A Study of Matter and Energy in Systems

Lesson 7: Effect of System Changes

Grade: 9-10 General Biology

Length of lesson: 120 minutes

Placement of lesson: Lesson 7 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 fixedinto 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, chemicalenergy 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 7 Main Learning Goal

Using models, we can predict how changes in components affect the systems.

Lesson 7 Focus Question

How does a change in one component of the biosphere system affect the other components of the system?

Ideal student response

Changing one part of a system can affect many other parts of the system. For example, increasing carbon dioxide levels in the biosphere can increase plant growth through increased photosynthesis. This occurs because carbon dioxide is an input for the chemical reactions of photosynthesis. However, increasing levels of carbon dioxide can have damaging effects of plants as well. There are both benefits and harmful effects of increasing carbon dioxide levels on plants. More evidence is needed to fully determine all the effects on plants.

Science Content Storyline

Changes in a system can be described and predicted in terms of inputs and outputs to the system. As humans release stored carbon by burning fossil fuels, carbon dioxide will increase in the atmosphere. Increases in atmospheric CO2 will change the rate and amount of the outputs of photosynthesis.

Materials

- Systems charts (terrarium and biosphere) from prior lessons
- Tape
- HO: Ask the Experts: Does Rising CO2 Benefit Plants?
- Highlighters or colored pencils in two colors, 1 of each color per student
- Lesson 7 slide deck

Advance Preparation

- Print copies of the handout for each student

Lesson 7 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**How does a change in one component of the biosphere system affect the other components of the system? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
90	**Effects of rising CO_2 levels on plants** <u>Activity Setup</u> Students predict the effects of rising carbon dioxide levels on plants. They read an article to identify and critique evidence for two claims. <u>Activity</u> Student teams develop a scientific argument evaluating the strength and quality of evidence for the two claims. <u>Activity Follow-up</u> Students share their arguments to get feedback and teams revise their argument.	Changes in a system can be described and predicted in terms of inputs and outputs to the system. As humans release stored carbon by burning fossil fuels, carbon dioxide will increase in the atmosphere. Increases in atmospheric CO_2 will change the rate and amount of the outputs of photosynthesis.
15	**Synthesize and Summarize** Students revise their answer to the unit central question and reflect on how their learning has changed over the course of the unit.	
5	**Summarize and Link** The teacher and students summarize their learning and link to the crosscutting concept of the unit.	

Lesson 7: Effects of System Change

Phase of Lesson: *How does a change in one component of the biosphere system affect the other components of the system?*

Main Learning Goal: Using models we can predict how changes in components affect the systems.

Focus Question: How does a change in one component of the biosphere system affect the other components of the system?

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 7: Effects of System Changes

Introduction

In the last lesson, you explored how matter and energy interact within the biosphere system. In this lesson, you will consider what might happen to the system when one of the components is changed.

Lesson Question

How does a change in on component of the biosphere system affect the other components of the system?

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 • Ask several students to summarize what they learned in the previous lesson. Highlight that they developed a system model to show the interactions of matter and energy in the biosphere system. *Lesson Focus Question* • **STEP 1:** Introduce the lesson focus question: "How does a change in one component of the biosphere system affect the other components of the system?" 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 7 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 7: Effects of System Change

Phase of Lesson: *Effects of rising CO_2 levels on plants*

Main Learning Goal: Using models we can predict how changes in components affect the systems.

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 7: Engage students in constructing explanations and arguments
- ❖ 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: 90 Minutes

Science Ideas

- Changes in a system can be described and predictedin terms of inputs and outputs to the system.
- As humans release stored carbon by burning fossil fuels, carbon dioxide will increase in the atmosphere.Increases in atmospheric CO_2 will change the rate and amount of the outputs of photosynthesis.

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.

Effects of Rising CO_2 Levels on Plants

2. What happens to the components, inputs, and outputs of a system when one part of the system is changed? To think more about this question, you will consider the effects of increased carbon dioxide levels on plants.

   As you learned in earlier lessons, carbon dioxide is an input molecule for the chemical reactions of photosynthesis. Carbon dioxide is also an output molecule of the chemical reactions of cellular respiration. You developed illustrations of system models to show the interactions of matter and energy in different systems.

   What might be the effects of rising carbon dioxide levels on plants? Record your predictions in the space below. Be sure to include reasons for your predictions.

   Expect a variety of predictions. The most common prediction is that increased levels of carbon dioxide will result in increased photosynthesis and increased amounts of the products of photosynthesis. This prediction can be supported by the increased rate of photosynthesis when leaf disks were placed in bicarbonate solution rather than just water.

   Other predictions may be linked to changing environmental conditions based on climate change caused by increasing levels of carbon dioxide.

Implementation	Notes
Activity Setup • **STEP 2:** Direct students' attention to their systems models of the terrarium and biosphere. Invite a student to read the introductory text. • Have students individually make a prediction about the effects of rising carbon dioxide levels on plants, writing their ideas in their notebooks. • After students have recorded their predictions, invite them to discuss their predictions with their team using sentence stems from the Communicating in Scientific Ways chart. • Invite several teams to share the key ideas of their conversation with the whole class.	

3. Scientists, policy makers, and farmers are very interested in the question, "What are the effects of rising CO_2 levels on plants?" Plants are not only an important food source for humans, they are also food for the animals that we eat. Different people have made claims about how rising CO_2 levels will affect the plants that we depend on. Consider the following claims:

   Claim A: Rising carbon dioxide levels will benefit plants and humans because it will result in increased rates of photosynthesis and greater crop yields.

   Claim B: Rising carbon dioxide levels will prove harmful to plants and humans because of the damaging effects of climate change.

   You and your team will develop a scientific argument that will evaluate the two claims. A scientific argument is used to compare and evaluate competing explanations by analyzing the quality and relevance of the evidence and reasoning used to support the claim. Scientists may 1) determine that one explanation has stronger evidence and reasoning to support it, while the alternative explanation has weaker evidence and may be refuted; 2) determine that neither explanation has strong enough evidence and reasoning to support or refute it and more evidence is needed to answer the question; or 3) the evidence for several explanations may be combined to create an even stronger explanation.

   A scientific argument includes two main parts: 1) a scientific explanation that provides evidence and reasoning to support a claim, and 2) a rebuttal that provides justification for why the alternative claim, evidence, and/or reasoning is insufficient, irrelevant, or inaccurate.

   Which claim best matches with your team's predictions from Step 2?

Implementation	Notes
• **STEP 3:** Invite students to silently read the introductory text and the two claims. Ask several students to summarize what they read for the whole class. Emphasize that because plants serve as producers for all animals, including humans, many people are interested in understanding the effects of rising CO_2 levels on plants. • Ask students to recall what they learned about developing a scientific argument in the unit, A Study of Changes in Populations. Then have teams read the rest of the Step 3 text and decide which claim best matches their predictions from Step 2. Use a show of hands to do a quick poll to see which claim aligned with most teams' predictions.	

4. To consider the two claims about the effects of rising carbon dioxide levels on plants, your teacher will provide you with a handout of the article, "Ask the Experts: Does Rising CO_2 Benefit Plants?"

   Half of your team will use the article to identify evidence that supports Claim A and critique the quality and strength of that evidence. The other half of your team will do the same for Claim B.

Question: What are the effects of rising carbon dioxide levels on plants?

Claim A Rising carbon dioxide levels will benefit plants and humans because it will result in increased rates of photosynthesis and greater crop yields.	**Claim B** Rising carbon dioxide levels will prove harmful to plants and humans because of the damaging effects of climate change.
The evidence that supports this claim is… • CO2 is essential for photosynthesis. • CO2 fertilization effect: increased biomass is produced with increased CO2 levels. • Isolated leaves with increased CO2 have increased photosynthesis. • Artificially doubling CO2 from pre-industrial levels in forest plots increased the trees' productivity by 23%. • CO2 fertilization has been observed in agricultural crops. Doubling CO2 from pre-industrial levels boosts productivity of wheat by 11.5% and corn by 8.4%. • Farmers add nitrogen to agricultural crops by adding fertilizer. This offsets the lack of nitrogen in natural environments.	**The evidence that supports this claim is…** • Nitrogen is often a limiting factor in increasing biomass. Even with increased CO2 biomass production does not increase. • Increasing CO2 levels result in climate change which negatively impact plants due to heat stress and drought. • Loss of soil moisture can interfere with plant reproduction. • As CO2 levels continue to rise, benefits of increased productivity level off. • Rising CO2 levels also benefit the weeds that compete with farm plants. • Food grown in elevated CO2 levels are less nutritious; they lose significant amounts of iron and zinc. Grains also lose protein. • If CO2 levels reach 550 ppm, food crops could lose enough key nutrients to cause protein deficiencies in 150 million people and zinc deficiencies in an additional 150-200 million people. A total of 1.4 billion women and young children would lose more than 3.8% of their dietary iron.
Critique *Critique the quality and strength of the evidence that supports this claim.* This claim has less different types of evidence to support it. The primary evidence is the CO2 fertilization effect. The CO2 fertilization effect has been demonstrated in the laboratory, in forests, and with agricultural crop plants. We also observed the effects of increased CO2 (from none) causing leaf disks to float more quickly.	**Critique** *Critique the quality and strength of the evidence that supports this claim.* This claim has more different types of evidence to support it. While there are many different types of evidence, only the decreased nutrients in crops has quantitative data. Other lines of evidence do not include actual data. Limitations of nitrogen can be offset with fertilizer.

Implementation	Notes
Activity • **STEP 4:** Distribute the article, "Ask the Experts: Does Rising CO2 Benefit Plants?" • Have students read the article in pairs: one student should read the first paragraph and their partner should summarize what was read. They should switch roles for each succeeding paragraph. • After reading each paragraph, pairs should work together to determine if the paragraph provided evidence that would support either of the two claims. Evidence that supports Claim A should be highlighted or underlined in one color and evidence that supports Claim B should be highlighted in a second color. Students should include a key at the top of the article.	

Focus on Student Thinking

- After students have read and annotated the article, "Ask the Experts: Does Rising CO_2 Benefit Plants?" lead a class discussion to make sure that students have identified evidence to support the two claims. Sample student-teacher dialog follows:
    - T: What evidence did you and your partner find that supports Claim A? (ELICIT)
    - S1: They talked about fertilization effect of adding carbon dioxide.
    - T: Can you say more about the fertilization effect? (PROBE)
    - S1: It means that the more carbon dioxide, the more plant biomass is produced because the plant can do more photosynthesis.
    - T: What can others add? (ELICIT)
    - S2: Our group talked about how the fertilization effect levels off as CO_2 levels keep rising.
    - T: Can you say more about how that supports Claim A? (PROBE- CHALLENGE)
    - S2: Well, it still says there's a fertilization effect, but that it doesn't last forever. It might actually be some evidence for Claim B.
    - T: What do others think? (ELICIT) S3?
    - S3: Well, I still think it's evidence for Claim A. Just because it levels off doesn't mean is not a benefit for plants.
    - S4: I agree with S3. It is still a benefit for plants, even if it's a small benefit.

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. • To regroup students to one of the two claims, have one member of each pair raise their hand. Assign students with raised hands to Claim A. Assign students that did not raise their hands to Claim B. This will separate reading partners and provide an opportunity to compare highlighting among the new pairings. • Using the chart and the highlighting from the article, the new pairs should identify evidence that supports their assigned claim, listing it in bullet points in the second row of the chart. They should then consider the quality and strength of the evidence that supports their assigned claim, recording their ideas in the third row of the chart. • As students work, circulate through the room, asking elicit, probe, and challenge questions to make thinking visible and move student thinking forward. • Move students into expert groups for claim A and claim B to compare their evidence and critiques. Designate two corners of the room for Claim A and the other two corners of the room for Claim B. The pairs that completed the chart should go to different corners to compare their evidence and critique with students from other groups. As students share the evidence and critiques for their claim, others should add to their evidence and critiques as needed. • After corner groups have compared their evidence and critiques, students should return to their partner to share what they learned, continuing to add to their chart as needed. Refer to the list of evidence in red found in the SE key to make sure that pairs have included key evidence.	

5. Work with your team to decide if
   a. one claim (A or B) has stronger evidence and reasoning to support it, while the alternative claim has weaker evidence and may be refuted,
   b. neither claim A or B has strong enough evidence and reasoning to support or refute it and more evidence is needed to answer the question, or
   c. the evidence for both claims A and B may be combined to create an even stronger claim.

   Using the criteria below, write a scientific argument that answers the question: Which claim about the effects of rising carbon dioxide levels on plants is best supported by evidence and reasoning? Your argument should include:
   - your claim (either a, b, or c above)
   - relevant evidence and reasoning that supports your claim
   - scientific reasoning that critiques the evidence and evaluates your claim.
   - a rebuttal that refutes the other two claims

Implementation	Notes

• **STEP 5:** At this point, students should be sitting with their original teams. Lead students through directions for this step to ensure that students are clear about their task.
  ○ Students should understand that they will compare the evidence and critiques to determine which of the three claims they will make:
  a. one claim (A or B) has stronger evidence and reasoning to support it, while the alternative claim has weaker evidence and may be refuted,
  b. neither claim A nor B has strong enough evidence and reasoning to support or refute it and more evidence is needed to answer the question, or
  c. the evidence for both claims A and B may be combined to create an even stronger claim.
  ○ Once they have determined which claim they will develop an argument for, they should work as a team to write a scientific argument that provides relevant evidence and reasoning to support their claim, scientific reasoning that critiques the evidence and evaluates the claim.
  ○ After developing and writing their argument, teams should write a rebuttal that refutes the other two claims.
• Provide 30 minutes for teams to write their argument and rebuttal. Remind students to use sentence stems from their Communicating in Scientific Ways charts as they work together to develop their argument and rebuttal.	

Scientific Argument

Two claims have been made about the question, "What are the effects of rising carbon dioxide levels on plants?": 1) rising carbon dioxide levels will benefit plants and humans because it will result in increased rates of photosynthesis and greater crop yields; and 2) rising carbon dioxide levels will prove harmful to plants and humans because of the damaging effects of climate change. Neither claim has strong enough evidence or reasoning to support or refute it and more evidence is needed to answer the question.

The first claim is supported by evidence of the CO_2 fertilization effect: increased biomass is produced with increased CO_2 levels. Increased biomass levels have been observed in the laboratory using isolated leaves, in forests (23% increase), and in agricultural crops (wheat: 11.5% increase and corn: 8.4% increase). In leaf disk investigations, leaf disks did not float without the addition of a source of carbon dioxide from bicarbonate added to water. Further, nitrogen limitations that would mitigate the increase in biomass due to increased CO_2 can be avoided through addition of fertilizer to agricultural crops. While the evidence for the CO_2 fertilization effect has been demonstrated in multiple settings, there is little additional evidence from other sources to support this claim. Further, evidence for the second claim includes a leveling off of the CO_2 fertilization effect.

The second claim is supported by several lines of evidence. Nitrogen, not CO_2 is often the limiting factor in increasing biomass. However, in agricultural settings, this limitation can be avoided through the addition of fertilizer. Increasing CO_2 and fertilizer also increases the biomass of weeds in fields that compete with crops. For all plants, as CO_2 levels continue to rise, benefits of increased productivity level off. Increasing CO_2 leads to climate change which can harm plants through heat stress, drought, and loss of soil moisture. However, farmers irrigate crops currently to offset limited soil moisture. Finally, food grown in elevated CO_2 levels are less nutritious; they lose significant amounts of iron and zinc. Grains also lose protein. This loss of nutrients could lead to significant nutritional deficiencies (protein deficiencies in 150 million people and zinc deficiencies in an additional 150-200 million people; billion women and young children would lose more than 3.8% of their dietary iron). While there are multiple lines of evidence to support this explanation, only the decreased nutritional value of plants includes quantitative data.

Rebuttal

The first claim, "one claim (A or B) has stronger evidence and reasoning to support it, while the alternative claim has weaker evidence and may be refuted," is not supported. Both claims A and B have evidence to support them, and both claims A and B have evidence that refute the other claim. For example, the second claim uses evidence that nitrogen, not carbon dioxide, limits biomass production. However, the first claim notes that farmers add fertilizer to mitigate nitrogen limitations. Similarly, loss of soil moisture noted by the second claim can be mitigated with irrigation in crop plants.

The third claim, "the evidence for both claims A and B may be combined to create an even stronger claim," is not supported by the evidence. Much of the evidence in the two claims is contradictory. Both claims A and B have lines of evidence that support the claim with quantitative data. Combining the claims does not make a more robust claim because some evidence supports benefits to plants and other evidence supports harmful effects on plants. More evidence to support one claim over the other is needed.

Implementation	Notes
For Argument and Rebuttal example refer to SE Key	

5. Work with your team to decide if
   a. one claim (A or B) has stronger evidence and reasoning to support it, while the alternative claim has weaker evidence and may be refuted,
   b. neither claim A or B has strong enough evidence and reasoning to support or refute it and more evidence is needed to answer the question, or
   c. the evidence for both claims A and B may be combined to create an even stronger claim.

   Using the criteria below, write a scientific argument that answers the question: Which claim about the effects of rising carbon dioxide levels on plants is best supported by evidence and reasoning? Your argument should include:
   - your claim (either a, b, or c above)
   - relevant evidence and reasoning that supports your claim
   - scientific reasoning that critiques the evidence and evaluates your claim.
   - a rebuttal that refutes the other two claims

Implementation	Notes

Activity Follow-up
• **STEP 6:** The purpose of this step is to provide an opportunity for students to engage in scientific argumentation in ways similar to those of scientists. Review the directions for this step with the whole class.
• Determine how you will have students share their argument and rebuttal. Options for sharing include:
  ○ Pairing two teams and having each member of one team partner with a member of the other team.
  ○ Numbering the class by half the number of students in the class and having like numbers partner. For example, if there are 30 students in class, number off by 15 and have the number 1s partner with each other.
  ○ Students self-select a partner from another team.
• Provide fifteen minutes for partners to exchange papers and provide feedback. If some pairs finish before others, regroup those that have finished so they can provide additional feedback on a second argument.
• Students should return to their home teams and share the feedback they received. They should work together to revise their argument based on the feedback. Share that teams should be prepared to turn in their final argument and rebuttal at the end of the lesson.	

Lesson 7: Effects of System Change

Phase of Lesson: *Effects of rising CO_2 levels on plants*

Main Learning Goal: Using models we can predict how changes in components affect the systems.

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

- 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.

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. The unit central question is **"How do matter and energy move through a system as living things interact with each other and the environment?"** Return to the first page of Lesson 1 and revise your ideas in a different color.

   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 7:** Remind students of the unit central question, "How do matter and energy move through a system as living things interact with each other and the environment?" Have students return to their original response in Lesson 1 and revise their ideas in a different color. • Have students individually write a reflection about how their ideas have changed over the course of the unit and the causes of the change. • Invite elbow partners to share their reflections with each other. Then invite several students to share their response or something their partner said with the whole class.	

Lesson 7: Effects of System Change

Phase of Lesson: *Summarize and Link*

Main Learning Goal: Using models we can predict how changes in components affect the systems.

Focus Question: How does a change in one component of the biosphere system affect the other components of the system?

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 ideas

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.

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.
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8. During this unit, you used the crosscutting concept of systems and system models to think about the interactions of matter and energy and to develop a scientific argument about the effects of rising carbon dioxide levels on plants. How did thinking about systems and system models help you understand interactions of matter and energy and develop a strong scientific argument (or not)?

Responses will vary. Possible responses might include:

- I learned that a system has inputs and outputs. This helped me think about how the outputs would change if you changed an input.
- I learned that you can use a system model to predict the way a system behaves normally and then predict what will happen when the system changes.
- I learned that a system has boundaries and that a component of a system at one level can be its own system at another level. This makes everything really complicated and hard to predict changes.
- I used cause and effect more than systems and system models to think about the argument.
- I didn't really use systems and system models in the argument. I just thought about the evidence.

Implementation	Notes
Summarize • **STEP 8:** Highlight that throughout this unit students used the crosscutting concept of systems and system models to think about the interactions of matter and energy in a system. They used systems thinking to develop an argument about the effects of rising carbon dioxide levels on plants. • Ask students to reflect on how using systems thinking and system models helped them develop a strong argument (or not). Invite students to share their ideas with the whole class.	