10 Gas Exchange

LABORATORY

2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students conduct an investigation to identify the presence of carbon dioxide in exhaled breath in order to build toward an understanding of the function of the respiratory system in excreting carbon dioxide produced as a result of cellular respiration. This activity is building towards an understanding of human body systems and subsystems from the level of the cell to the complete system, and to the interacting roles of these systems in providing nutrients and oxygen and removing carbon dioxide wastes from the cells throughout the body.

NGSS CORRELATIONS

Performance Expectations

Working towards MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Disciplinary Core Ideas

MS-LS1.A Structure and Function: In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

MS-PS3.D Energy in Chemical Processes and Everyday Life: Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

Science and Engineering Practices

Planning and Carrying Out Investigations:

Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Crosscutting Concepts

Systems and System Models: Systems may interact with other systems and be a part of larger complex systems.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHAT STUDENTS DO

This activity explores the role of the respiratory system in the regulation of gases in the blood. Students investigate how to quantitatively measure the amount of carbon dioxide in their exhaled breath by using an indicator to perform a titration.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

* 1 large sheet of chart paper
* 1 large sponge
* 1 bottle of carbonated water (optional)

- *For each group of four students*

1 dropper bottle of bromothymol blue (BTB) indicator
5 plastic cups
* supply of water (may require distilled water—see below)

- *For each pair of students*

1 dropper bottle of 0.05 M sodium hydroxide
1 SEPUP tray
1 dropper
1 graduated cup (30-mL)

- *For each student*

2 plastic bags (1-gallon)
2 straws
1 stir stick
* 1 pair of chemical splash goggles

* access to a wall clock or watch that displays seconds
1 Student Sheet 10.1, "Anticipation Guide: Gas Exchange"

**not included in kit*

In areas with extremely soft water (in which the addition of the bromothymol blue results in a yellow-green color rather than a blue color), mix 1 drop of 0.05M sodium hydroxide with 1 drop of water in a cup of a SEPUP tray. Add 1 or 2 drops of the dilute sodium hydroxide to the BTB solution until it turns blue. You may also use distilled water instead of tap water. If the distilled water turns yellow-green with the addition of BTB, use 1 or 2 drops of dilute sodium hydroxide until the solution turns blue.

Prepare a large sheet of chart paper or use another method for students to post their results in Part A. Construct two columns, as shown below, and enough rows for all students.

CLASS DATA

Name	Number of Drops of Sodium Hydroxide

SAFETY NOTE

Students will be blowing through a straw into chemicals. Make sure they do not inhale through the straw! They should breathe in through their noses and exhale through their mouths. If they accidentally swallow liquid, make sure they rinse out their mouths thoroughly and drink plenty of water.

Make sure that students wear chemical splash goggles while working with chemicals. Students should not touch the chemicals or bring them into contact with their noses or mouths. Have them thoroughly wash their hands after completing the activity.

TEACHING SUMMARY

GET STARTED

1. Introduce the respiratory system and the use of an indicator.
    a. (LITERACY) Use Student Sheet 10.1, "Anticipation Guide: Gas Exchange," to further elicit students' ideas about the respiratory system.
    b. Introduce indicators and how BTB will be used in this activity.

DO THE ACTIVITY

2. Introduce the laboratory investigation.

   Refer to "Using a Dropper Bottle" in Appendix C in the Student Book to demonstrate how to hold SEPUP dropper bottles correctly.

3. Have students conduct Part A of the investigation.

   a. Discuss the important Safety Note in the Student Book before students begin, and monitor them as they follow the Procedure.

   b. Have students develop data tables to record their results.

   c. Discuss students' results before they go on to Part B.

   d. If appropriate, explain why sodium hydroxide turns the BTB solution back to blue.

4. Students complete Part B of the investigation.

   a. Before students begin Part B, be sure to review Step 17, which explains how to perform the titration.

   b. You may wish to set up a control with a bag containing BTB solution left open to the air and then shaken.

   c. Select an aerobic exercise that the entire class will perform for 5 minutes.

   d. Before students start exercising, have them set up bags containing the BTB solution.

BUILD UNDERSTANDING

5. Review and discuss students' results and what they mean.

   a. Review the data students collected in the investigation, and discuss Analysis items 1 and 2.

   b. Review Analysis items 3 and 4, and relate them to the crosscutting concept of structure and function.

6. Discuss how student ideas have changed, and have students apply what they have learned to respiratory disease.

   a. (QUICK CHECK) Discuss Analysis item 5, which has students return to Student Sheet 10.1.

   b. Review Analysis item 6.

TEACHING STEPS

GET STARTED

1. Introduce the respiratory system and the use of an indicator.

    a. (LITERACY) Use Student Sheet 10.1, "Anticipation Guide: Gas Exchange," to further elicit students' ideas about the respiratory system.

    Student Sheet 10.1 provides a preview of important concepts in the activity. It provides an opportunity for students to explore their initial ideas, and revisit and modify them when they have finished the activity.

    You might read the statements aloud and clarify any questions students have about their meaning. Be sure they understand that they should complete only the "Before" column at this time because they will have a chance to revisit these statements after the activity to see whether their ideas have changed or remained the same. For a sample student response, see Sample Response to Student Sheet 10.1 at the end of this activity. For more information on Anticipation Guides, see the Literacy section of Teacher Resources II, "Diverse Learners."

    Encourage students to work in pairs or small groups as they respond to the items on the Anticipation Guide and be prepared to share their ideas. When students share their answers, encourage them to use evidence and reasoning as they argue for their answers, but do not attempt to reach consensus. They will return to the Anticipation Guide and these concepts later in the activity.

    b. Introduce indicators and how BTB will be used in this activity.

    Explain that students will be collecting evidence about this gas exchange by using an indicator to test for the presence of carbon dioxide in their exhaled breath. Be sure to discuss the second paragraph of the introduction, which introduces indicators. In this activity, students will be using bromothymol blue (BTB) as an indicator for carbon dioxide.

    To further establish the use of BTB as an indicator for carbon dioxide, discuss the presence of dissolved carbon dioxide in carbonated beverages, such as soft drinks and sparkling water. Have students read the label from a bottle of sparkling water and test the water for the presence of carbon dioxide. Use the results of the test to reinforce the idea that BTB turns yellow in a solution containing carbon dioxide.

DO THE ACTIVITY

2. Introduce the laboratory investigation.

   Refer to "Using a Dropper Bottle" in Appendix C in the Student Book to demonstrate how to hold SEPUP dropper bottles correctly.

   Explain that the bottles produce consistent drops when used as shown, allowing for more consistent results.

3. Have students conduct Part A of the investigation.

   a. Discuss the important Safety Note in the Student Book before students begin, and monitor them as they follow the Procedure.

      In Part A of the Procedure, students should observe that the presence of dissolved carbon dioxide causes a change in the color of BTB from blue to yellow.

   b. Have students develop data tables to record their results.

      Note that students are required to create their own data tables in Step 3. You may wish to assist them as needed to structure their tables to record the data observed for each cup. Their tables may look something like the one below, in which the expected results have been entered.

TESTING FOR CARBON DIOXIDE

Cup	Initial BTB color	Final BTB color	After adding NaOH
A (control)	*blue*	*blue*	*X*
B (air)	*blue*	*blue*	*X*
C (sodium hydroxide)	*blue*	*blue*	*X*
D (exhaled breath)	*blue*	*yellow*	*blue*
E (partner's exhaled breath)	*blue*	*yellow*	*blue*

   c. Discuss students' results before they go on to Part B.

      As student pairs complete Part A, they can go on to work on Analysis items 1 and 2. Depending on your student population, it may be necessary to discuss the responses to these questions before moving on to Part B.

   d. If appropriate, explain why sodium hydroxide turns the BTB solution back to blue.

      This is due to the fact that BTB is an acid–base indicator (as described in the Background Information) and not simply an indicator for the presence of carbon dioxide. Decide whether you want to introduce the role of acid–base chemistry in these reactions.

4. Students complete Part B of the investigation.

   a. Before students begin Part B, be sure to review Step 17, which explains how to perform the titration.

      After adding each drop of sodium hydroxide solution, it is important that students wait at least 10 seconds to compare the resulting color with the color of the control (the unchanged cup of BTB solution shared within each student group). If students are not sure whether another drop is needed, advise them to add the drop and simply not include it in the final count if it is clear that the drop was unnecessary. Most students will use 3–4 drops to complete the titration at this point. Students may be interested in knowing that using an indicator and another chemical (e.g., sodium hydroxide) to determine the amount of another substance (e.g., carbon dioxide) is known as titration, a procedure used frequently by chemists. The amount of sodium hydroxide needed is proportional to the amount of carbon dioxide in the exhaled breath.

   b. You may wish to set up a control with a bag containing BTB solution left open to the air and then shaken.

      If so, use Procedure Steps 12 and 15 as a guide to preparing this control (note that Steps 13 and 14 are not part of setting up the control). This will provide additional evidence that the yellow color obtained by students is due to their exhaled breath. Students may notice that yellow BTB solution left open to the air gradually returns to the color of the control. This is not a neutralization effect: the carbon dioxide dissolved in the solution gradually returns to the surrounding air. (A more dramatic example of this occurs when carbonated beverages are allowed to go "flat.")

   c. Select an aerobic exercise that the entire class will perform for 5 minutes.

      Reach consensus on how to keep the exercise as close as possible to the same for every student. Some options are jogging in place, a step exercise, jumping jacks, squats, or running between two points if you are able to go outside or to the gym.

   d. Before students start exercising, have them set up bags containing the BTB solution.

      Have students repeat Procedure Steps 14 through 18 after they exercise for 5 minutes. In general, it will take 1 to 2 more drops of BTB to complete the titration after exercise than it did before exercise. Briefly discuss the students' results with the class.

BUILD UNDERSTANDING

5. Review and discuss students' results and what they mean.

   a. Review the data students collected in the investigation, and discuss Analysis items 1 and 2.

      As you review Analysis item 2, use the table in the Student Book, "Composition of Breath," to review with the class that neither inhaled breath nor exhaled breath is composed entirely of a single gas, and that exhaled breath (as corroborated by this activity) contains about 100 times as much carbon dioxide as inhaled air. Emphasize the interaction between the human body and the environment. The body uses oxygen, so oxygen flows in through the lungs; it produces carbon dioxide as waste, so carbon dioxide flows out.

      As you review Analysis item 2, you might also refer back to students' data on their breathing rate before and after exercise. Emphasize the importance of inhaling to bring in oxygen from the atmosphere and exhaling to remove carbon dioxide wastes produced in the body. The transport of oxygen to the organs and tissues, and carbon dioxide wastes from the organs and tissues, will be a focus of the next two activities. You can prepare students by asking them, "What do you think happens to the oxygen taken in when you breathe? Where do you think the carbon dioxide wastes come from?" Their ideas can serve as a transition to the next activity.

   b. Review Analysis items 3 and 4, and relate them to the crosscutting concept of structure and function.

      Point out the other organs of the respiratory system, and then focus attention on the lungs. Students often have the mistaken idea that the lungs are like two empty balloons in the chest. You might wish to have students consider the structure of a sponge. Point out that the sponge is filled with numerous spaces for holding water, yet the sponge is a solid object. Human lungs are solid organs containing millions of air spaces. The tissue of the lungs forms the walls of these spaces. These air spaces branch through the lungs, similar to the branches of a tree. In fact, if plastic resin is injected into the spaces of a human lung and the tissue removed from around it, the plastic mold looks like a small upside-down tree, as shown in the Student Book. When a person inhales, air flows into these smallest spaces, known as alveoli (or air sacs). This is where the exchange of oxygen and carbon dioxide between the air and the bloodstream occurs.

6. Discuss how student ideas have changed, and have students apply what they have learned to respiratory disease.

   a. (QUICK CHECK) Discuss Analysis item 5, which has students return to Student Sheet 10.1.

      To help students review and reflect on what they have learned, return to the Anticipation Guide and have them complete the "After" column. Review students' responses, and discuss whether and how any of their ideas have changed. For a sample student response, see Sample Response to Student Sheet 10.1 at the end of this activity. This can be used as a QUICK CHECK of students' understanding of the respiratory system.

   b. Review Analysis item 6.

      Students should be able to explain that the conditions described make it difficult for the lungs to take in and absorb oxygen.

SAMPLE RESPONSES TO ANALYSIS

1. What was the purpose of the solution in Cup A?

   Cup A was the control for BTB color.

2. Review your results.

   a. Which of the solutions in Part A contained carbon dioxide? Support your answer with evidence from your experimental results.

      The solutions in Cups D and E contained carbon dioxide. These were the solutions we exhaled into. BTB is an indicator that turns yellow in solutions containing carbon dioxide. After blowing into the solutions, both turned yellow. This provides evidence that the solutions contained carbon dioxide.

   b. What does this tell you about the exhaled breath of human beings?

      Testing the air (Cup B) for carbon dioxide is equivalent to testing a person's inhaled breath. Comparing the results in Cup B with those in Cups D and E provides evidence for a large increase in the carbon dioxide in exhaled vs. inhaled breath

c. Look at the table below. Compare the composition of air you breathe in to that of air you breathe out. Describe the differences.

COMPOSITION OF BREATH

Components of Earth's Atmosphere	Composition of Air Breathed In (%)	Composition of Air Breathed Out (%)
Nitrogen	78	75
Oxygen	21	16
Argon	0.93	0.93
Carbon dioxide	0.036	4.0
Water vapor	0.4	4.0

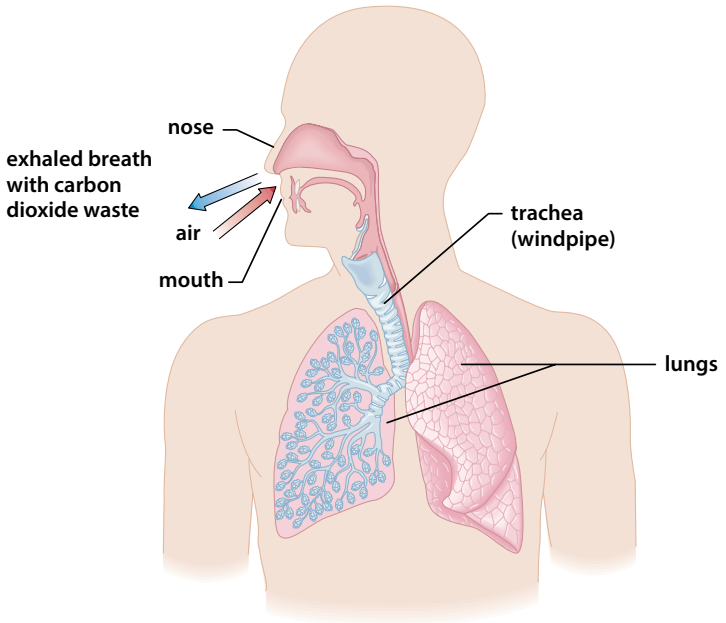
The air that is breathed in has 78% nitrogen compared to 75% in the air that is breathed out. The air that is breathed in has 21% oxygen compared to 16% in the air that is breathed out. Yet the air that is breathed out has far more carbon dioxide and water vapor than the air that is breathed in.

3. Based on the results of this activity, describe the function of the respiratory system.

   The respiratory system takes in air and allows oxygen to enter the body. It also gets rid of carbon dioxide wastes.

4. Look at the diagram below of the human respiratory system. Considering the function of the respiratory system that you described for Analysis item 3, why do you think the inside of the lung is structured the way it is?

   The tree-like structure of the lungs, with many levels of branching from the trachea to



tiny alveoli, give the lungs far more surface area than they would have if structured like empty balloons. This enables the lungs to accomplish gas exchange well enough to supply oxygen to and remove carbon dioxide from the entire bloodstream. In a similar way, all the villi in the small intestine enable that organ to absorb and digest nutrients rapidly enough that they are not allowed to pass through the digestive system unused.

5. (QUICK CHECK) Complete Student Sheet 10.1. Be sure to explain how the activity provided evidence for your initial ideas or caused you to change your thinking.

   See Sample Response to Student Sheet 10.1 at the end of this activity.

6. **Reflection:** Many respiratory diseases limit a person's capacity to exchange oxygen. One of these diseases is pneumonia, which causes the lungs to fill up with fluid. Another is pleurisy, which is an inflammation of the lining of the lung, making it painful to inhale and exhale. If you had one of these diseases, how do you think it would affect your body's function?

   Student answers may vary depending on what they might know about these conditions. One sample response is shown here:

   As the lungs fill up with fluid, the exchange of gases cannot occur in the alveoli. Similarly, if a person has pleurisy, the lungs cannot be fully inflated, which means that oxygen intake is reduced, as is carbon dioxide removal.

EXTENSION

Have students brainstorm and write down questions they have about asthma. Then have students go to the *SEPUP Third Edition Body Systems* page of the SEPUP website *at www.sepuplhs.org/middle/third-edition* and go to the resources on asthma to try to find answers to their questions about asthma and the respiratory system.

REVISIT THE GUIDING QUESTION

How much carbon dioxide is in your exhaled breath before and after you exercise?

Review students' results from the activity, reminding students if necessary that their exhaled breath contains other gases besides carbon dioxide.

ACTIVITY RESOURCES

KEY VOCABULARY

control

indicator

function

organ

range

structure

BACKGROUND INFORMATION

INDICATORS

Bromothymol blue (BTB) is a chemical indicator that is yellow in acidic solution and blue in basic solution. Its equivalence point is at pH = 6.7; consequently, it is blue in a neutral solution (pH = 7). As a solution of BTB gradually changes color, it appears to go through an intermediate green stage. The green color results from some of the BTB molecules being in the blue state and some in the yellow state. Since carbon dioxide in solution produces carbonic acid, BTB is yellow in the presence of sufficient carbon dioxide. Addition of a base (e.g., sodium hydroxide) to a yellow BTB solution eventually turns the solution blue because the sodium hydroxide neutralizes the acidity and then turns the overall solution basic.

RESPIRATION

Cellular respiration is the complex series of chemical reactions by which cells use oxygen to burn glucose for energy, producing waste carbon dioxide. (Respiration at the cellular level is addressed in the From Cells to Organisms unit of *Issues and Life Science*.) Respiration by the respiratory system is better described as "breathing and gas exchange."

The internal structure of each lung shows several stages of branching, from the bronchi (tubes from the trachea into each lung) to the 300 million or so tiny alveoli, or air sacs. This incredibly high surface-to-volume ratio allows for rapid diffusion of oxygen and carbon dioxide across the alveolar membranes in the direction of high to low concentration. Since the blood that enters the lungs has been partially depleted of its oxygen supply and is laden with waste carbon dioxide, oxygen flows into the capillaries while carbon dioxide flows out. As a result, over a quarter of the oxygen inhaled is transferred to the bloodstream, whereas the exhaled air acquires a concentration of carbon dioxide 100 times that of the inhaled air.

During exercise, the primary way in which the body meets the need for increased oxygen is by increasing the number of breaths per minute. This increases the average oxygen concentration in the air inside the lungs, so there is increased oxygen diffusion across the lung surfaces. Meanwhile, oxygen delivery increases due to an increased rate of blood flow to the exercising muscles. Oxygen extraction by the muscles also increases, since they are using more oxygen in cellular respiration. This results in the venous blood carrying less oxygen than when at rest, which in turn increases the rate of oxygen diffusion across the lung surfaces. However, the concentration of oxygen in the arterial blood shows no change during exercise because your body regulates breathing rate during exercise to maintain normal concentrations of both oxygen and carbon dioxide in the blood.

Name_____ Date_____

STUDENT SHEET 10.1

ANTICIPATION GUIDE: GAS EXCHANGE

Before starting the activity, mark whether you agree (+) or disagree (—) with each statement below.

After completing the activity, mark whether you agree (+) or disagree (—) with each statement below. Under each statement, explain how the activity gave evidence to support or change your ideas.

BEFORE	AFTER	
_____	_____	1. Carbon dioxide is produced when your body chemically breaks down substances in food.
_____	_____	2. All of the air that you exhale is carbon dioxide.
_____	_____	3. Your body needs oxygen to get energy from food.
_____	_____	4. The amount of carbon dioxide that you exhale is different from the amount exhaled by other people.
_____	_____	5. The air you breathe in is pure oxygen.
_____	_____	6. Your lungs are sacs with smooth walls, similar to the walls of a balloon.
_____	_____	7. Air and food are meant to go down the same passageway.
_____	_____	8. The walls of your lungs are filled with many tiny blood vessels.

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Name *Sample student response* Date_____

STUDENT SHEET 10.1

ANTICIPATION GUIDE: GAS EXCHANGE

Before starting the activity, mark whether you agree (+) or disagree (—) with each statement below.

After completing the activity, mark whether you agree (+) or disagree (—) with each statement below. Under each statement, explain how the activity gave evidence to support or change your ideas.

BEFORE	AFTER	
_____	+	1. Carbon dioxide is produced when your body chemically breaks down substances in food. *The introduction says that when your cells break down food, they produce wastes. One of those wastes is carbon dioxide.*
_____	—	2. All of the air that you exhale is carbon dioxide. *The "Composition of Breath" chart shows that we exhale lots of other things besides carbon dioxide.*
_____	+	3. Your body needs oxygen to get energy from food. *It says this in the introduction.*
_____	+	4. The amount of carbon dioxide that you exhale is different from the amount exhaled by other people. *Based on our data, the BTB turned different shades of blue depending on who was blowing through the straw, so I would say yes, we exhale different amounts of carbon dioxide.*
_____	—	5. The air you breathe in is pure oxygen. *The "Composition of Breath" chart shows that we inhale other things besides oxygen.*
_____	—	6. Your lungs are sacs with smooth walls, similar to the walls of a balloon. *The diagram of the human respiratory system shows that the lungs are more like a sponge, solid but with lots of pockets for air.*
_____	—	7. Air and food are meant to go down the same passageway. *Air goes down the windpipe, as shown in the diagram of the respiratory system. Food goes down the esophagus.*
_____	+	8. The walls of your lungs are filled with many tiny blood vessels. *An image in our book shows that this is true.*

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NGSS UNIT OVERVIEW

BODY SYSTEMS

Performance Expectation MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Performance Expectation MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Performance Expectation MS-LS1-7: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. (working towards, this PE is assessed in *From Cells to Organisms*)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **View and Reflect: The Pellagra Story** Students obtain and evaluate information from a short video segment and a text passage on the investigation of pellagra, a nutritional deficiency common in the early 1900s. They reflect on how scientists gather evidence about cause-and-effect relationships in the human body and are introduced to the concept of clinical trials. The issues associated with investigating and experimenting on humans provides a context for the exploration of the human body system as a system of interacting subsystems.	MS-LS1.A	Obtaining, Evaluating, and Communicating Information Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Cause and Effect Connections to Nature of Science: Science Is a Human Endeavor	ELA/Literacy: RST.6-8.7 RST.6-8.9
2. **Modeling: Parts of a Whole** Students draw the organs of the human body based on their prior knowledge. They then use diagrams to create a three-dimensional clay model of some of the organs and structures in the human torso. The concepts of structure and function are introduced as students begin to think about how the organs can be grouped into body systems based on their function within the human body.	MS-LS1.A	Developing and Using Models Asking Questions and Defining Problems	Structure and Function Systems and System Models	ELA/Literacy RST.6-8.7
3. **Investigation: What's Happening Inside?** Students group organs and structures into body systems based on their functions. They compare their initial ideas to information about human body systems and learn about the function of various systems. The idea that the human body is a system of interacting subsystems is formally introduced.	MS-LS1.A	Constructing Explanations and Designing Solutions	Structure and Function Systems and System Models	ELA/Literacy: SL.8.1

BODY SYSTEMS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Reading: Digestion: An Absorbing Tale** Students integrate information from text and visual displays about the structure and function of the digestive system. They further develop the concept of interacting systems and how subsystems can be part of a larger complex system.	MS-LS1.A	Constructing Explanations and Designing Solutions	Systems and System Models	ELA/Literacy: RST.6-8.4
5. **Modeling: Food Breakdown** Students read two text passages about the composition and breakdown of food. After the first passage, they begin to develop a model to explain how organisms obtain matter and energy. After the next passage, they modify and elaborate their models to account for the new information provided.	MS-LS1.A MS-LS1.C	Developing and Using Models Constructing Explanations and Designing Solutions	Energy and Matter	ELA/Literacy: RST.6-8.2 RST.6-8.9
6. **Laboratory: Observing Organisms** In this laboratory, students begin to explore how sense receptors respond to stimuli in the blackworm (*Lumbriculus variegatus*). Students are introduced to the concept of immediate behavior being a response to stimuli. Students use what they have learned to predict blackworm behavior in response to specific application of stimuli.	MS-LS1.D	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Cause and Effect	
7. **Laboratory: Can You Feel the Difference?** In this laboratory, students investigate how the human nervous system and sensory receptors respond to stimuli that induce immediate behaviors. They are introduced to the idea that there are similar systems in different organisms.	MS-LS1.D	Planning and Carrying Out Investigations Analyzing and Interpreting Data Obtaining, Evaluating, and Communicating Information	Cause and Effect	
8. **Reading: Finding the Nerve** In this reading, students deepen their understanding of the structure and function of the human nervous system. They learn about how information is transmitted and processed to result in behaviors or memories. They also learn more about how the nervous system works with other body systems to perform particular body functions. Students are formally assessed on Performance Expectation MS-LS1-8.	MS-LS1.D	Obtaining, Evaluating, and Communicating Information	Systems and System Models Cause and Effect	ELA/Literacy: RST.6-8.4

BODY SYSTEMS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
9. **Laboratory: Heartily Fit** Students use mathematics and computational thinking as they conduct an investigation and analyze and interpret data on their own heart and respiratory rates before and after exercise. The investigation stimulates a discussion of the interactions between human body systems—specifically the circulatory and respiratory systems—in order to meet the body's need for more oxygen during exercise.	MS-LS1.A	Analyzing and Interpreting Data Using Mathematics and Computational Thinking	Systems and System Models	Mathematics: 6.SP.B.4 ELA/Literacy: RST.6-8.3
10. **Laboratory: Gas Exchange** Students conduct an investigation to identify the presence of carbon dioxide in exhaled breath. The function of the respiratory system in excreting carbon dioxide waste is highlighted. This activity is building towards an understanding of human body systems and subsystems from the level of the cell to the complete system, and to the interacting roles of these systems in providing nutrients and oxygen and removing carbon dioxide wastes from the cells throughout the body.	MS-LS1.A MS-PS3.D	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Systems and System Models	ELA/Literacy: RST.6-8.3
11. **Reading: Interacting Systems** In this activity, students obtain more information about the circulatory and respiratory systems, which they investigated in the previous two activities. They read about the structure and function of each of these systems and how they interact at the system, organ, tissue, and cellular levels of organization. They construct an explanation for how each level of organization contributes to circulatory function. This helps them to prepare for the argument they will develop in the next activity.	MS-LS1.A	Constructing Explanations and Designing Solutions Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence	Systems and System Models Structure and Function	ELA/Literacy: RST.6-8.2
12. **Modeling: The Circulation Game** Students use what they have learned from the activities and readings in this unit to develop a whole-class model of the interactions of the circulatory, respiratory, and digestive systems. This activity provides an opportunity to formally assess MS-LS1-3.	MS-LS1.A	Developing and Using Models Engaging in Argument from Evidence Constructing Explanations and Designing Solutions	Systems and System Models Structure and Function	ELA/Literacy: WHST.6-8.1 WHST.6-8.2

BODY SYSTEMS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
13. **Investigation: Testing Medicines: A Clinical Trial** In this investigation, students analyze and interpret data about a simulated clinical trial of a headache medicine. They use the evidence from their analysis to engage in an argument about the potential use of this medicine. They begin to think about how body system interactions may need to be considered when developing new medicines for human use.	MS-LS1.A	Engaging in Argument from Evidence Analyzing and Interpreting Data	Cause and Effect Systems and System Models Connections to Nature of Science: Science Is a Human Endeavor	ELA/Literacy: RST.6-8.3 WHST.6-8.1
14. **Talking It Over: Evaluating Clinical Trials** In this activity, students analyze and interpret data from a fictional headache medicine clinical trial to develop an argument for which of three medicines should be further developed and tested. Students consider how body system interactions play a role in the side effects of the medications and what that might mean for future possible use of the medicines.	MS-LS1.A	Engaging in Argument from Evidence Analyzing and Interpreting Data	Cause and Effect Systems and System Models Connections to Nature of Science: Science Is a Human Endeavor	ELA/Literacy: WHST.6-8.1 WHST.6-8.9

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

BODY SYSTEMS

This is a work in progress. Please check the Tools and Resources opening page in the online Teacher Portal for future updates.

This unit explores the anchoring phenomenon: The human body is composed of body systems. Although each system has certain functions, the systems all interact in a healthy body. An example is the interaction of the circulatory and respiratory systems during exercise. Students generate and answer questions such as: How do systems in the human body function? How do they interact? How can a problem in one system affect another system or systems?

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Medicines can treat diseases but can have unintended consequences.	How do scientists ensure that a medication to treat a health condition works and is safe?	How do scientists investigate and gather evidence about the human body? (Activity 1)	1 (13, 14)	MS-LS1-3 MS-LS1-8	Students learn about the challenge of pellagra and the methods scientists use to investigate and treat/cure medical conditions.
The human body is a system made up of subsystems, including organ systems, organs, cells, and tissues.	What are the systems in the human body, and what are they composed of?	What do you know about the organs in the human body? (Activity 2)	2, 3	MS-LS1-3	The human body has different systems with different functions.
		How do organs in the human body interact to perform a specific function? (Activity 3)			Body systems are composed of organs, which are composed of tissues, which are composed of cells.
Each body system has specific structures and functions.	What does each body system contribute to the overall function of the body?	How does your digestive system function and interact with other systems in your body? (Activity 4)	4, 5, 6, 7, 8	MS-LS1-3 MS-LS1-8	Each specific body system connects to other body systems.
		How does food provide energy and matter for organisms? (Activity 5)			Stimuli can affect behavior of organisms.
		What can your observations tell you about how an organism's nervous system will respond to stimuli? (Activity 6)			
		How does your brain gather and synthesize information from sensory receptors in your skin? (Activity 7)			Nervous systems gather and synthesize information differently.
		How does your body gather and synthesize information to respond to stimuli? (Activity 8)			Nervous system responses can affect other body systems.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

BODY SYSTEMS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Changes in one body system can cause changes in another body system.	How do different body systems interact and affect each other?	How do your body systems respond to exercise? (Activity 9)	9, 10, 11, 12	MS-LS1-3 MS-LS1-8	Systems interact.
		How much carbon dioxide is in your exhaled breath? (Activity 10)			Interactions between systems affect both systems.
		How do systems in your body work together to keep you healthy? (Activity 11)			Structures and functions of systems facilitate interactions.
		How do oxygen, nutrients, and wastes move into, within, and out of your body? (Activity 12)			Problems in one system can cause problems in another system.
Medicines can treat diseases but can have unintended consequences.	How do scientists ensure that a medication to treat a health condition works and is safe?	How are medicines tested during a clinical trial? (Activity 13)	(1) 13, 14	MS-LS1-3 MS-LS1-8	Students learn more about the methods scientists use to investigate and treat/cure medical conditions. Cycles back to Activity 1.
		How can data be used to determine the best medicine to research and test? (Activity 14)			Students investigate data about effects of a medicine on several systems in human body. Cycles back to Activity 1.

UNIT OVERVIEW

BODY SYSTEMS

This unit explores the issue of human body interactions and how those interactions can be affected by disease, medications, and other factors. Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 21–26 periods of approximately 45–50 minutes (approximately 5–6 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **View and Reflect: The Pellagra Story** Students learn about how scientists gather evidence on the functioning of the human body through a video segment on pellagra and a short reading about modern clinical trials.	Pellagra, investigating human health, clinical trials, data, evidence, hypothesis, inference, informed consent, observations, trade-offs LITERACY	Preview the video. Copy Student Sheets.	E&T A3	1–2
2. **Modeling: Parts of a Whole** Students begin to learn about major organs and systems in the human body. First, they complete an activity that exposes their current knowledge and ideas about the sizes and locations of specific organs. They then create a three-dimensional model of selected organs and structures and revisit their ideas about the human body.	Body systems, organs, organ systems, function, structure	Obtain chart paper, balances, and markers; copy Student Sheet; line torso models with plastic.	QUICK CHECK Proc.	2
3. **Investigation: What's Happening Inside?** Students learn about systems in the human body and their functions. Students group Organ or Structure Cards into systems and explore the function of organs and their associated body systems.	Organs, structures, body systems, levels of organization LITERACY	Copy Student Sheet.	QUICK CHECK A1, A3	1
4. **Reading: Digestion: An Absorbing Tale** Students read about functions and structures of the human digestive system. The reading also introduces the idea of system interactions between the muscular and circulatory systems.	Digestive system, stomach, intestine, system interactions, digestion, nutrients LITERACY	Copy Student Sheets. Gather string and tape.	EXP QUICK CHECK A2 MOD A2 EXP A4	1
5. **Modeling: Food Breakdown** Students use information provided in the text to develop physical models of proteins and carbohydrates. They use these models to explore the breakdown of food during digestion and the use of the resulting subunits as building blocks for human proteins (in the case of amino acids) or for generating usable energy (in the case of sugars). They create drawn models to represent the use of food as a source for matter and energy.	Matter and energy from food, carbohydrate, cell, energy, fat, matter, model, protein.	Copy Student Sheets. Divide pop beads into sets.	MOD A3	1–2

BODY SYSTEMS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
6. **Laboratory: Observing Organisms** Students investigate the behavior of living organisms (blackworms) in response to touch (stimulus response).	Stimulus, response LITERACY	Order blackworms two weeks ahead. Gather fish food, plastic bin, unbleached paper towels, microscopes, spring water.	QUICK CHECK A1	1–2
7. **Laboratory: Can You Feel the Difference?** In Part A, students explore their individual sensitivity to touch. They test their abilities to feel the difference between one and two points on different parts of their hands and arms. In Part B, students further investigate human sensitivity to touch by determining the smallest distance at which they can still feel two points. This experience reinforces the concept of sensory limitations and explores the phenomenon of variation among individuals.	Interpreting stimuli, control, variable.	Copy Student Sheets.	AID A1 EXP A5	2
8. **Reading: Finding the Nerve** Students read more about the human nervous system, how it functions, and how it interacts with other systems in the human body.	Nervous system, interneuron, motor neuron, nerves, neuron, sensory neuron, touch receptors. LITERACY	Copy Student Sheet.	EXP A4 (Assessment of PE MS-LS1-8)	1
9. **Laboratory: Heartily Fit** Students collect data on their heart and respiratory rates by measuring their pulses and breathing rates before and after moderate-impact exercises. They analyze the data to establish the relationship between circulatory and respiratory function during exercise. As an Extension, students can measure the effect on recovery time of regular exercise performed over a month-long period.	Circulatory system, respiratory system, effects of exercise, pulse, range. LITERACY, MATHEMATICS	Copy Student Sheets.	AID QUICK CHECK A3	1–2
10. **Laboratory: Gas Exchange** This activity explores the role of the respiratory system in the regulation of gases in the blood. Students investigate how to quantitatively measure the amount of carbon dioxide in their exhaled breath by using an indicator to perform a titration.	Exchange of oxygen and carbon dioxide, indicator. LITERACY	Copy Student Sheet. Gather chart paper, sponge, carbonated water, chemical splash goggles. Arrange access to wall clock or watch that displays seconds.	QUICK CHECK A5	2

BODY SYSTEMS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
11. **Reading: Interacting Systems** Students use the Stop to Think strategy as they read about levels of organization in the circulatory and respiratory systems, and how these systems and subsystems interact with each other and the digestive system to maintain life.	Interactions between circulatory, respiratory, and digestive systems, alveoli, artery, atrium, blood, blood vessels, capillaries, cardiovascular system, circulatory system, heart, lungs, respiratory system, veins, ventricle. LITERACY	Copy Student Sheets.	EXP A3	2
12. **Modeling: The Circulation Game** As a class, students model the path of blood as it travels through the human circulatory system to the lungs and other organs. The activity emphasizes the transport function of blood, particularly the transport of gases, nutrients, and wastes, and how the circulatory system interacts with other body systems.	Circulatory system, gas exchange, waste removal LITERACY	Copy Student Sheets. Gather drum.	ARG A4 (Assessment of PE MS-LS1-3)	2
13. **Investigation: Testing Medicines: A Clinical Trial** Students simulate a clinical trial to investigate how medicines are tested. In this model, students participate in a taste test to stimulate the clinical trial of a new headache medicine. The class pools results and draws conclusions based on their data.	Clinical trials	Copy Student Sheets. Gather large stirring spoon, permanent marker, 1 2-quart container, 2 1-quart containers, sugar, water.	AID A2 E&T A4	3
14. **Talking it Over: Evaluating Clinical Trials** Students work together to analyze the clinical trial results of three new headache medicines that a company is testing. Students look at effectiveness of the drugs and reported side effects. Students use this information to decide which drug should be put forward for further testing and development.	Clinical trials, evaluating medicines, side effects of medicines LITERACY	Copy Student Sheets.	ARG A1	1–2