lungs, each of which contains a system of branching airways and hundreds of millions of alveoli, which are air-filled sacs specialized for gas exchange. Regular inhalation is necessary, as it brings in approximately half a liter of air, a mix of a number of gases, including the oxygen necessaryto create cellular energy. The air enters the pharynx then trachea through the mouth or nose, flows to either the left or right bronchi, then to progressively smaller branches called bronchioles, which end in clusters of alveoli. There are approximately 23 forks along this pathway [19] . Each alveolus is surrounded by a sheet of capillaries that is fed with oxygen-poor blood pumped by the right heart. Gas exchange occurs at the alveolus-capillary interface [20] .

Lung tissue is passive, not muscular, so its ability to take in and expel air for gas exchange relies on the surrounding muscles and pressure properties of the lung and chest wall. The lungs are in constant contact with the chest wall, although the contact is indirect because they are separated by a thin layer of pleural fluid, creating a closed system. The lung and chest wall are both elastic in nature; the lung constantly pulls inward, and the chest wall constantly pulls outward. The muscles involved—the diaphragm, abdomen, and intercostal muscles—increase and decrease the volume of the thoracic cavity cyclically [21] . Since volume and pressure are inversely proportional and the lung cavity is a closed system, these changes in chest wall cause a change in the volume of the lungs. Upon inspiration (breathing in), the diaphragm contracts and pulls down, increasing the volume of the thoracic cavity. The pressure in the cavity decreases (as the inverse function of the cavity volume increasing), causing the lungs themselves to increase in volume. This increase in volume creates a partial vacuum, which air flowing from the trachea must fill to counter. This refreshes some of the air around the alveoli, where gas exchange occurs. The expiration process then proceeds in reverse [22] . During normal inspiration, the diaphragm contracts approximately 1 centimeter, but can move up to 10 centimeters during forced exhalation [23] . Just as the heart increases stroke rate and volume with physical activity, the lung also increases its inspiration/exhalation volume and rate to maintain sufficient oxygen levels

Alveoli and Gas Exchange

The process of gas exchange in the alveoli relies upon diffusion. Diffusion occurs throughout the body to move various molecules, but is particularly important in the lungs, where it freshens the blood's supply of oxygen while removing carbon dioxide waste. Diffusion is simply the movement of molecules from a region of higher to lower concentration so as to work towards equilibrium. Often, diffusion occurs across a membrane, which separates regions of different concentration. For diffusion to occur, the membrane must be permeable to the diffusing substance. Not all materials can support the diffusion of a particular substance; however, small, uncharged molecules such as oxygen and carbon dioxide can diffuse across most biological membranes, even without the presence of special transporters like channels or pores.

The air entering the lungs has a higher concentration of oxygen than the blood in the capillaries embedded in the alveoli; consequently, oxygen molecules move from the oxygen-rich air of the alveoli to the oxygen-deficient blood of the capillaries. The opposite is true for the concentrations of carbon dioxide, so diffusion removes the carbon dioxide waste from the blood in the capillaries into the alveoli. The newly oxygenated blood returns to the heart for distribution to tissues; an exhalation from the lungs expels the carbon dioxide from the body. The process proceeds in reverse in the capillary beds throughout the body, where internal respiration continually uses oxygen and produces carbon dioxide in the pursuit of the chemical energy molecule ATP (see below) [24] .

Alveoli are specially adapted for this process, as they have a spherical shape to create a large surface area for gas exchange. In addition, the boundary of the alveoli are only a single cell layer thick, minimizing the distance through which diffusion must occur. Each alveolus is associated with a capillary bed to ensure close proximity to the circulatory system [25] . The lungs collectively have approximately 300 million alveoli, which create a massive surface area roughly the size of a tennis court (approximately 80 square meters) [26] . The importance of surface area is a key concept for understanding both the circulatory and respiratory systems. Effective diffusion and molecular delivery would be impossible without the intricate branching of both systems, because of the large surface area that is obtained from highly branched architectures.

Cellular Energy and the Need for Circulation and External Respiration

Every action performed by the human body requires chemical energy. All of our cells depend upon ATP (adenosine triphosphate) to fuel their functions. The process of aerobic respiration involves the breakdown of sugar in the presence of oxygen within the mitochondria of the cell to release ATP. This chemical energy must be created at a steady rate, which depends on the body's needs; for example, demand is higher during exercise. The lungs are necessary to supply cells with steady access to oxygen and a means to remove carbon dioxide waste, and the heart and associated vessels are needed to circulate these materials throughout the body.

As the body uses more oxygen to create greater amounts of ATP, it also creates more carbon dioxide waste. The heart can respond to this increased demand by producing higher rates of bloodflow. A region of the brain called the medulla monitors carbon dioxide levels in the brain and sends a signal through the cardiac nerve when it detects an increase. This signal travels to the sinoatrial (SA) node and causes the heart to increase both the number of beats per minute and volume of blood per contraction. When the medulla detects a decrease in carbon dioxide, it sends a signal through the vagus nerve to slow contractions in the SA node [27] .

Health Consequences and the Heart and Lung

The final sections will be covered by the students through in-class research. Useful resources (both web and print) are located in the appendices. The following paragraphs contain a brief introduction to preventable diseases of the heart and lung, as the focus is on health and awareness.

Cardiovascular-related diseases (damage to the heart or blood vessels) are the leading cause of death in the United States; collectively heart disease and stroke are responsible for more than 40% of all adult deaths in the nation [28] . Coronary heart disease results from arteriosclerosis, the accumulation of cholesterol and lipid deposits (collectively called plaque) in the coronary arteries. This buildup causes the arteries to narrow and harden, eventually causing myocardial ischemia, low oxygen concentration in the tissue due to reduced blood supply to the heart. If blood flow becomes interrupted through blockage or rupture, the heart tissue will actually die (myocardial infarction), and if the region of infarction is sufficiently large (such as the region served by the major coronary arteries) the infarction can destroy enough muscle tissue to cause cardiac arrest. These events are commonly referred to as having a heart attack [29] . Plaque can build up in other major arteries as well; a stroke is caused by a blockage of blood flow to the brain.

While heart disease is not entirely preventable—there are numerous genetic factors involved—there are several risk factors that can be reduced by a healthy lifestyle: elevated blood lipids, high blood pressure (hypertension), smoking cigarettes, and having diabetes.

Poor decisions—choosing to smoke, in particular—can lead to several chronic and sometimes fatal lung conditions. Emphysema is a condition where the alveolar structure has been ruptured throughout the lung, creating empty air spaces instead. People with emphysema often have chronic bronchitis (long-term inflammation of the bronchioles) as well. The reduction of surface area for gas exchange combined with swelling and irritation makes the lungs much less efficient [30] . Smoking can cause fatal damage to the lungs. Lung cancer is the leading cause of cancer in the United States, and smoking is responsible for 80-90% of cases. Toxins from tobacco smoke damage lung cells over time and lead to mutations that cause damaged cells to grow out of control [31] .

Organ Transplantation

The heart and lungs are clearly necessary for human survival. However, as noted in the previous section, a number of conditions can cause failure. Transplantation is possible for either or both organs when all other health options have been exhausted. In 1984, the United States Congress passed the National Organ Transplant Act to maintain a national registry for organ matching [32] . As of July 15 th , 2011, 111,943 people are waiting for organ transplants. Of these, 3,185 are waiting for a heart, 1,769 for a lung, and 66 for both [33] .

These transplants are nearly always taken from deceased donors who have volunteered the posthumous use of their organs. Donors must be registered on their state registry (links available through http://www.organdonor.gov) and in the event of brain death, the hospital contacts the Organ Procurement and Transplantation Network to search for a matching candidate [34] . The American Academy of Neurology has a very specific set of standards that determine what constitutes brain death: "the irreversible loss of function of the brain, including the brainstem." [35] Organs are matched with candidates through a detailed selection process, involving factors such as blood type, immune system compatibility, size of organs, time waiting on the candidate list, and distance between donor and recipient (since quick movement of the organ from donor to recipient is critical for most organs) [36] .

Doctors performed 2,333 heart transplants in 2010. Heart transplantation is generally successful, with 88% of patients surviving the first year and 75% surviving five years. Lung transplants are not as common due to the low number of organs available; 1,769 patients received lung transplants in 2010 but the five-year survival rate is considerably lower than for the heart—just 54% [37] .

Organ transplantation remains a difficult issue due to medical and ethical factors. The organ recipient must have a compatible blood type and take a number of immune system-suppressing drugs to ensure that their body does not reject or attack its donated organ. An organ donor must be careful to maintain (or in many cases, improve) their health after receiving a donation. Organ donation remains an issue of controversy in regards to personal belief as well. The United States Department of Health and Human Services states that "most major religions in the United States support organ donation and consider donation as the final act of love and generosity toward others, [38] " but since only 40% of Americans are registered donors [39] , there seems to be a persistent issue of belief or education.

Since the limiting factor in organ replacement is the number of organs available, there is a great deal of research going into the production of artificial organs and tissue engineering for replacement and repair. Synthetic heart machines can be used as a short-term bridge between heart failure and heart transplantation, though no permanent options currently exist. Certain components of the heart have been successfully reproduced, however, such as replacement valves and pacemakers, and stents can be used to open up blocked or narrowed blood vessels. Scientists have also been able to grow living tissue in vitro with the hopes of someday being able to graft patches onto dead or damaged organs in the body [40] .

Class Activities

Note on Activities:

IB labs and activities have an emphasis on student inquiry and are in most cases meant to be student-designed. Therefore, many of the activities below do not have extensive directions or step-by-step procedures. They include enough information for more elaborate and structured instruction. Many of these activities include a form of multimedia assessment, which can be used in the culminating project of the unit. The content knowledge addressed in the standards listed in Appendix B will be assessed on a summative exam as well as on the senior IB exams in the spring. Activities are presented in chronological order of the unit and should be performed in conjunction with lectures rather than collectively at the end. Additionally, a pulse and blood pressure lab is recommended if school policies allow one.

Title: Displaying Circulation

Timeframe: Two class periods or one block

Necessary Background: This activity should serve as reinforcement after already covering the structure and basic functions of the heart and circulatory system.

Materials: red and blue yarn, scissors, butcher paper, markers, tape, iPad 2 or camcorder

Procedure: Have students work in groups of 3-4. One student should serve as a "stencil" and lay down on the butcher paper while another student draws an outline around the outside of their body. Students should then work together to draw the two lungs, a heart in the appropriate location and labels for the four chambers (left and right atria and ventricles) and the major arteries and veins (aorta, pulmonary artery, pulmonary vein, and vena cava). Instruct the students to cut the red yarn in the following pattern: 8 pieces long enough to go from the heart to the fingers, 8 pieces long enough to go from the heart to the toes, and 8 pieces long enough to go from the heart to the lungs. Students should cut the blue yarn in the same pattern. Next, students should lay the yarn strands out within the body structure so that the red yarn serves as the arterial network and the blue yarn as the venous system. Emphasize that the yarn represents blood volume rather than individual vessels. Remind them that one of the key ideas within the circulatory system is branching and maximizing surface area. Students should be able to work together to set up parallel arterial and venous systems that start as a cluster of 4 strands of yarn close to the heart, branching to two sets of two further along the limb or lung, and into individual strands in the hand, foot, or lung. When students are satisfied with their circulatory system, they should tape the yarn in place.

Modifications: Use markers or paint instead for a faster, more transportable project. Provide a demonstration or diagram for students that are struggling with the concept. To simplify the project, cover only the arterial or venous systems, or just the pulmonary or systemic circuits.

Assessment: Videotape the group explaining how and why they laid the yarn out in that particular pattern. Each student should have a speaking role and use specific terminology. Videos will be saved and available for students to use in their final portfolio project.

Title: Modeling Diffusion

Timeframe: One class period or half block

Necessary Background: This lesson should follow the lecture on gas exchange. My students learned diffusion and osmosis the previous year, so this activity is a quick review. Because osmosis is not an emphasized factor in the oxygen/carbon dioxide gas exchange, guide students in focusing on the movement of the iodine molecules rather than the water.

Materials: cornstarch, iodine, water, beakers, plastic baggies, camera

Procedure: Demonstrate the set-up to students and have them take notes to write their procedure (I have found this to be a useful technique when doing simple labs to review the importance of clear procedure-writing). Place a spoonful of cornstarch into a plastic bag, then add 100 mL of water, seal, and mix to dissolve into a solution. Fill a beaker with water and add 15 drops of iodine. Rinse off the exterior of the plastic baggie and place it in the iodine-water solution. Explain that iodine is an indicator for starch and that it will turn from golden/red to purple/black in its presence. Students should then review their procedures, make a hypothesis about if and where a color change may occur, and follow their own directions in pairs or groups of three. About 10-15 minutes after completing their set-up, students should see the interior of the baggie turn black as the iodine diffuses in and reacts with the starch.

Modifications: As mentioned with the other activities, more detailed directions can be offered to adjust the grade level for this activity. Advanced students can make the experiments more challenging by changing starch or iodine concentrations and measuring the rate at which the reaction (and diffusion) occurs.

Assessment: Students will prepare a simple lab report with their hypothesis, procedure, a diagram of their set-up and results (showing the movement of the iodine into the bag), and explanation of what happened. As a conclusion, they should relate their lab findings to gas exchange in the capillary beds. Students may take a picture of their results to include in their final portfolio.

Title: "A Day in the Life of Red Blood Cell"

Timeframe: Two class periods or one block

Necessary Background: Students should have mastery of the general structure and function of both the circulatory and respiratory systems.

Materials: iPads (1-2 students per device), internet access, "Comic Book" app (available from the iTunes app store for $1.99), LCD projector (this activity may also be done without any technology to create paper comic strips; "Comic Life" is a similar Macbook application if those are available instead of iPads)

Procedure: The idea behind this activity (whether performed with technology or not) is to have students show the path of an erythrocyte through the circulatory system. Students should incorporate the respiratory system by showing how the red blood cell picks up oxygen in the alveoli of the lung and deposits it at the capillary level of a tissue. Having students create comic books to show these events makes a difficult concept fun and tangible. Students should first brainstorm in groups about major events of the circuit of a red blood cell. Where does it go? What does it do? The students should be asked to summarize these events in 6-8 blocks of information using proper terminology (left atrium, capillaries, venules, etc.). Then students will be taught how to use "Comic Book" on the iPad on the LCD projector. The program is very simple and intuitive—save pictures to the iPad, select a format, drag and drop images, add captions, dialog bubbles, titles, and fun comic stickers. Students should use one panel for each major event that they wrote down in their summaries. Completed comics can be saved and emailed directly from the iPads.

Modifications: If time is limited, students may work in pairs and one can complete a comic for the pulmonary circuit and the other for the systemic circuit. The activity can be simplified by providing the significant events in a list for the students instead of having the initial brainstorm. If Comic Book is not an option, any graphic creation/editing program such as Microsoft Paint will suffice. Alternately, this entire activity can be completed entirely on paper. Students that are self-conscious or non-artistically inclined may bring in printed images or diagrams and add their own captions.

Assessment: Students creating multimedia projects will again include them in their final portfolio. Individual comic strips should be assessed on completion, complexity, and scientific accuracy, as well as for creativity.

Title: Circulation and Respiration Through Dissection

Timeframe: Two class periods or one block

Necessary Background: Students should have mastery of the general structure and function of both the circulatory and respiratory systems.

Materials: fetal pigs (dual injected, available through Ward's Scientific or Carolina Biological), dissecting kits and trays, gloves, lab aprons, goggles, iPad 2 or camcorder

Procedure: Students will be performing a standard dissection to examine the circulatory and respiratory systems within a living system, identify their primary components, and explain the structures as they relate to their functions. Pigs make an excellent dissection model because their systems are remarkably similar to humans. I recommend showing coloring plates from the *Fetal Pig Coloring Book* and a virtual dissection or tutorial (see Teacher Resources), especially if this is your students' first dissection. Students should work in groups of 3 or 4 and share responsibilities throughout the lab. Draw or use a diagram to show students the proper incisions to make. Instruct them to use scissors to gently cut a vertical line from the top of the chest to the bottom of the abdomen, then a horizontal line at both ends of the incision. Students will need to gently cut through skin, muscle, and the rib cage, but should be careful not to penetrate deeper, then pull and pin the skin and muscle layers off to the side to expose the internal organs. Using a text or dissection guide, students should work together to identify the heart, aorta, pulmonary artery, venae cavae, pulmonary vein, and lungs. Students may make shallow incisions to trace the femoral artery at the hip down through the smaller arteries and arterioles in the leg. The latex injections make it easy to see the path of the blood through the tissues.

The heart and lungs may be removed for further study; students can dissect the heart to view the different chambers. When ready, students take turns narrating the structures and functions listed above and explain how the respiratory and circulatory systems work together.

Modifications: Frogs are a cheaper alternative to pigs, which still allow students to see some of the major components of the two systems. Virtual dissection is an option for students that are morally opposed to dissections or are squeamish.

Assessment: Students will need to create a diagram of the pig's internal anatomy at a later point in time and draw and label the tissues specifically mentioned above. Make a video recording of the students' narration and make it available for students to use in their unit project portfolios.

Ethical Debate Panel—Organ Transplantation and Artificial Organs

Timeframe: 2 class periods or 1 block

Necessary Background: Students should have an understanding of the major organ systems and their interactions and an overview on organ transplantation (need, statistics, general United States processes).

Materials: Technology with internet access (iPads or computers; alternately you can provide students with print resources; see Recommended Teacher Resources)

Procedure: Students should be given a day to research organ transplantation in the United States, focusing on the major question of how organ donation is regulated (both on the donating and receiving ends). Students should choose (or be assigned) a specialty to diversify the discussion. Some examples of specialization are:

-which organs can be donated

-how one becomes an organ donor in your state

-organ trade (point students toward Iran as an example)

-organ candidates and the waiting list

-unusual transplants (face, uterus)

Each student should prepare at least two questions on their specialty (at least one should be an ethics-based question) and be prepared to answer questions in their assigned area. On the second day, lead a discussion where students share their questions and respond to one another. The instructor should serve as moderator to keep the pace of the discussion on target, ensure scientific accuracy, call on "specialists" when related questions arise, and maintain respect for students' opinions.

Modifications: This activity could be made more personal by assigning students a series of questions to be answered in an essay format. If students are opinionated but not confident in speaking aloud on controversial topics, you could set up an online discussion board (see Appendix A— Technology Resources) instead.

Assessment: Students will be evaluated on the scientific accuracy of their output and critical analysis skills.

Unit Portfolio Project:

The unit will conclude with a project that will allow students to communicate their organ knowledge and apply research and media literacy. Each student will prepare an online portfolio using Glogster (see Appendix A—Technology Resources) to present their choice of three of the following:

-video of "Displaying Circulation" activity

-picture and annotation from "Modeling Diffusion" activity

-comic book diagram from "Day in the Life of Red Blood Cell" activity

-video from dissection activity

Students should also include the following two sections:

-a summary of current organ transplantation procedures and an opinion statement on these policies

-a summary of current health issues regarding either the heart or the lung and the ways in which they can be prevented

Announce this project at the beginning of the unit so that students are aware that they need to gather artifacts. Files shared between students can be uploaded and downloaded from Dropbox (see Appendix A—Technology Resources). Students may use the information presented in class as a foundation but will need to do further research (see Technology Resources for useful links) for the latter two sections. If the computer technology is not available for this project, students can gather artifacts and create paper-based portfolios instead. Evaluation will be based on scientific accuracy, creativity, and communication (presentation of materials in a way that the public can understand, as these are meant to be shared).

Recommended Teacher Resources:

Damon, Alan, Randy McGonegal, Patricia Totso, and William Ward. *Biology Standard Level.* Oxford: Heinemann International Literature and Textbooks, 2007.

An excellent, straightforward text for IB biology, this book also includes a number of useful images, diagrams, and hyperlinks to web activities.

Kapit, Wynn, Robert I. Macey, and Esmail Meisami. *The Physiology Coloring Book.* San Francisco: Benjamin Cummings, 2000.

This book contains a number of complex diagrams as well as some useful general slides. It is more than a coloring book—the details force you to think about the structure and function of each part and piece of the physiological systems.

McCann, Stephanie, and Joanne Tillotson. Fetal Pig Coloring Book. New York: Kaplan Publishing, 2007.

This may serve as an alternative to the *Physiology Coloring Book* and will assist with preparing students for the fetal pig dissection lab.

Page, Martyn. *Human Body: An Illustrated Guide to Every Part of the Human Body and How It Works.* New York: Dorling Kindersley, Inc., 2001.

Filled with vivid pictures and diagrams, this book makes a very approachable visual anatomy companion to the more complex text resources.

"Organ Transplantation - The Hastings Center ." The Hastings Center - Bioethics and Public Policy. http://www.thehastingscenter.org/Issues/Default.aspx?v=254 (accessed July 31, 2011).

This site contains a number of non-partisan bioethics articles examining different angles on organ donation and transplantation.

Appendix A— Technology Resources

Useful Class Websites and Tools:

Note: These sites can be made entirely private, but check with your district and school policy on media privacy and obtain the appropriate permissions before implementation.

Edmodo (http://www.edmodo.com): Edmodo is a school social-networking site that allows me to easily share files and links with students, start discussion boards, and provides a media for submitting online quizzes and assignments. Kids like Edmodo too because it has a familiar Facebook-like interface and allows them to access a number of materials. Edmodo is free but requires a school-district email.

Google Docs (http://docs.google.com): Google Docs allows you to create shareable files (word processing, spreadsheets, presentations, drawings) that can be accessed and modified on the internet. In addition, you can also create Google forms to give quizzes, homework, classwork or collect data from students. http://docs.google.com/support/ has videos and tutorials to help you get set up. Google Docs is free but you need a Google account (also free).

Prezi (http://www.prezi.com): Prezi is a Flash-based presentation-builder. You can add text, videos, animations, and images, and link them together in a unique and engaging set-up. Prezi has a free "public" option as well as licenses for students and teachers.

Glogster (http://www.glogster.com): Glogster allows you to create interactive online posters. Like Prezi, you can add text, video, images, animations, etc. and share the presentation with anyone. This will be the media used for students' project portfolios so that they can demonstrate different facts about the heart and lungs along with video clips they have created throughout the unit.

Dropbox (http://www.dropbox.com): Dropbox is a free file-sharing site. You can create an account for students to access resources for class and store shared files such as group videos. The site is accessible from any internet browser and can store a number of file types.

Heart and Lung Animations:

http://www.smm.org/heart/heart/top.html (Heart Animations and Interactives, Science Museum of Minnesota)

http://www.nhlbi.nih.gov/health/dci/Diseases/hhw/hhw_pumping.html (How the Heart Works, National Heart, Lung, and Blood Institute)

http://www.pbs.org/wgbh/nova/body/map-human-heart.html (Animated Human Heart Map, PBS) http://highered.mcgraw-hill.com/sites/0072507470/student_view0/chapter23/animation__gas_exchange_during_respiration.html (Animation of Gas Exchange During Respiration, McGraw-Hill)

http://highered.mcgraw-hill.com/sites/0072507470/student_view0/chapter23/animation__movement_of_oxygen_and_carbon_dioxide.html (Animation of the Movement of Oxygen and Carbon Dioxide, McGraw-Hill)

Fetal Pig Resources:

http://www.whitman.edu/content/virtualpig (Virtual Fetal Pig Dissection, Whitman College)

Appendix B—Alignment to Standards

International Baccalaureate Biochemistry Biology Objectives:

6.2.1 Draw and label a diagram of the heart showing the four chambers, associated blood vessels, valves, and the route of blood through the heart.

6.2.2 State that the coronary arteries supply heart muscle with oxygen and nutrients.

6.2.3 Explain the action of the heart in terms of collecting blood, pumping blood, and opening and closing of valves.

6.2.4 Outline the control of the heartbeat in terms of myogenic muscle contraction, the role of the pacemaker, nerves, the medulla of the brain and adrenaline.

6.2.5 Explain the relationship between the structure and function of arteries, capillaries, and veins.

6.2.6 State that blood is composed of plasma, erythrocytes, leucocytes, and platelets.

6.2.7 State that the following are transported by the blood: nutrients, oxygen, carbon dioxide, hormones, antibodies, urea, and heat.

6.4.1 Distinguish between ventilation, gas exchange, and cell respiration.

6.4.2 Explain the need for a respiration system.

6.4.3 Describe the features of alveoli that adapt them to gas exchange.

6.4.4 Draw and label a diagram of the ventilation system, including trachea, lungs, bronchi, bronchioles, and alveoli.

6.4.5 Distinguish between ventilation, gas exchange, and cell respiration.

6.4.6 Explain the need for a respiration system.

6.4.7 Describe the features of alveoli that adapt them to gas exchange.

6.4.8 Draw and label a diagram of the ventilation system, including trachea, lungs, bronchi, bronchioles, and alveoli.

Illinois State Standards:

STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

A. Know and apply the concepts, principles and processes of scientific inquiry.

11.A.5a Formulate hypotheses referencing prior research and knowledge.

11.A.5b Design procedures to test the selected hypotheses.

11.A.5c Conduct systematic controlled experiments to test the selected hypotheses.

11.A.5d Apply statistical methods to make predictions and to test the accuracy of results.

11.A.5e Report, display and defend the results of investigations to audiences that may include professionals and technical experts.

STATE GOAL 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

A. Know and apply concepts that explain how living things function, adapt and change.

12.A.5a Explain changes within cells and organisms in response to stimuli and changing environmental conditions (e.g., homeostasis, dormancy).

12.A.5b Analyze the transmission of genetic traits, diseases and defects.

STATE GOAL 13: Understand the relationships among science, technology and society in historical and contemporary contexts.

A. Know and apply the accepted practices of science.

13.A.5b Explain criteria that scientists use to evaluate the validity of scientific claims and theories.

13.B.5b Analyze and describe the processes and effects of scientific and technological breakthroughs.

13.B.5e Assess how scientific and technological progress has affected other fields of study, careers and job markets and aspects of everyday life.

Endnotes

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