A Study of Matter and Energy in Systems

Lesson 5: A Closer Look at Cellular Respiration

Grade: 9-10 General Biology

Length of lesson: 90 minutes

Placement of lesson: Lesson 5 of 7

Unit Overarching Goal

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Unit Central Question

How do matter and energy move through a system as living things interact with each other and the environment?

Lesson 5 Main Learning Goal

Other organisms, including animals, perform cellular respiration to form large molecules through both aerobic and anaerobic processes which can be used for growth, reproduction, and as fuel for chemical reactions.

Lesson 5 Focus Question

How do other organisms use the outputs of photosynthesis?

Ideal student response

Animals and microorganisms use their food as inputs to the chemical reactions of cellular respiration. Cellular respiration produces carbon dioxide and water. The energy released by cellular respiration is used by the organisms to run other chemical reactions that keep the organism alive. Some microorganisms and certain plant and animal cells can perform fermentation in the absence of oxygen. These anaerobic reactions produce carbon dioxide and ethanol. Aerobic respiration by microorganisms decomposes large molecules in compost to recycle carbon, oxygen, and water back into the environment.

Science Content Storyline

Energy transfers and matter cycles between organisms. Some organisms use aerobic cellular respiration producing large amounts of energy for other systems. Some organisms (yeast and bacteria) perform fermentation through an anaerobic process, providing smaller energy outputs for other systems inputs.

Aerobic respiration requires the inputs of oxygen and glucose. In fermentation, oxygen is not required as an input. As a result of respiration, outputs of CO2 and H2O are produced. Some of the glucose molecules are not used in respiration but are used to build large carbon-based molecules (such as proteins) to grow.

Materials

Bromothymol Blue and Yeast Demonstration (all quantities are per demonstration)

- Safety goggles
- 4 test tubes
- Tape and marker for labeling test tubes
- 0.04% bromothymol blue solution, 2.5 ml/125 ml H2O

- Rapid Rise dry yeast, 1g/100 ml H2O
- Sugar, 100g/100 ml H2O
- Water bath at 40ºC
- 3 stirring rods

Respiration Rate of Yeast Demonstration (all quantities are per demonstration)

- 5 250 ml Erlenmeyer flasks
- 5 balloons that will fit over the Erlenmeyer flask opening
- Tape and marker for labeling flask
- Rapid Rise dry yeast, 1g/100 ml H2O
- Sugar, 100g/100 ml H2O
- Glucose, 100g/100 ml H2O
- Starch, 100g/100 ml H2O
- 5 pieces of string, 40 cm in length
- 5 rulers

Other materials

- Lesson 5 slide deck
- Chart markers
- Charts with terrarium diagrams from Lesson 1

Advance Preparation

- Make sure you have all materials prepared for use and distribution before class to be efficient with time. You may not be able to complete the lesson in one class period because students will need time to think, read, write, and talk.

<u>Bromothymol Blue and Yeast Demonstration</u>

Directions are provided for a single demonstration per class. Increase materials accordingly if you wish to have groups conduct the demonstration.

- Prepare the bromothymol blue (BTB) solution.
    - Determine the total amount of BTB needed by multiplying the number of test tubes for the demonstration (four test tubes) by the volume needed to fill one test tube ¾ full.
    - The ratio of BTB to distilled water is 2.5 ml of 0.04% BTB to 125 ml of distilled water. The solution should be blue. This diluted solution can be made a day in advance and kept at room temperature in a sealed bottle.
- Premeasure the appropriate amounts of yeast and sugar to set up the four test tubes as follows:
    - Tube 1: Bromothymol blue solution
    - Tube 2: Bromothymol blue solution and sugar
    - Tube 3: Bromothymol blue solution and yeast
    - Tube 4: Bromothymol blue solution and sugar and yeast
- Label the test tubes with marker and tape or grease pencil.
- Determine how you will prepare a 40ºC water bath for the test tubes and how you will keep the test tubes upright in the water bath. Possible water bath setups include a) a test tube rack in a small cooler, b) test tubes in a large glass beaker on a hot plate, c) test tubes in a glass beaker filled with warm water. It is not critical that the water bath be exactly 40ºC, however this is the optimal temperature for yeast fermentation.

Respiration Rate of Yeast Demonstration

Directions are provided for a single demonstration per class. Increase materials accordingly if you wish to have groups conduct the demonstration.

- Premeasure the appropriate amounts of yeast, sugar, glucose, and starch to set up the five flasks as follows:
  - Flask 1: water and yeast
  - Flask 2: water and glucose
  - Flask 3: water and glucose and yeast
  - Flask 4: water and sucrose and yeast
  - Flask 5: water and starch and yeast
- Label the flasks with marker and tape or grease pencil.
- Inflate and deflate the balloons so they will inflate more easily during the demonstration. Ensure the balloons fit over the mouth of the flasks.
- Determine where the flasks can remain undisturbed for 24 hours.
- Create a large data table on chart paper or the board, replicating that in the student notebook, to record data and observations after 20 minutes and after 24 hours.

Lesson 5 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**How do other organisms use the outputs of photosynthesis? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
60 plus 15 min. in Lesson 6	**Aerobic and Anaerobic Respiration** <u>Activity Setup</u> Students read and annotate a short article about cellular respiration in non-photosynthetic organisms and are introduced to fermentation in yeast. They observe a demonstration using BTB to show that yeast release carbon dioxide during fermentation. <u>Activity</u> Student teams set up a class demonstration to indirectly compare the rate of fermentation by yeast in the presence of various food sources. <u>Activity Follow-up</u> Students complete a short article to consider the role of decomposition by microorganisms in compost.	Energy transfers and matter cycles between organisms. Some organisms use aerobic cellular respiration producing large amounts of energy for other systems. Some organisms (yeast and bacteria) perform fermentation through an anaerobic process, providing smaller energy outputs for other systems inputs. Aerobic respiration requires the inputs of oxygen and glucose. In fermentation, oxygen is not required as an input. As a result of respiration, outputs of CO2 and H2O are produced. Some of the glucose molecules are not used in respiration but are used to build large carbon- based molecules (such as proteins) to grow.
15	**Synthesize and Summarize** Students revise and add a plant system to their initial model drawing, adding labels showing the key features of a plant system. They revise and add to their initial response to the focus question.	
5	**Summarize and Link** In this lesson, students have considered aerobic and fermentation by non-photosynthetic organisms and considered the importance of compost in the terrarium system. In the next lesson, students will consider how the terrarium is an analogy for matter and energy interactions in an ecosystem.	

Lesson 5: A Closer Look at Cellular Respiration

Phase of Lesson: *How do other organisms use the outputs of photosynthesis?*

Main Learning Goal: Other organisms, including animals, perform cellular respiration to form large molecules through both aerobic and anaerobic processes which can be used for growth, reproduction, and as fuel for chemical reactions.

Focus Question: How do other organisms use the outputs of photosynthesis?

Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Notes:

Time: 10 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions.
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy B: Set the purpose with a focus question

Science Ideas

- Non-photosynthetic organisms, such as animals and microorganisms' use cellular respiration to obtain energy from food.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Lesson 5: A Closer Look at Cellular Respiration

Introduction

In the last lesson, you explored how plants use glucose as food. Through the chemical reactions of cellular respiration, glucose reacts with oxygen to produce carbon dioxide and water. The reactions of cellular respiration provide a net output of energy, some of which is used by the plant to rearrange molecules to form starch and other compounds used in the plant's body. Other energy is used for movement, growth, and reproduction.

In this lesson, you will consider how other organisms use the chemical reactions of cellular respiration to stay alive.

Lesson Question

How do other organisms use the outputs of photosynthesis?

Process and Procedure

1. Write your best ideas about the lesson focus question in the space below. Leave space to revise your ideas as you learn throughout this lesson. As you have new ideas, record them in a different color.

Implementation	Notes
Link to Previous Lesson • Remind students that in the last lesson, learned that food for plants is the glucose they produce through photosynthesis. Plants use cellular respiration to react to glucose and oxygen to form starch and other molecules that become part of a plant's body. Glucose also serves as fuel in chemical reactions. Cellular respiration provides energy used for movement, building body structures, and reproduction with outputs of carbon dioxide and water. *Lesson Focus Question* • **STEP 1:** Introduce the lesson focus question: "How do other organisms use the outputs of photosynthesis?" Write this question on the board so students can write it in the box on step 1 and refer to the question throughout the lesson. • Ask a student to read the focus question aloud. Then ask another student to paraphrase the lesson focus question in their own words. • Ask students to turn to an elbow partner to discuss their ideas about the lesson focus question. Put 30 seconds on the clock for partner one to share their ideas. Put another 30 seconds on the clock for partner two to share their ideas. • Have students write the Lesson 5 focus question in the box in their notebooks and, keeping in mind what they learned in the previous lesson, write their best ideas in the space below the box, leaving room so they can modify their response as needed. • Invite several students to share their ideas with the whole class. Use Strategy 1: Ask questions to elicit student ideas and predictions and Strategy 2: Ask questions to probe student ideas and predictions to make student thinking visible.	

Lesson 5: A Closer Look at Cellular Respiration

Phase of Lesson: *Matter and Energy Interactions in Cellular Respiration*

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: How do other organisms use the outputs of photosynthesis?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

STeLLA Strategies

- ❖ Strategy 4: Engage students in communicating in scientific ways
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy F: Make explicit links between science ideas and activities
- ❖ Strategy G: Link science ideas to other science ideas

Time: 60 Minutes

Science Ideas

- Energy transfers and matter cycles between organisms.
- Some organisms use aerobic cellular respiration producing large amounts of energy for other systems. Some organisms (yeast and bacteria) perform fermentation through an anaerobic process, providing smaller energy outputs for other systems' inputs.
- Aerobic respiration requires the inputs of oxygen and glucose.
- In fermentation, oxygen is not required as an input. As a result of respiration, outputs of CO2 and H2O are produced. Some of the glucose molecules are not used in respiration but are used to build large carbon-based molecules (such as proteins) to grow.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
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Matter and Energy Interactions in Cellular Respiration

2. To think more about how animals and other organisms use cellular respiration to obtain the energy needed to stay alive, read and annotate the article, *Cellular Respiration in Other Organisms*.

Cellular Respiration in Other Organisms

We have learned that plants use glucose produced through the process of photosynthesis as food. This glucose reacts with oxygen in the chemical reactions of cellular respiration to produce carbon dioxide and water. Cellular respiration results in a net release of energy which plants use to perform life functions including growth and reproduction.

Plants
Glucose + oxygen → carbon dioxide + water
(net release of energy)

Like plants, all other organisms, including animals, bacteria, and fungi, require matter and energy to stay alive. These organisms obtain matter from consuming food, which is broken down through digestion into small molecules, including glucose. In both plants and animals, glucose reacts with oxygen in the chemical reactions of cellular respiration to produce carbon dioxide and water. Cellular respiration results in a net release of energy which all organisms, including animals, bacteria, and fungi use to perform life functions including growth and reproduction.

All organisms
Glucose + oxygen → carbon dioxide + water
(net release of energy)

In both plants and animals, the chemical reactions of cellular respiration involve glucose reacting with oxygen. These reactions are often referred to as aerobic (with oxygen) respiration. Aerobic respiration produces carbon dioxide and water as output molecules along with a release of energy.

All organisms do cellular respiration! Aerobic = with oxygen

Yeast and some bacteria are living microorganisms that conduct an anaerobic (without oxygen) process called fermentation. In these reactions, glucose is the input molecule, and the output molecules are lactic acid or carbon dioxide and ethanol. In anaerobic reactions, there is a net release of energy. However, the amount of energy released is much smaller because the energy released by the formation of ethanol is much less than the energy released when water is formed.

Anaerobic = without oxygen. Outputs = CO_2 and ethanol
Less energy produced (energy released by ethanol is less than energy released by water)

Implementation	Notes

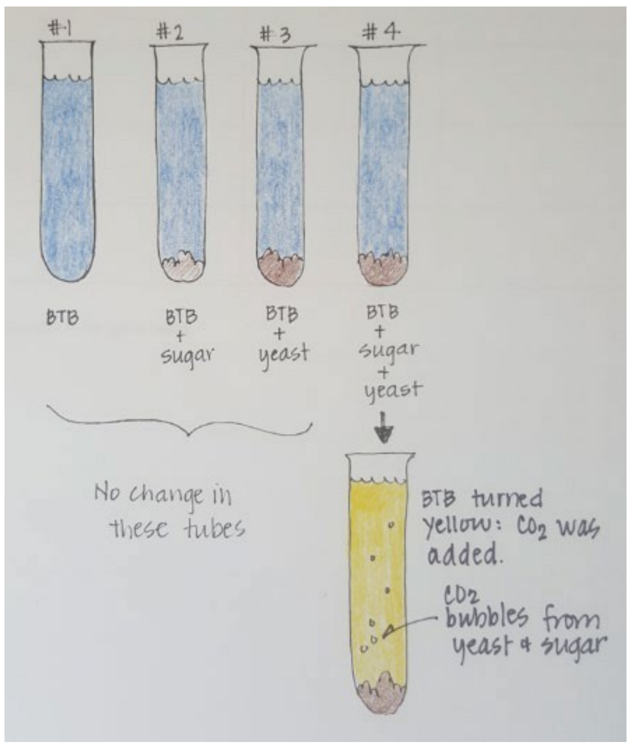
Activity Setup
• Remind students of the unit central question. Direct students' attention to the question chart and ask which questions have been answered by the lesson activities thus far. As students identify answered questions, encourage them to use science ideas to support their thinking. Invite students to add any additional questions to the question board.
• Highlight ideas about plant cellular respiration from the previous lesson. If ideas about animal respiration have not surfaced in the discussion to this point, ask the elicit questions, "Where do animals and other organisms get their food? Why do animals and other organisms need food?" Gather a variety of ideas from the class, asking probe questions as needed to make student thinking visible.
• **STEP 2:** Use an appropriate literacy strategy to have students read and annotate the article, "Cellular Respiration in Other Organisms." After students have completed the reading, ask several students to summarize key ideas from the article.
    ○ As students share their ideas, listen for common student ideas. For example, students may be surprised that yeast are living organisms.
    ○ Highlight that yeast produce carbon dioxide through the process of fermentation. Share that we will use yeast to think more about fermentation.	

3. Yeast are single-celled microorganisms that are classified as fungi. You may know that yeast is commonly used in the production of bread and fermented beverages such as kombucha, beer, and wine. These beverages are called fermented because, in the process of making them, the yeast cells use only fermentation to supply their energy needs.

   The carbon dioxide produced by yeast during fermentation causes bread to rise and results in the carbonation of some fermented beverages. The ethanol produced by yeast during fermentation evaporates when the bread is baked. It remains when alcoholic beverages are produced; thus, the alcohol in these beverages is ethanol.

   As you learned in previous lessons, bromothymol blue can be used to indicate the presence of carbon dioxide. Follow your teacher's directions to set up a demonstration to confirm that carbon dioxide is produced during fermentation. Draw a labeled diagram of the demonstration in the space below.

   The top half of this sample shows a diagram of the demonstration set up. The bottom half of this sample shows the results after 20 minutes in a warm water bath.



Focus on Student Thinking

- As students make predictions about what they expect to occur in each test tube, help them link to science ideas about cellular respiration as well as inputs and outputs of systems. Sample teacher student dialog follows:
  - T: What do you predict will happen in test tube 3 with yeast and BTB? (ELICIT)
  - S1: I think it will stay blue because the yeast doesn't have any food
  - T: Do others agree? (ELICIT)
  - S2: (pointing to CSW chart) I disagree. I think the tube might turn yellow because the yeast might have stored food like the seed did. Maybe the yeast can survive for a little while without food.
  - T: What do others think? (ELICIT)
  - S3: (pointing to CSW chart) That idea doesn't make sense to me. The reading said yeast are fungi that do cellular respiration. I don't think that yeast can store their own food.

Implementation	Notes
(see below)	

- **STEP 3:** Remind students that, in Lesson 2, they learned that bromothymol blue is an indicator for the presence of carbon dioxide. Invite students to read the first paragraphs.

  Note: Students may wonder if bread contains ethanol. While the yeast do produce ethanol as the bread is rising, the small amount of ethanol produced evaporates while the bread is baking.

  Note: Kombucha does contain small quantities of ethanol. However, it is not considered an alcoholic beverage as the amount of ethanol is too low. Kombucha sold in a grocery store contains less than 0.5% ethanol. For perspective, a 12 ounce beer contains 5% ethanol.

- Set up the demonstration, sharing each step with students:
  - Add the prepared bromothymol blue to each test tube, filling them ¾ full. As you add yeast and/or sugar to the tubes, ask elicit and probe questions to make student predictions public.
  - Mark that test tube 1 will contain only bromothymol blue solution
  - To test tube 2, add sugar and stir with a stirring rod
  - To test tube 3, add yeast and stir with a different stirring rod.
  - To test tube 4, add sugar and yeast. Stir with a clean stirring rod. It is important to stir with different stirring rods to avoid cross contamination.
  - Place the labeled tubes in the warm water bath, noting that 40ºC is the temperature at which yeast show the greatest rate of fermentation.

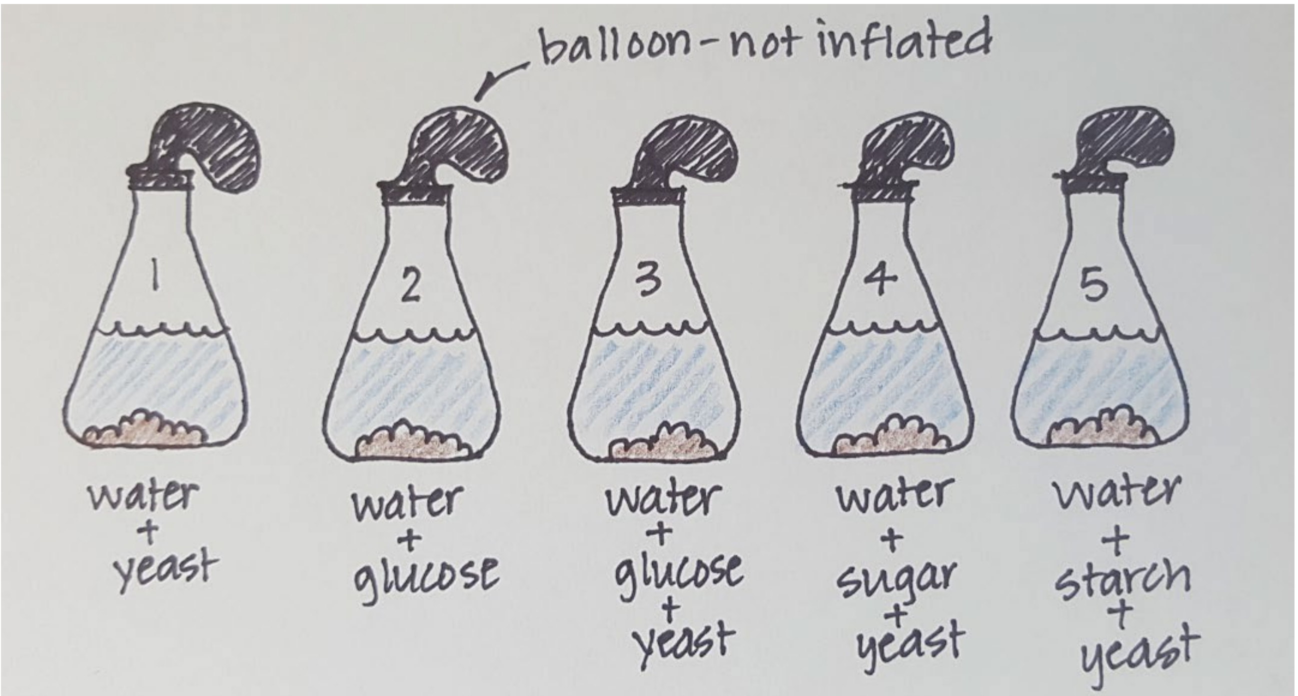
- Have students draw a labeled diagram of the demonstration setup in their notebooks. After drawing, students should share their drawing with their elbow partner to check for the clarity and completeness of their drawing. Have students make predictions about what they expect to occur in each test tube and why. Encourage students to discuss their predictions using sentence stems from the Communicating in Scientific Ways chart.

Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit student ideas.

- To be efficient with time, begin the setup for the next demonstration to provide time for the yeast to incubate in the warm water bath. After settingup the next demonstration, direct students to observe any changes in the test tubes and record their observations in a different color in their notebooks.

4. Yeast and other microorganisms break down many large molecules in addition to glucose in both respiration and (anaerobic) fermentation. Remember that aerobic respiration also produces carbon dioxide. But do they break down these molecules at the same rate? We can determine the rate of cellular respiration indirectly by measuring the amount of carbon dioxide produced.

   Follow your teacher's directions to set up a demonstration that will explore the production of carbon dioxide by yeast during fermentation. Draw a labeled diagram of the demonstration in the space below.



Implementation	Notes

Activity
 	
• **Step 4**: Invite a student to read the introductory text aloud to the class.
 	
<u>Teacher Note:</u> You may choose to set up the demonstration for the class or assign table groups to set up one of the five demonstration flasks. Alternatively, depending on the amount of materials available, you may set up multiple demonstration sets (e.g. two sets of five flasks). Directions are provided for set up of a single demonstration by the teacher.
 	
• Set up the demonstration, sharing each step with students:
  ○ Add 100 ml of warm water to the five labeled 250ml Erlenmeyer flasks.
  ○ Add the appropriate substances to the flasks as shown below, swirling the flasks to mix thoroughly:
    ▪ Flask 1: yeast
    ▪ Flask 2: glucose
    ▪ Flask 3: yeast and glucose
    ▪ Flask 4: yeast and sucrose
    ▪ Flask 5: yeast and starch
  ○ Cover the mouth of each flask with a balloon
 	
• Have students draw a labeled diagram of the demonstration setup in their notebooks. After drawing, students should share their drawing with their elbow partner to check for the clarity and completeness of their drawing. Have students make predictions about what they expect to occur in each test tube and why. Encourage students to discuss their predictions using sentence stems from the Communicating in Scientific Ways chart.
 	
Note: This is an appropriate time to return to the bromothymol blue and yeast demonstration and have students record the changes they observe in their notebooks using a different color. Invite students to share their ideas about what happened in each test tube, encouraging them to make links between science ideas.
 	
• Twenty minutes after the setup of the flasks, have student teams make observations of one flask and measure the diameter of the balloon. Use a string to wrap the largest diameter of the balloon and measure the length of the string, in cm, with a ruler.	

5. Record your data in the chart below.

Flask Components	Balloon Circumference (cm)		Observations
	After 20 minutes	After 24 hours	
Water + Yeast	8 cm not inflated	8 cm not inflated	This balloon did not inflate
Water + Glucose	8 cm not inflated	8 cm not inflated	This balloon did not inflate
Water + Yeast + Glucose	14.5 cm inflated	22 cm inflated	This balloon inflated the fastest at first, after 24 hrs it was even more inflated
Water + Yeast + Sucrose	13 cm inflated	21.5 cm inflated	This balloon inflated almost identically to the one on the glucose and yeast flask.
Water + Yeast + Starch	11 cm Barely inflated	18 cm inflated	This balloon inflated more slowly at first and then inflated after 24 hrs, but not as much as flasks 3-4.

Add notes from the class discussion in the space below.

Focus on Student Thinking

- Remind students that thinking about systems and system models, including inputs, outputs and interactions between components will help them think about their observations of these two demonstrations. The following is an example of a dialogue between teacher and students after observing both demonstrations:
  - T: How can we explain our observations in terms of inputs and outputs to a system? (ELICIT)
  - S1: Only the balloons on the flasks with water, yeast, and food inflated. So, the yeast need an input of food.
  - T: Can you say more about what was food for the yeast? (PROBE)
  - S1: Their food was glucose, sugar, or starch.
  - S2: Yeah, but the food isn't all the same. The flask with starch took longer to inflate the balloon.
  - T: Why do you think it took longer? (PROBE)
  - S2: Because the yeast had to break down the starch. It's a big molecule.
  - T: Can you connect these observations to inputs, outputs, and interactions of a system? (CHALLENGE, link ideas and activities)
  - S3: The inputs are food – sugar or starch.
  - S4: And an output is carbon dioxide.
  - T: Do you have evidence to show that carbon dioxide is an output? (CHALLENGE)
  - S4: In the first demo, the test tube with BTB, yeast, and sugar turned from blue to yellow. Yellow shows the presence of carbon dioxide.
  - T: Are there any other inputs or outputs to the system? (ELICIT)

Implementation	Notes

- **STEP** 5: Have student teams record their data for their assigned flask on the class data chart.
- Lead a class discussion of the differences between the flasks and what might lead to these differences. Ideas to highlight in the discussion include:
    - No evidence of reaction in Flask 1 should be observed. It is possible that Flask 1, containing water and yeast, may have a slight reaction due to the coating surrounding yeast when it was packaged for sale. However, students should note that there is no food source for the yeast to break down, thus no carbon dioxide should be produced.
    - Flask 2 should show no sign of reaction. The glucose merely dissolved in the water. No chemical reaction took place.
    - Flask 3 should have a strong initial reaction. Glucose is easily broken down by yeast, producing carbon dioxide.
    - Flask 4 should also show an initial reaction. Sucrose, a polymer made of glucose and fructose, can be broken down by yeast with the production of carbon dioxide.
    - Flask 5 should also show a reaction although the rate of reaction may be less than that of flasks 3 and 4. Starch is a polymer made of repeating glucose monomers.
    - All three sources of food for yeast (glucose, sucrose, and starch) are made by plants. Glucose is the product of photosynthesis while sucrose and starch are large molecules produced by plants through chemical reactions using energy produced from cellular respiration.
- After the class discussion, place the flasks where they will be undisturbed until the next class period. Mark that students will take their final measurements and observations at the beginning of the next class period.

Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit, probe, and challenge student ideas.

6. In this and previous lessons, we have been considering how matter and energy interact in a system. In Mr. Latimer's terrarium system, he planted a spiderwort plant in compost. Read and annotate the article below to learn more about compost.

Decomposition and Compost

What happened to all the spiderwort leaves that died and fell to the bottom of Mr. Latimer's terrarium? Without the process of decomposition, the dead leaves would have filled the terrarium. Decomposition is a naturally occurring process that begins at the death of an organism, or part of an organism. Large molecules, such as the starch in leaves, are broken down by worms and microorganisms into smaller molecules such as glucose. Organisms that break down the matter of once-living organisms are called decomposers.

Decomposers (worms, microorganisms) break down starch into glucose.

Decomposers use aerobic respiration to gain energy from the chemical reactions of glucose and oxygen, producing carbon dioxide and water. The decomposition of leaves by microorganisms releases carbon dioxide and water back into the atmosphere. Other chemical substances, such as nitrogen and phosphorus are returned to the soil. These chemicals are taken up by plants and incorporated into plant body structures.

Decomposers use aerobic respiration – CO_2 and H_2O go into the air, nitrogen and phosphorus go into the soil

Composting is a human-driven decomposition process. People combine dead plant materials such as leaves and food scraps in a pile or bin. Naturally occurring microorganisms grow and consume the plant materials, releasing carbon dioxide and water. In the process of aerobic respiration, heat is released. In compost piles where decomposition is rapidly occurring, the temperature at the center of the compost pile is between 135° – 165° F.

Compost: decomposition sped up by humans. Heat is released. Is this where some of the energy released by the products of cellular respiration in other organisms goes?

Record notes from your class discussion in the space below.

Implementation	Notes

Activity Follow-up
 	
• **STEP 6:** Direct students' attention to the unit central question, noting that we have been considering how matter and energy interact in a system. The system we have been exploring is Mr. Latimer's terrarium. Highlight that Mr. Latimer planted the spiderwort plant in compost. Invite students to share their prior knowledge about what compost is and how it is made.
 	
• Have students read the article, "Decomposition and Compost" to learn more about how compost is made.
 	
• After students have read and annotated the article, lead a class discussion about the role of compost in keeping the terrarium plant alive for over fifty years in a sealed bottle. Students should realize that:
 	
    ○ The compost in the terrarium contains microorganisms that are using aerobic respiration to decompose dead leaves from the plant.
 	
    ○ Based on the Law of Conservation of Mass reading in Lesson 4, carbon, oxygen, and water cycle through the plant and the environment in the bottle.
 	
    ○ Light energy enters the terrarium system to drive the chemical reactions of photosynthesis. Heat energy leaves the terrarium system although the amount of heat is too small to be noticeable.
 	
    ○ Energy drives the interaction of matter through chemical reactions. Depending on the amount of energy needed to break the bonds of the reactant molecules and the amount of energy released when the products are formed, a chemical reaction has a net gain or loss of energy.	

Lesson 5: A Closer Look at Cellular Respiration

Phase of Lesson: *Synthesis and Summarize*

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: How do other organisms use the outputs of photosynthesis?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

STeLLA Strategies

- ❖ Strategy 6: Engage students in developing and using content representations and models
- ❖ Strategy 9: Engage students in making connections by synthesizing and summarizing key science ideas
- ❖ Strategy H: Highlight key science ideas and focus questions throughout

Time: 15 Minutes

Science Ideas

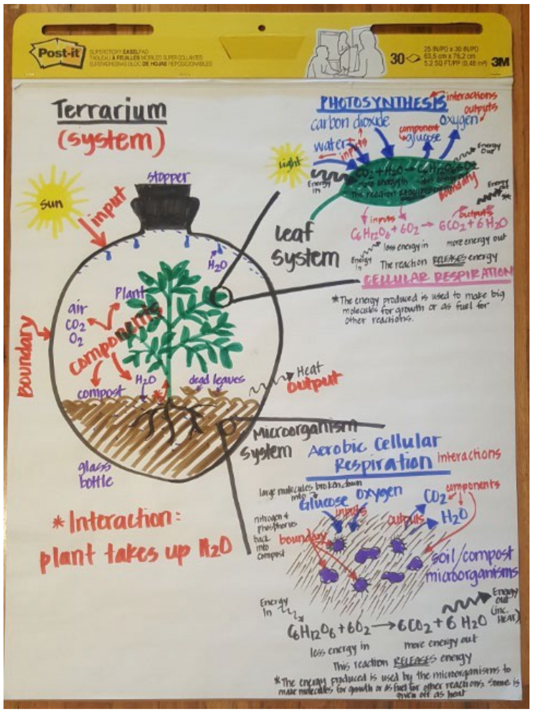
- Energy transfers and matter cycles between organisms.
- Some organisms use aerobic cellular respiration producing large amounts of energy for other systems. Some organisms (yeast and bacteria) perform fermentation through an anaerobic process, providing smaller energy outputs for other systems' inputs.
- Aerobic respiration requires the inputs of oxygen and glucose.
- In fermentation, oxygen is not required as an input. As a result of respiration, outputs of CO2 and H2O are produced. Some of the glucose molecules are not used in respiration but are used to build large carbon-based molecules (such as proteins) to grow.

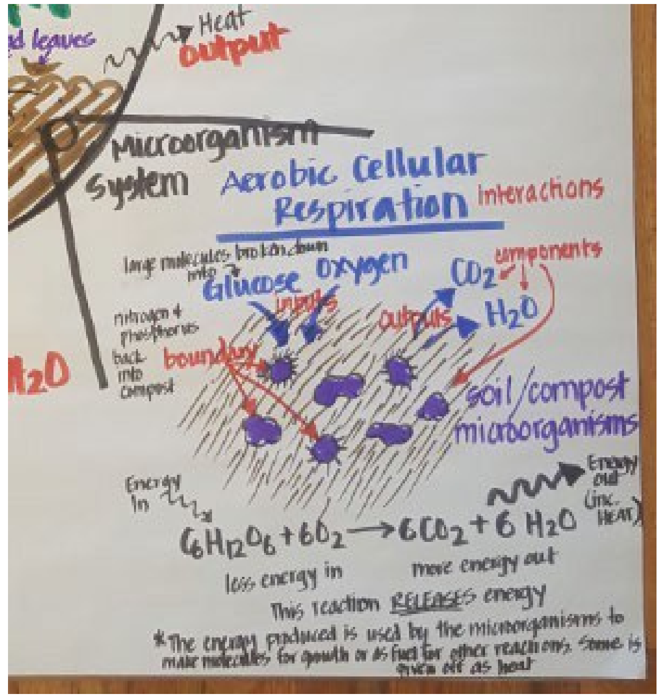
Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Synthesize and Summarize Ideas

7. Add your ideas about cellular respiration conducted by the microorganisms in the compost to your model of the terrarium system. Add labels to help others understand your model.





8. Reread your initial response to the lesson focus question. Consider the ideas from the activities you completed. If you would like to add to or revise your ideas, do so in a different color.

Implementation	Notes
Synthesize and Summarize Science Ideas • **STEP 7:** Provide directions for adding labels and other information about decomposers in the compost and their matter and energy interactions to their drawing of the plant system • As teams construct their drawing, circulate through the room asking probe and challenge questions to make student thinking visible. • **STEP 8:** Have students reread their initial response to the lesson focus question. After considering the activities they completed in this lesson, students should add to or revise their answer to the focus question in a different color. • Invite several students to share how their thinking changed over the course of the lesson.	

Lesson 5: A Closer Look at Cellular Respiration

Phase of Lesson: *Summarize and Link*

Main Learning Goal: Other organisms, including animals, perform cellular respiration to form large molecules through both aerobic and anaerobic processes which can be used for growth, reproduction, and as fuel for chemical reactions.

Focus Question: How do other organisms use the outputs of photosynthesis?

Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Notes:

Time: 5 Minutes

STeLLA Strategies

- Strategy I: Summarize key science idea

Science Ideas

- A system is an organized group of related objects or components that form the whole. Systems have boundaries, components, processes, and inputs and outputs. Often parts of a system are interdependent, and each one depends on or supports the functioning of the system's other parts.
- A terrarium can be considered a closed system in which matter cycles and through which energy flows.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Implementation	Notes
Summarize • Share that in this lesson, students learned that non-photosynthetic organisms, such as animals and microorganisms also use cellular respiration to obtain the energy needed to carry out life functions. Microorganisms can use fermentation to obtain energy from food as can some cells in plants and animals. Compost is produced by aerobic respiration and produces carbon dioxide and water that are returned to the environment for use by plants. *Link to the Next Lesson* • Link to the next lesson by sharing that, in the next lesson, we will apply our understanding of matter and energy interactions in the terrarium system to a larger system.	