A Study of Matter and Energy in Systems

Lesson 6: Earth: A Phenomenal Living System

Grade: 9-10 General Biology

Length of lesson: 90 minutes

Placement of lesson: Lesson 6 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 6 Main Learning Goal

The Earth's biosphere is a system in which matter and energy interact.

Lesson 6 Focus Question

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

Ideal student response

The Earth is a system. The boundary of the system is the atmosphere. Light energy from the sun enters the system to power the reactions of photosynthesis in plants. Carbon dioxide and water are the inputs to the plant system, with outputs of glucose and oxygen. The outputs of photosynthesis can be used as inputs to cellular respiration reactions in the plant system to produce large molecules like starch or as fuel for other chemical reactions.

Animals and decomposers use plants or other animals as food. The larger molecules of their food are broken down in digestion to simple molecules of glucose which, along with oxygen, become the input molecules for the chemical reactions of cellular respiration with outputs of carbon dioxide and water. Some decomposers use anaerobic fermentation to produce carbon dioxide and ethanol.

Within the biosphere ecosystem, matter such as carbon and water cycle between living organisms and their environment. Energy enters the system as light energy and some of the energy leaves the system as heat.

Science Content Storyline

Matter, including carbon and water, cycles through the biosphere. Energy flows through biosphere as light energy is transferred between organisms and leaves as thermal energy.

Matter and energy are conserved as they move between organisms and the environment, meaning that the number of atoms and the amount of energy remains the same.

Materials

- Chart paper, 1 sheet/team
- Markers, 1 set/team
- Tape for hanging chart paper
- Sticky notes, 1 pad/team
- Lesson 6 slide deck

Advance Preparation

- Determine if you want to change student groups for this lesson.

Lesson 6 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**How do matter and energy move through the biosphere as living things interact with each other and the environment? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
60	**The Earth as a system** <u>Activity Setup</u> Students read a short article about the biosphere and use an analogy map to compare the terrarium system and the biosphere system. <u>Activity</u> Student teams draw an illustration (model) of the biosphere system on chart paper. <u>Activity Follow-up</u> Students complete a gallery walk and revise their model based on feedback from the gallery walk.	Matter, including carbon and water, cycles through the biosphere. Energy flows through the biosphere as light energy is transferred between organisms and leaves as thermal energy. Matter and energy are conserved as they move between organisms and the environment, meaning that the number of atoms and the amount of energy remains the same.
15	**Synthesize and Summarize** Students reflect on their initial response to the focus question and how their thinking has changed over the course of the lesson. The evaluate their confidence in their ability to answer the focus question.	
5	**Summarize and Link** In this lesson, students have developed a model of the biosphere as a system. In the next lesson, students will consider how changing one component of the system affects other components of the system.	

Lesson 6: Earth: A Phenomenal Living System

Phase of Lesson: *How do matter and energy move through the biosphere system as livingthings interact with each other and their environment?*

Main Learning Goal: The Earth's biosphere is a system in which matter and energy interact.

Focus Question: How do matter and energy move through the biosphere as living things interact with each other and the environment?

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

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 6: Earth: A Phenomenal Living System

Introduction

In the last lesson, you explored how other organisms, including decomposers, use aerobic cellular respiration and (anaerobic) fermentation to provide a net output of energy, some of which is used by the organism to rearrange molecules to form other compounds used in the organism's body. Other energy is used for movement, growth, and reproduction.

To think about the interactions of matter and energy in a system, you have explored the interactions in Mr. Latimer's terrarium. In this lesson, you will consider how the Earth can be considered a system and how the interactions of matter and energy keep all organisms on Earth alive.

Lesson Question

How do matter and energy move through the biosphere as living things interact with each other and the environment.

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, they 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 (anaerobic) to obtain energy from food. Compost is produced by aerobic respiration and produces carbon dioxide and water that are returned to the environment for use by plants. *Lesson Focus Question* • **STEP 1:** Introduce the lesson focus question: "How do matter and energy move through the biosphere as living things interact with each other and the environment?" 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. • Have students write the Lesson 6 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 6: Earth: A Phenomenal Living System

Phase of Lesson: *The Earth as a System*

Main Learning Goal: The Earth's biosphere is a system in which matter and energy interact.

Focus Question: How do matter and energy move through the biosphere as living things interact with each other and the environment?

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 8: Engage students in using and applying new science ideas in a variety of ways and contexts
- ❖ Strategy G: Link science ideas to other science ideas

Time: 60 Minutes

Science Ideas

- Matter, including carbon and water, cycles through the biosphere.
- Energy flows through biosphere as light energy is transferred between organisms and leaves as thermal energy.
- Matter and energy are conserved as they move between organisms and the environment, meaning that the number of atoms and the amount of energy remains the same.

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.

The Earth as a System

2. To think more about how the Earth can be considered a system in which matter and energy interact to keep organisms alive, read and annotate the article, *The Biosphere*.

The Biosphere

Scientists often describe the Earth in terms of spheres. The solid, outer surface of the Earth is called the lithosphere. It is surrounded by a layer of air called the atmosphere. The hydrosphere is composed of all the water on Earth – in the air, on the surface, and in the ground. The biosphere consists of all life on Earth, and extends into the lithosphere, atmosphere, and hydrosphere. The lithosphere, atmosphere, and hydrosphere are often referred to as the environment in which organisms live and interact.

Four spheres: lithosphere, atmosphere, hydrosphere, biosphere

Within the biosphere, matter and energy interact in the chemical reactions of photosynthesis and cellular respiration. The Law of Conservation of Mass allows scientists to follow atoms of biologically important elements, such as carbon, as they move through living organisms and their environment. Because the atoms of these elements are very stable and are not created or destroyed in chemical reactions, elements cycle between living and nonliving parts of the biosphere. For example, the carbon cycle follows carbon from carbon dioxide in the atmosphere to glucose in a plant cell, to a molecule in an animal that eats the plant, and then back to carbon dioxide released into the atmosphere from the chemical reactions of a decomposer that has consumed the animal after its death.

Photosynthesis and cellular respiration move matter between the spheres.

Implementation	Notes
Activity Setup • Direct students' attention to the Question Board. Ask which questions have been answered in the unit thus far. As students identify answered questions, they should provide the answer and link to science ideas. • **STEP 2:** Use an appropriate literacy strategy to have students read and annotate the article, "The Biosphere." For example, you may choose to have student pairs work together with one student reading the first paragraph aloud and the second student summarizing what was read. Pairs should switch roles for the second paragraph.	

3. Mr. Latimer's terrarium is a closed system in which the living organisms, plants and microorganisms in the soil have thrived for over fifty years. Scientists estimate that life in the Earth's biosphere has existed for about 3.5 billion years.

   Use the analogy map below to compare Mr. Latimer's terrarium with the Earth's biosphere. The last row is blank for you to add any additional comparisons.

Analogy Map

Feature of the Terrarium		Feature of the Biosphere	They are alike because…
Spiderwort plant	**is/are like**	plants	Plants do photosynthesis and are the producers in the food chain
microorganisms		decomposers	Decomposers break down big molecules ofdead things for cellular respiration and return important elements like nitrogen and phosphorus to the soil and carbon dioxide to the air.
water		hydrosphere	Water is taken up by plants. Plants release some water into the air and that rains down to the soil
compost		lithosphere	The compost was the solid part of the terrarium, like the soil in which plants grow
air inside the bottle		atmosphere	The air in the bottle came from the atmosphere originally. Carbon dioxide, oxygen, and water are gasses in the atmosphere.
glass bottle		atmosphere	The bottle and the atmosphere represent the boundary of the systems.

Animals are not present in the terrarium, but they are present in the biosphere.

Implementation	Notes
• **STEP 3:** Invite students to read the introductory text. Students should complete the analogy map in pairs and then compare their ideas with their team. As students work, circulate among teams asking elicit, probe and challenge questions to make student thinking visible. • After students have completed the analogy map, hold a discussion with the class. Mark that the biosphere may contain features that the terrarium did not, such as animals. • Ask students to recall the key characteristics of a system. If students have difficulty with this task, direct them to the reading in Lesson 1. Have student teams identify the key characteristics of a system for the biosphere. After teams have had an opportunity to discuss their ideas, invite several teams to share their ideas with the whole class. Ideas to highlight include: o The boundary of the biosphere system is the atmosphere. o Light energy from the sun is the primary input to the biosphere system. While meteors represent occasional inputs of matter, scientists do not generally consider them to be inputs to the biosphere system. o Heat is the primary output of the biosphere system. Like meteors, scientists generally do not consider satellites and “space junk” to be outputs of the biosphere system. o Matter cycles within the biosphere system. Matter and energy interact within the system through the chemical reactions of photosynthesis and cellular respiration to keep biosphere organisms alive.	

Focus on Student Thinking

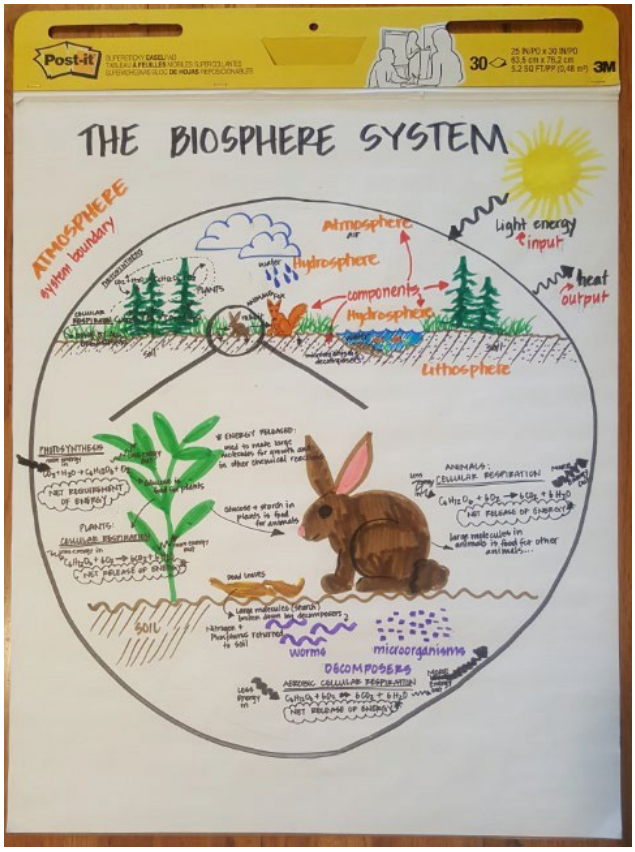
- Help students focus on the characteristics of a system as they complete the analogy map to link science ideas to the activity. Sample teacher-student dialogue follows:
  - T: How does the biosphere show the key characteristics of a system? (ELICIT)
  - S1: It has an input of light energy just like the terrarium
  - S2: It has lots of the same components as the terrarium, but I don't know if it has a boundary like the terrarium did.
  - T: What was the boundary of the terrarium? (PROBE)
  - S2: The glass bottle.
  - T: How did the glass bottle function as a boundary? (CHALLENGE)
  - S2: It kept the components inside isolated from the outside.
  - T: Is there anything in the biosphere that might function in the same way? Turn and talk with an elbow partner (The Turn and Talk makes this an ELICIT question)
  - T: What ideas did you discuss with your partner about parts of the biosphere that might function as a boundary to isolate the components of the biosphere from the outside? (ELICIT)
  - S3: We talked about how the atmosphere keeps heat in.
  - T: What did others discuss? (ELICIT)
  - S4: We said the gravity helps keep things on Earth in the biosphere because without gravity, things would float off into space
  - S5: I don't think gravity is a boundary though.
  - T: What do others think? (ELICIT)
  - S4: I think you're right. But the atmosphere is definitely a boundary.

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

4. Scientists consider the biosphere to be a system. As a team, you will create an illustration of the biosphere system that shows the interactions of matter and energy.

   Your illustration should show the following criteria:

   - ❑ Boundary of the biosphere system
   - ❑ Components of the biosphere system
     - plants
     - animals
     - decomposers
     - air
     - soil
     - water
   - ❑ Interactions of matter through the biosphere system components
   - ❑ Interactions of energy through the biosphere system components
   - ❑ Inputs to the biosphere system
   - ❑ Outputs from the biosphere system
   - ❑ Zoomed in interactions of matter and energy in a plant
   - ❑ Zoomed in interactions of matter and energy in an animal
   - ❑ Zoomed in interactions of matter and energy in a decomposer



Implementation	Notes
Activity • **STEP 4:** Invite students to read the directions for creating an illustration of matter and energy interactions in the biosphere system and the illustration rubric. Have students discuss the directions and rubric with their teammates. Ask groups if they have any clarifying questions about the task or rubric. • Teams may find it useful to draw a draft of their model before drawing it on chart paper. Suggest that teams wishing to draw a sketch of their ideas do so on one of the notes pages in their notebook. Encourage teams to use sentence stems from the Communicating in Scientific Ways chart as they work to develop their model. • Remind students that their illustration is a visual representation of their model of the biosphere system. Share that groups will have 30 minutes to complete their illustration. At the end of that time, they should be prepared to share their illustration with the whole class. Provide several time checks throughout the process to help groups with time management. • As students are working on their models, circulate through the room, asking probe questions to clarify student thinking and challenge questions that help move student thinking forward. Note their thinking around common student ideas identified on the previous page. Support students as they use and apply science ideas from Lessons 1 – 5 to their model. You may also consider feedback that you might include on a sticky note during the gallery walk. • After 45 minutes, have groups hang their illustration on the wall, grouping the illustrations that have similar organisms.	

Rubric for Matter and Energy in the Biosphere Illustration

Task	Good	Best
Create an illustration that includes the interactions of matter and energy in the biosphere system.	I created an illustration, but it was missing some of the interactions of matter and energy or some of the components of the system.	I created an illustration that includes all the interactions of matter and energy as well as all of the components of the system.
Include the characteristics of a system.	I included some of the characteristics of the system and/or did not clearly identify all the characteristics of the system.	I included all the characteristics of the system with clear labels.
Include the components of the biosphere system.	I included some of the components of the biosphere system and/or did not clearly identify all the components of the system.	I included all the components of the biosphere system with clear labels.
Include the interactions of matter and energy in the system. Include important molecules: carbon dioxide, water, oxygen, and glucose.	I included some of the interactions of matter and energy, including carbon dioxide, water, oxygen, and glucose.	I included all of the interactions of matter and energy, including carbon dioxide, water, oxygen, and glucose.
Include interactions of matter and energy in zoomed in plant, animal, and decomposer systems.	I included some of the interactions of matter and energy in the zoomed in systems of a plant, animal, and decomposer.	I included all the interactions of matter and energy in the zoomed in systems of a plant, animal, and decomposer.
Present the information clearly so that it is easy to understand the illustration.	Most parts of my illustration were clear, but some parts were confusing.	My illustration is clear and includes the correct information, labels, arrows, and brief descriptions where needed.

Implementation	Notes

Activity Follow-up
• Provide directions for students to complete an uncurated gallery walk, leaving sticky note feedback on the charts. Each student should leave three separate pieces of sticky note feedback. Remind students to use the rubric criteria to leave thoughtful feedback. If needed, define and provide examples and non-examples of productive feedback.
  ○ Non-productive feedback is general or vague and does not help the authors think differently about their work or help them improve their work during a revision process. Examples of non-productive feedback might include, “Your illustration is neat and easy to read.” or “Your illustration is really colorful.” or “It is hard to read your writing.”
  ○ Productive feedback is specific and helps the authors think more deeply about their ideas and improve their work during a revision process. Examples of productive feedback might include, “The parts of the Earth are not labeled, so it is not clear where the hydrosphere and lithosphere are located in the system.” or “You described the outputs of photosynthesis, but not the inputs of the process.”
• As students are providing feedback during the gallery walk, circulate through the room to scan the feedback being provided. If appropriate, add sticky notes with your feedback to the charts.	

5. Following your teacher's directions, discuss the feedback your team received.

   a) Which pieces of feedback are most helpful to your group? Why?

   b) Are there pieces of feedback that you do not plan to use as you revise your model? Why will you not use them?

Revise your model using the feedback that your team agrees with.

Implementation	Notes

• **STEP 5:** After there are multiple sticky notes with feedback on each chart, have teams take the charts back to their tables and review the feedback they received.
  ○ Encourage groups to group their sticky notes into categories to see patterns and trends in the feedback.
  ○ After sorting their sticky notes, teams should discuss both the patterns and individual feedback to determine how they will use, or not use, the feedback. Teams should record the highlights of their discussion in their workbooks.
• After reviewing the feedback, teams should revise their illustration based on their feedback. As teams work, circulate through the room, using probe and challenge questions to clarify and move student thinking forward about both science ideas and their decisions about the feedback they received.
• Teams should rehang their chart near their table to refer to later in the lesson.	

Lesson 6: Earth: A Phenomenal Living System

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: The Earth's biosphere is a system in which matter and energy interact.

Focus Question: How do matter and energy move through the biosphere as living things interact with each other and the environment?

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 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

- Matter, including carbon and water, cycles through the biosphere.
- Energy flows through biosphere as light energy is transferred between organisms and leaves as thermal energy.
- Matter and energy are conserved as they move between organisms and the environment, meaning that the number of atoms and the amount of energy remains the same.

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

6. How has your response to the lesson focus question changed over the course of this lesson? In the space below, write a reflection that summarizes the changes in your thinking and what caused your ideas to change. Be prepared to share your reflection with the whole class.

Implementation	Notes
Synthesize and Summarize Science Ideas • **STEP 6:** This step provides students with an opportunity to be metacognitive about their learning and consider how their ideas have changed. It also supports students in thinking about how they learn as they consider what caused the change in their ideas. • Ask students to think individually about how their response to the lesson focus question has changed. Have students write a reflection in their workbook that summarizes the changes, including how their ideas changed and what caused their ideas to change. • Ask students to share their ideas with the whole class. Use probe questions to understand and clarify student thinking.	

Lesson 6: A Phenomenal Living System

Phase of Lesson: *Summarize and Link*

Main Learning Goal: The Earth's biosphere is a system in which matter and energy interact.

Focus Question: How do matter and energy move through the biosphere as living things interact with each other and the environment?

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 1: Summarize key science ideas

Time: 5 Minutes

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.
- The biosphere 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.
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- Energy can be recycled.

7. During the next lesson, we will return to the unit central question, **"How do matter and energy move through a system as living things interact with each other and the environment?"** You will think about this question and make predictions about what might happen to the system when one of the components is changed.

   How confident are you that you can answer this unit central question completely?
   Circle a number to show your confidence.

   Not very confident 1 2 3 4 Very confident

   Provide reasons for your rating in the space below.

Implementation	Notes
Summarize • Share that in this lesson, students considered the biosphere as a system and the ways in which matter and energy interact in the biosphere. *Link to the Next Lesson* • Share that, in the next lesson, students will consider what might happen to the system when one of the components is changed. • **STEP 7:** Ask students to read the prompt and circle the number on the Likert scale that best represents their confidence in their ability to answer the unit central question. They should provide reasons for their choice in the space below the Likert scale.	