Lesson 3: Matter Cycles and Energy Flows in Ecosystems

Overview

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In Lesson 2, students identified a pattern of the organic matter pyramid in a meadow ecosystem. In Lesson 3, they explain why that pattern exists by tracing matter and energy and connecting scales: (a) matter cycling and energy flow among carbon pools at the ecosystem scale, (b) growth, life functions, and death of organisms at the macroscopic scale, and (c) carbon-transforming processes (photosynthesis, biosynthesis, digestion, cellular respiration) at the atomic-molecular scale.

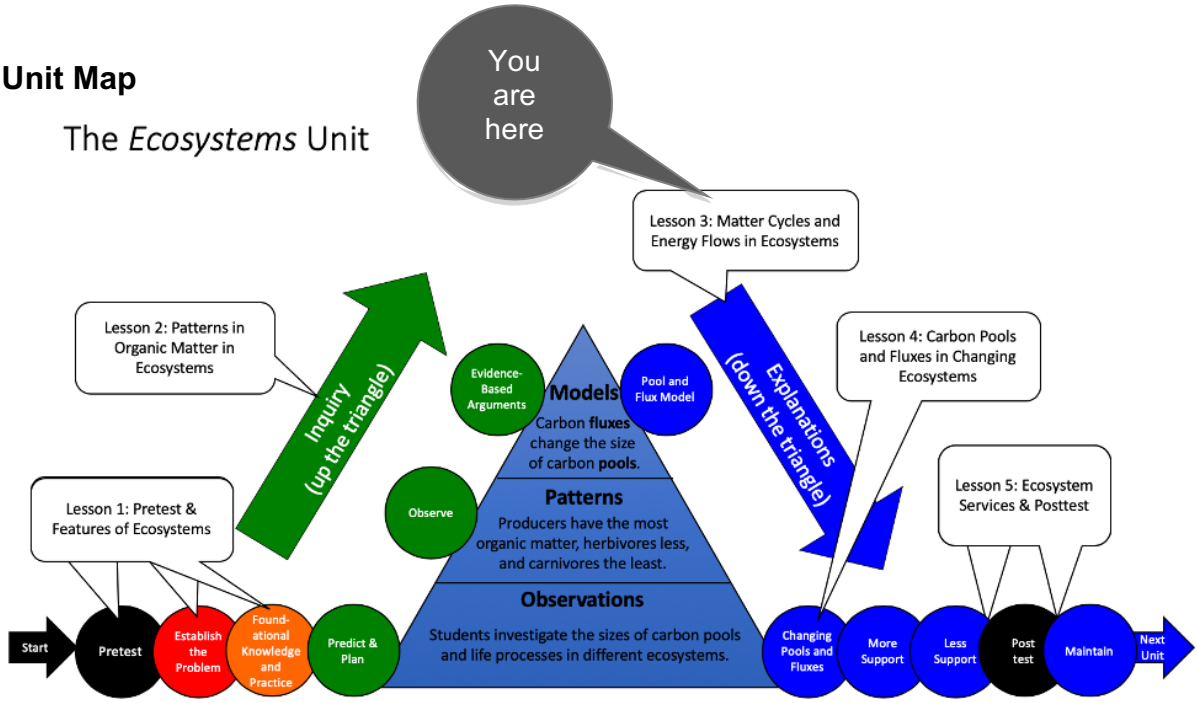
Guiding Question

How do carbon atoms and energy move through an ecosystem?

Activities in this Lesson

- Activity 3.1: Large-Scale Four Questions (20 min)
- Activity 3.2: Carbon Dice Game (30 min)
- Activity 3.3: Tracing Carbon Through Ecosystems (30 min)
- (Optional) Activity 3.4: What Happens to Soil Carbon? (30 min)
- Activity 3.5: Tracing Energy Through an Ecosystem (30 min)
- Activity 3.6: Explaining Patterns in Ecosystems (30 min)

Unit Map



Learning Goals

Target Performances

Activity	***Target Performance***
Lesson 3 – Matter Cycles and Energy Flows in Ecosystems (students as explainers)	
Activity 3.1: Large-Scale Four Questions	Students identify carbon pools in ecosystems and processes that move carbon atoms from one pool to another.
Activity 3.2: Carbon Dice Game	Students record and share data about their movement to different carbon pools when they play the role of carbon atoms in an ecosystem (the Carbon Dice Game).
Activity 3.3: Tracing Carbon Through an Ecosystem	Students name carbon pools and the processes that move carbon atoms among pools in terrestrial ecosystems.
(Optional) Activity 3.4: What Happens to Soil Carbon?	Students explain the role of detritus and detritus-based food chains in ecosystems.
Activity 3.5: Tracing Energy Through an Ecosystem	Students trace changes in energy and energy flow through carbon pools in ecosystems.
Activity 3.6: Explaining Patterns in Ecosystems	Students explain matter cycling and energy flow in ecosystems, answering the Carbon Pools Question, the Carbon Cycling Question, and the Energy Flow Question.

NGSS Performance Expectations

High School

- Chemical Reactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-1. Use mathematical and or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems at different scales.
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- Earth's Systems. HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

Middle School

- Matter and Energy in Organisms and Ecosystems. MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- Interdependent Relationships in Ecosystems. MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- Matter and Energy in Organisms and Ecosystems. MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- Matter and Energy in Organisms and Ecosystems. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- Matter and Energy in Organisms and Ecosystems. MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy in and out of organisms.
- Earth's Systems. MS-ESS2-1. Develop a model to describe the cycling of earth's materials and the flow of energy that drives this process.
- Human Impacts. ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Background Information

Three-dimensional Learning Progression

In Lesson 3, students develop complete explanations for what causes the organic matter pyramid, the key pattern in ecosystems they examined in Lesson 2. Using carbon pools as a context, students trace matter through representations that connect carbon-transforming processes at the atomic-molecular, organismal, and ecosystem scales, and they consider the differences between matter cycling and energy flow through ecosystems.

Key Ideas and Practices for Each Activity

Activity 3.1 Large-Scale Four Questions introduces students to the carbon pools: atmosphere, soil, producer, herbivore, and carnivore. They further simplify these into two groups: "organic matter" and "inorganic matter" pools to help distinguish between pools with CO_2 and pools with C-C and C-H bonds. These pools become the context through which matter and energy move throughout the rest of the unit. This forms a foundation for answering the Four Questions for the Large Scale: The Carbon Pools Question, the Carbon Cycling Question, the Energy Flow Question, and the Stability and Change Question. It is important to note that additional pools exist in ecosystems, but this ecosystem is intentionally simplified to focus on the organic matter pyramid as a theme in the unit.

Activity 3.2, Carbon Dice Game, helps students think about how carbon is cycled through different organisms in an ecosystem. The Meadow Simulation showed that the pattern of the organic matter pyramid emerges repeatedly in ecosystems but did not provide evidence for what drives this pattern. Through the dice game students can see that the organic matter pyramid is a natural consequence of the carbon-transforming processes that take place in all organisms: photosynthesis, digestion/biosynthesis, cellular respiration, being eaten, or death/defecation. Students play the role of individual carbon atoms, and rolls of the dice represent the likelihood of which process will happen to them inside an organism. Students can see the pattern in their visits to different carbon pools: They go through plants, soil carbon, and the atmosphere often, through herbivores less often, and through carnivores hardly ever.

In Activity 3.3, students *explain the reason* for the pattern of size of carbon pools that was observed in the Meadows Simulation and the Carbon Dice Game. When they followed individual carbon atoms through an ecosystem in the Carbon Dice Game, they observed that the carbon atoms visited some pools more often than others. In this Activity they consider the implications of this observation for the size of the pools.

In order to explain the organic matter pyramid, students need to think about movement of carbon in semi-quantitative ways. Most of organic carbon created through photosynthesis is used for cellular respiration (energy needs) is used by organisms and returns to the atmosphere. Because most of the organic carbon in an organism is used for cellular respiration (and much of it is lost during death and defecation), very little organic carbon is available to be passed from one level in a food chain to another. Thus, in a "steady state" ecosystem, carbon atoms are constantly in motion, but the relative size of the large-scale carbon pools stays about the same.

In Activity 3.4, which is optional, students are further introduced to the soil carbon pool.

In Activity 3.5, students connect the dice game with the Large-Scale Four Questions to describe how carbon cycles and energy flows in ecosystems:

- *Carbon cycles:* carbon atoms move between pools via carbon transforming processes
- *Energy flows:* in describing energy flow students must add the energy source for all energy in ecosystems: sunlight, which is transformed into chemical energy and ultimately heat. That heat energy is ultimately radiated into space in the form of infrared light (this is why the earth cools down at night). So, while heat energy may move through the atmosphere (and some of it may temporarily be trapped in the atmosphere due to the greenhouse effect), eventually all of it will be lost from ecosystems, and radiate into outer space.
- It is especially important for students to understand that while matter and energy move through an ecosystem in tandem when they are combined in organic matter, they follow different pathways at the beginning and end of food chains and food webs:

- Producers get matter ONLY from carbon dioxide, water, and minerals and energy ONLY from sunlight.
- When organisms use organic matter for cellular respiration, ALL the matter goes back into carbon dioxide, water, and minerals, while ALL the energy leaves the ecosystem as heat (which is ultimately radiated out into space). So *matter cycles, energy flows* through ecosystems.

In Activity 3.6 students use the Explanations Tool for Ecosystems to explain the reason for the key pattern in this unit: the organic matter pyramid. Students use their knowledge of energy flow and matter cycling to explain why the producer pool has more organic matter than the herbivore pool, and why the herbivore pool has more organic matter than the carnivore pool.

Key carbon-transforming processes: photosynthesis, cellular respiration, combustion

Content Boundaries and Extensions

Activity 3.1: Large-Scale Four Questions (20 min)

Overview and Preparation

Target Student Performance

Students identify carbon pools in ecosystems and processes that move carbon atoms from one pool to another.

Resources Provided

- 3.1 Large-Scale Four Questions PPT

Recurring Resources

- Large-Scale Four Questions Handout with Checklist (1 per student)

Setup

Open the 3.1 Large-Scale Four Questions PPT and project it. Prepare one copy of the Large-Scale Four Questions Handout with Checklist for each student.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 3.1 Large-Scale Four Questions PPT.

2. Use Slides 3 and 4 of the PPT to connect this activity to the previous lesson.

Show Slides 3 and 4 of the 3.1 Large-Scale Four Questions PPT to remind students of the Organic Matter Pyramid as an important pattern in most terrestrial ecosystems.

3. Discuss unanswered questions about organic matter in ecosystems.

Ask students to review their questions that they still have about the organic matter pyramid and matter and energy in ecosystems. They can review questions they asked on the 2.3 Evidence-Based Arguments Tool or the Driving Question Board.

Use Slide 5 to suggest *why* questions about patterns in organic matter pools.

4. Introduce the Large-Scale Four Questions.

Give each student a copy of the Large-Scale Four Questions Handout with Checklist.

- Use Slide 6 to introduce and discuss the Large-Scale Four Questions, discussing how they are similar to the Three Questions from previous *Carbon TIME* units, but at the Ecosystem scale.

5. Answer the Carbon Pools Question for a meadow ecosystem.

Use Slide 7 to remind students that they already know an answer to the Carbon Pools Question for meadows and other terrestrial ecosystems.

6. Connect the Carbon Cycling and Energy Flow Questions to carbon transforming processes.

Use Slides 8-12 to help students make connections between the Carbon Cycling and Energy Flow Questions and carbon transforming processes that they have studied in previous *Carbon TIME* units.

- Use Slide 8 to have student read the Carbon Cycling and Energy Flow Questions on their handouts and discuss how they are like the Matter Movement, Matter Change, and Energy

Change Questions that they used in previous *Carbon TIME* units. Discuss the Rules to Follow and Evidence We Can Observe portions of the handout.

- Use Slides 9-13 to review how all organisms use their food in two ways: materials for growth (biosynthesis) and energy (cellular respiration).
    - Use Slide 11 to remind students that animals CANNOT digest some of the food that they eat (such as cellulose and other fiber molecules for humans). This food leaves the animals as feces that add to soil organic carbon.
    - Use Slides 12 and 13 to discuss what happens to soil organic carbon: some is digested by decomposers and used for growth and cell respiration; some is not digested and remains in the soil (as humus).
- Note: It is important that students recognize that living organisms do not create or destroy matter or energy but only transform them in biological processes.

7. Summarize what students know about processes that move carbon from one carbon pool to another.

Use Slide 14 to summarize the biological processes that connect carbon pools. Point out to students that feces and death move but do not transform carbon.

Assessment

This unit builds on previous knowledge about organic versus inorganic carbon and the carbon-transforming process of photosynthesis, biosynthesis, decomposition, and cellular respiration. If students experience difficulty making the connections in this activity, they should be provided further instruction or review before moving on.

Differentiation & Extending the Learning

Differentiation

- Provide students with additional examples or references of carbon-transforming processes (biosynthesis, photosynthesis, cellular respiration) and/or organic and inorganic carbon.
- Use and refer to a word wall for questions on vocabulary related to transforming processes.

Modifications

Extending the Learning

Compare the Three Questions with the Four Questions. How are they alike? How are they different?

Activity 3.2: The Carbon Dice Game (30 min)

Overview and Preparation

Target Student Performance

Students record and share data about their movement to different carbon pools when they play the role of carbon atoms in an ecosystem (the Carbon Dice Game).

Resources You Provide

- Containers to put twist ties in (one for each pool)
- Die (1 for each student)
- Yellow twist ties (at least 300)

Resources Provided

- 3.2 The Carbon Dice Game PPT
- 3.2 Carbon Dice Game Tracking Sheet (1 per student)
- 3.2 Carbon Dice Game Posters (1 per class)
- 3.2 Carbon Dice Game Tally Cards (1 per class)
- 3.2 Carbon Dice Game Energy Labels (1 per class)
- 3.2 Carbon Dice Game Class Results Spreadsheet

Setup

- Print at least one copy of the 3.2 Carbon Dice Game Posters, 3.2 Carbon Dice Game Tally Cards, and 3.2 Carbon Dice Game Energy Labels and set them up as 5 "pools" (atmosphere, producer, herbivore, carnivore, and soil pools) around the classroom.
- Put the twist ties (these represent energy) in a container at the atmosphere pool and empty containers at each of the remaining pools.
- Prepare materials for individual students:
    - Have the dice ready to distribute to students (either singly or in pairs).
    - Print one copy of the 3.2 Carbon Dice Game Tracking Sheet for each student.
- Prepare a computer to show the PPT and record tally card results in 3.2 Carbon Dice Game Class Results Spreadsheet.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 3.2 Carbon Dice Game PPT.

2. Remind students of unanswered questions about the organic matter pyramid.

Use Slides 3 and 4 to remind students that they are working to explain the organic matter pyramid by answering three of the Large-scale Four Questions: the Carbon Pools Question, the Carbon Cycling Question, and the Energy Flow Question.

3. Explain the Carbon Dice Game.

Show students the 3.2 Carbon Dice Game Posters, 3.2 Carbon Dice Game Tally Cards, and 3.2 Carbon Dice Game Energy Labels in their locations around the classroom. These are the carbon pools for a meadow ecosystem.

- Use Slide 5 to introduce the Carbon Dice Game, explaining that they will play the roles of carbon atoms as they go through processes that move them from one pool to another in the ecosystem.

- Use Slides 6-9 to explain the rules of the Carbon Dice Game. Show students where the different carbon pools are set up around the room. Explain that sometimes they will be a part of organic molecules (that contain chemical energy), and sometimes they will be a part of inorganic molecules (that do not contain useable chemical energy). When they are part of an organic molecule, they need to carry a yellow twist tie with them to represent this energy. Show students the containers where they should pick up and drop off their twist ties. At each pool, students should make tally marks on the 3.2 Carbon Dice Game Tally Cards each time they visit a pool and fill in their individual tracking sheet, 3.2 Carbon Dice Game Tracking Sheet.

Accommodation: Have students work in pairs to play the game.

4. Students prepare to play the game.

Before playing the game, distribute one die and one copy of the 3.2 Carbon Dice Game Tracking Sheet to each student.

- Model how to play the game by having one or two students roll the dice and move through the ecosystem a few times in front of the whole class. Be sure students understand when to pick up or drop off a twist tie and that a carbon atom can only have one twist tie at one time. Twist ties can be used only once when some organism needs to use energy.
- Remind students to make a tally mark and record the pool and process on their tracking sheet every time they enter a carbon pool or roll the dice and remain in a carbon pool.
- Ask the students if they have any questions.

5. Students play the game.

Have all students start in the atmosphere pool as carbon in carbon dioxide molecules. Every student should record atmosphere as their first pool on their tracking sheet. Remember, these do not have energy, so students should begin without a twist tie. However, when they move to the Producer pool, they need to take a twist tie with them!

- Give students 10-15 minutes to play the game. Remember, in the Atmosphere pool, the twist ties represent sunlight energy; when students arrive at the Producer pool, the twist ties represent chemical energy; and when students leave twist ties at the Producer, Herbivore, Carnivore, and Soil Organic Carbon pools, the twist ties represent heat energy lost to the environment.
- Have your students save their 3.2 Carbon Dice Game Tracking Sheet. They will use them in the next activity.

Accommodation: Give students more time to move around the room to play the game. Set up a timer so students know to stay on task and that you expect them to have finished the game before the timer goes off. If you think your students will need more guidance, stop the students every five minutes or so to check on their progress and allow students to ask questions.

6. Evaluate the results of the game.

Use Slides 10-11 to evaluate the results of the game when it is over.

- Have students collect the 3.2 Carbon Dice Game Tally Cards from each station and add up the tally marks.
- Enter the number of tally marks in the 3.2 Carbon Dice Game Class Results Spreadsheet under the “visitations” tab. This will automatically generate a graph for your class. These results will be further evaluated in Activity 3.3

7. Observe the location of the energy twist ties.

Use Slide 12 for a discussion of what happened to the energy twist ties in the game. Energy movement through ecosystems will be discussed in greater detail in Activity 3.5, so for now, simply have students observe where the twist ties ended up in the ecosystem.

8. Ask students to connect the Carbon Dice Game to the organic matter pyramid.

Use Slide 13 to remind students of the questions about the organic matter pyramid that they started with. Ask them to connect their experiences in the Carbon Dice Game to the Carbon Cycling Question and the organic matter pyramid.

9. Have students complete an exit ticket.

Show Slide 14 of the 3.2 Carbon Dice Game PPT.

- Conclusions: Which carbon pool did the carbon atoms visit less than the others?
- Predictions: How can the Carbon Dice Game help us to explain the organic matter pyramid?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead into the next activity.

Assessment

During the discussion after the game, formatively assess how well students are able to make connections between the pools in the game and the charts that are generated from the graph. If they do not see the connection, you may want to spend time helping them understand the different representations.

Tips

You may want to print more than one copy of the 3.2 Carbon Dice Game Posters, 3.2 Carbon Dice Game Tally Cards, and 3.2 Carbon Dice Game Energy Labels. Printing multiple copies allows more students to visit each pool at a time.

Stress that although we are using twist ties to represent energy, energy is actually not made of matter/molecules!

Differentiation & Extending the Learning

Differentiation

- Have students play the game in pairs, rather than as individuals, with students in each pair sharing the work of reading the instructions, throwing the die, and recording the carbon pools that they visited on the tracking sheet.

Modifications

Extending the Learning

Use Slides 15-16 (hidden in the PPT) to explain that the Carbon Dice game was a model, and therefore has some limitations when representing actual ecosystems. Ask students to

brainstorm ways that a real ecosystem differs from the model ecosystem and share their ideas with the class.

Activity 3.3: Tracing Carbon Through Ecosystems (30 min)

Overview and Preparation

Target Student Performance

Students name carbon pools and the processes that move carbon atoms among pools in terrestrial ecosystems.

Resources You Provide

- (From Previous Activity) 3.2 Carbon Dice Game Tracking Sheet

Resources Provided

- 3.3 Tracing Carbon Through Ecosystems PPT
- 3.3 Tracing Carbon Through Ecosystems Graphic Organizer (1 per student)
- 3.3 Assessing Tracing Carbon Through Ecosystems Graphic Organizer
- (Optional) 3.3 Supplemental PPT

Setup

Print a copy for each student of 3.3 Tracing Carbon Through Ecosystems Graphic Organizer.
Set up a computer and projector for 3.3 Tracing Carbon Through Ecosystems PPT.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 3.3 Tracing Carbon Through Ecosystems PPT.

2. Review the results of the Carbon Dice Game and the Carbon Cycling Question.

Use Slide 3 to discuss the initial patterns students found in the Carbon Dice Game.

Use Slide 4 to introduce the purpose of this activity: using the results of the Carbon Dice Game to answer the Carbon Cycling Question.

3. Introduce the Ecosystem Matter and Energy Diagram.

Show Slide 5 of the 3.3 Tracing Carbon Through Ecosystems PPT. Explain that the diagram shows an overall picture of carbon cycling and energy flow in ecosystems.

- Use Slide 6 to discuss the left side of the diagram, showing how carbon cycles from inorganic to organic carbon pools.
- Use Slide 7 to discuss the right side of the diagram, showing carbon pools as rectangles and carbon movement as arrows. The green rectangles are organic carbon and the grey rectangles are inorganic carbon. For this Activity, students will be using the right side of the diagram.

4. Students complete the graphic organizer.

Pass out copies of the 3.3 Tracing Carbon Through Ecosystems Graphic Organizer.

- Have students complete the graphic organizer by writing the process represented by each arrow on the line in each arrow.
- When students are finished, show Slide 8 to allow students to check their graphic organizers. Talk with students about which arrows are carbon transforming processes

(photosynthesis, cellular respiration) and which arrows are carbon moving processes (falling leaves, death, eating).

5. Students trace their paths on the graphic organizer.

Have students take out their 3.2 Carbon Dice Game Tracking Sheet. Display Slide 9.

- Have students use a pencil to trace how they traveled during the carbon dice game on their graphic organizer. Each time they reach the bottom of the diagram they should circle back to the top (the top and bottom pool are the same).

6. Students identify the organic matter pyramid in the Ecosystem Matter and Energy Diagram.

Show Slide 10. Ask students to find the organic matter pyramid on their graphic organizer, then show where it is located.

7. (Optional) Show the Supplemental PPT.

The 3.3 Supplemental PPT includes animation that has a different representation of the organic matter pyramid, following 500 carbon atoms through a meadow ecosystem and showing the numbers of carbon atoms that reach different carbon pools.

8. Have a class discussion relating the organic matter pyramid to the Carbon Cycling Question.

Display Slide 11. Have a discussion about carbon cycling to explain the small amount of organic carbon that reaches carnivores.

9. Review the patterns.

Show Slide 12 to recap some of the main points about the processes that cause carbon to cycle in an ecosystem.

Assessment

Use the discussion as a formative assessment. If your students are having trouble describing carbon atoms moving through pools, you may want to review the graphic organizer and the patterns.

Tips

For this Activity, you will need to revisit some materials from Activity 3.2 Carbon Dice Game.

Differentiation & Extending the Learning

Differentiation

- Project the graphic organizer onto a white board, and fill in the names of processes and arrows as students work with their individual graphic organizers (see 3.3 Assessing Tracing Carbon Through Ecosystems Graphic Organizer).
- Have students work in pairs on the 3.3 Tracing Carbon Through Ecosystems Graphic Organizer.

Modifications

If students need additional practice thinking about carbon movement, use the 3.3 Supplemental PPT with animations of carbon movement.

Extending the Learning

Challenge the students to think about what would happen to a plant or animal in this ecosystem if they could not perform cellular respiration.

(Optional) Activity 3.4: What Happens to Soil Carbon? (30 min)

Overview and Preparation

Target Student Performance

Students explain the role of detritus and detritus-based food chains in ecosystems.

Resources Provided

- 3.4 Food Webs Video Worksheet (1 per student)
- 3.4 Grading the Food Webs Video Worksheet

Setup

Prepare one copy of 3.4 Food Webs Video Worksheet for each student. Prepare a computer with a projector to display the video.

Directions

1. Introduce students to the "extensions" in this activity: a video.

Tell students that in this activity, they will be think about what happens to the carbon that ends up in the soil through death, feces, and defecation.

2. Watch the video.

On a computer with an Internet connection, open the video at this link: https://www.youtube.com/watch?v=KI7u_pcfAQE. Give each student a copy of 3.4 Food Webs Video Worksheet. Instruct students to complete questions 1-7 during the video. Pause the video as the worksheet suggests giving students a chance to complete their worksheet.

- After students have completed questions 1-7 on their worksheet, watch the video again.
- After they watch the video for the second time, instruct students to answer question 8 on their worksheet.

Accommodation: After the first full viewing of the video, discuss each question before moving on to the next segment of the video and next question.

3. Discuss the video.

Ask students to share their responses from the worksheet with the class. Look to see if they are able to tell a story about why the soil pool (that contains detritus and decomposers) is so important to the food web.

- Ask students what will happen to the carbon from the soil after it is eaten by decomposers and animals. Students should recognize that the soil carbon will eventually become CO_2 in the atmosphere through cellular respiration.

Assessment

During this activity, check to see if students are making connections between the cycling of matter between pools they learned in previous activities with the content of the video.

Tips

Watch the video a few times to help students become familiar with the content.

Differentiation & Extending the Learning

Differentiation

- Allow students to watch the video on personal devices so they can pause and re-play parts of the video as needed while independently completing questions on the 3.4 Food Webs Video Worksheet.
- Combine students into strategic groups and have them watch the video together and complete the 3.4 Food Webs Video Worksheet as a group before sharing ideas with the class.

Modifications

Instead of using the 3.4 Food Webs Video Worksheet, have students discuss the video as a whole class afterwards.

Extending the Learning

Have students write and perform their own skit or song that models matter and energy cycling in an ecosystem.

Activity 3.5: Tracing Energy Through an Ecosystem (30 min)

Overview and Preparation

Target Student Performance

Students trace changes in energy and energy flow through carbon pools in ecosystems.

Resources Provided

- 3.5 Tracing Energy PPT
- 3.5 Tracing Energy Worksheet (1 per student)
- 3.5 Grading the Tracing Energy Worksheet

Setup

Set up a computer and projector for 3.5 Tracing Energy PPT. You will also need to remind students about the movement of twist ties the in Activity 3.2 Carbon Dice Game to solicit their initial ideas about energy flow in an ecosystem. Print out one copy of 3.5 Tracing Energy Worksheet for each student.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 3.5 Tracing Energy PPT.

2. Revisit the energy patterns from the Carbon Dice Game.

Using Slide 3, remind students of how they traced energy movement with yellow twist ties in Activity 3.2 Carbon Dice Game. Ask: *Where did most of the twist ties end up in the game?* Solicit student ideas about energy flow through carbon pools from the Game.

Accommodation: Before beginning this Activity, review the results of 3.2 The Carbon Dice Game.

3. Practice tracing energy.

Use Slides 4-13 to help students think about the Energy Flow Question and the process of tracing energy. These slides are animated, so view them in presentation mode for the best effect. Be sure to explain that all energy in the ecosystem is eventually converted into heat energy, which is released to the atmosphere. Heat energy dissipates, moves through the atmosphere and ultimately is radiated into space.

Accommodation: As you go through Slides 4-13, provide students with guided notes that include the information from the slides with a few words taken out so students can fill in the information during the lecture. Encourage students to use different colors to depict different forms of energy (i.e. yellow for sunlight energy, green for chemical energy, and red for heat and motion energy) while taking notes.

4. Students complete Part A of worksheets and compare responses.

Give each student a copy of 3.5 Tracing Energy Worksheet. Have students try to complete the first page on their own, and then have them compare with a neighbor to see if they both agree on all of the processes.

- Show Slide 14 of 3.5 Tracing Energy PPT while they work.

- You may want to tell students to draw a sun on the worksheet to indicate the initial source of energy for ecosystems.

5. Students complete Part B and discuss the movement and transformation of energy between carbon pools.

Have students answer questions 4-7 on the second page of the 3.5 Tracing Energy Worksheet based on what they just learned.

- Use Slide 15 to discuss the answer to the Energy Flow Question. Have students compare this to the answers that they wrote on their worksheet.

6. Answer the Energy Flow Question

Review energy flows in an ecosystem with the animations on Slide 16. Be sure to view it in presentation mode to see the animations.

- Use Slides 17-18 to link energy flows with the organic matter pyramid.
- On Slide 17, ask students what they think the distribution of energy looks like in an ecosystem. Have them explain their reasoning to the class.
- Slide 18 explains it would look the same as the organic matter pyramid.

7. Reviewing Matter Cycles and Energy Flow

Use Slides 19-22 to review with students how matter and energy move through an ecosystem.

- Slide 19 show the summative figure depicting how matter and energy move through an ecosystem.
- Slides 20-21 provide four key concepts from this Lesson about matter and energy in an ecosystem. Discuss with students how each of the concepts is portrayed in the figures.
- Return to the figure on Slide 22 to ask some more in-depth questions about its content, such as: *Where is the organic matter pyramid on the figure? Why doesn't energy cycle like matter? What ultimately happens to* ***most*** *of the carbon that enters the ecosystem through photosynthesis? (answer: it is returned to the atmosphere through cellular respiration carried out by producers, herbivore, carnivores, and decomposers)*

8. Have students complete an exit ticket.

Show Slide 23 of the 3.5 Tracing Energy PPT.

- Conclusions: What is the only way that energy gets into living plants, animals, and decomposers?
- Predictions: How are matter cycling and energy flow alike and different?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead into the next activity.

Assessment

Use 3.5 Grading the Tracing Energy Worksheet to get a sense of students' ideas and explanations about tracing energy. At this point, students should trace energy correctly through an ecosystem. Pay close attention to how students describe the movement and transformation of energy: in their explanations, do they ever break the "rule" by suggesting that energy is created or destroyed? Make sure to review the rule: energy lasts forever!

Tips

For this Activity, you will need to revisit some materials from previous activities, Activity 3.2 Carbon Dice Game.

Differentiation & Extending the Learning

Differentiation

- Have student work in strategic groups to complete the 3.5 Tracing Energy Worksheet.

Modifications

Extending the Learning

Have students discuss the difference between the way we talk about energy in an ecosystem (as light energy, chemical energy, and heat energy) and the way we talk about energy in casual conversations.

Activity 3.6: Explaining Patterns in Ecosystems (30 min)

Overview and Preparation

Target Student Performance

Students explain matter cycling and energy flow in ecosystems, answering the Carbon Pools Question, the Carbon Cycling Question, and the Energy Flow Question.

Resources Provided

- 3.6 Explaining Patterns in Ecosystem PPT
- 3.6 Explanations Tool for Ecosystems (1 per student)
- 3.6 Grading the Explanations Tool for Ecosystems
- 3.6 Telling the Ecosystems Story Reading (1 per student)

Recurring Resources

- Large Scale Four Questions Handout with Checklist (1 per student)
- (Optional) Big Idea Probe: Wolves and Deer (1 per student)
- (Optional) Assessing Big Idea Probe: Wolves and Deer
- Learning Tracking Tool for Ecosystems (1 per student)
- Assessing the Learning Tracking Tool for Ecosystems

Setup

Print one copy of the 3.6 Explanations Tool for Ecosystems and 3.6 Telling the Ecosystems Story Reading for each student. Prepare a computer and projector to show the 3.6 Explaining Patterns in Ecosystem PPT.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 3.6 Explaining Patterns in Ecosystems PPT.

2. Review the Ecosystems Story.

Display Slide 3. Tell students that at this point in the unit they should have evidence to support an explanation for the pattern in the organic matter pyramid. The Explanations Tool in this activity will help them record their ideas about the Large-Scale Four Questions and combine these ideas into a scientific explanation.

- Display Slide 4. Pass out the 3.6 Telling the Ecosystems Story Reading to each student. Have students read the section on Lessons 1, 2, and 3.
- Discuss how this section summarizes what students have learned about ecosystems so far.

3. (Optional) Have students complete the Big Idea Probe: Wolves and Deer for the final time.

If you decided to use the Big Idea Probe: Wolves and Deer, have students complete it and share their ideas for a third time. See Assessing the Big Idea Probe: Wolves and Deer and Using Big Idea Probes for suggestions about how to use the Big Idea Probe.

- Discuss how their ideas have changed since the beginning of the unit.

4. Students answer the first three Large-Scale Questions on their Explanations Tool.

Show Slide 5. Give each student one copy of the 3.6 Explanations Tool for Ecosystems. Tell students that in order to make sure we have the pieces for a complete explanation they will first compose their ideas in pieces that correspond with the first three of the Four Questions.

- Give students 10 minutes to complete the questions on the front of the Explanations Tool.

5. Students compare their responses to a partner's responses.

Display Slide 6. After students have had a chance to record their own ideas, have them find a partner and swap papers. Have the partners read each other's explanations and compare. Encourage them to look for differences between each other's ideas. They can refer to the Large Scale Four Questions Handout with Checklist. Have them look for key components:

- Does the explanation follow the rules (atoms and energy last forever?)
- Does the explanation use evidence from the atomic-molecular, cellular, and macroscopic scales to answer the question?
- Does the explanation explain why the organic matter pyramid pattern happens in ecosystems?

Give students a chance to revise their explanations based on the results of their discussion with a partner.

6. Discuss the answer to the Carbon Pools question.

Use Slide 7 to have the students discuss the Carbon Pools question on their 3.6 Explanations Tool for Ecosystems.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

7. Discuss the answer to the Carbon Cycling question.

Use Slide 8 to have the students discuss the Carbon Cycling question on their 3.6 Explanations Tool for Ecosystems.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

8. Discuss answer to the Energy Flow question.

Use Slide 9 to have the students discuss the Energy Flow question on their 3.6 Explanations Tool for Ecosystems.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

9. Students write paragraphs with full explanations.

Overview their answers to the Four Large-Scale Questions so far. Give students an additional 10 minutes to write a paragraph explaining the organic matter pyramid on the back of the Explanation Tool: *Why does the meadow ecosystem need so much grass to support so few foxes?*

10. Students critique and improve their full explanations.

Display Slide 10 for the full explanation. Have students use the Large Scale Four Questions Handout with Checklist to check that their story includes each of the parts (carbon pools, carbon cycling, and energy flow).

- If students don't have all three parts in their explanation, instruct them to add to their explanation using a different colored writing utensil.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

11. Students complete the Ecosystems Story Reading and discuss upcoming lessons.

Show Slide 11 of the PPT.

- Have students read the section on Lessons 4 and 5 in 3.6 Telling the Ecosystems Story Reading.
- If you are not teaching Lesson 4, tell students, but still have them read the subsection on Lesson 4.
- Discuss the section as a class. Include discussion of the new vocabulary. Have students explain the new vocabulary in their own words.

12. Have a discussion to complete the Learning Tracking Tool for this Lesson.

Show Slide 12 of the 3.6 Explaining Patterns in Ecosystem PPT.

- Pass out a Learning Tracking Tool for Ecosystems to each student.
- Have students write the activity chunk name in the first column, "Matter Cycles and Energy Flows, Explainers"
- Have a class discussion about what students did during the activity chunk. When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students figured out during the activity chunk that will help them in answering the unit driving question. When you come to consensus as a class, have students record the answer in the third column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the fourth column of the tool.
- Have students keep their Learning Tracking Tool for Ecosystems for future activities.
- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Matter Cycles and Energy Flows Explainer	Use the Carbon Dice game to model how carbon atoms move through ecosystems and use the Explanations Tool to explain the organic matter pyramid.	Matter cycles and energy flows among carbon pools because of life processes and functions: photosynthesis, cellular respiration, biosynthesis, eating, death, defecation.	How and why do carbon pools in ecosystems change over time?

Assessment

Use 3.6 Grading the Explanations Tool for Ecosystems to get a sense of students' explanations for the organic matter pyramid. At this point, students should have well-developed explanations for the pattern they see. Look for the range of ideas in the class and consider what may need more emphasis to help the students develop more sophisticated explanations.

Differentiation & Extending the Learning

Differentiation

- Provide sentence stems for discussion and filling in the Explanations Tool
- Work through the front of the Explanations Tool as a class.
- Hand out and refer to Example Ecosystems Explanation Handout when working on the Explanations Tool.
- Use and refer to the word wall to support students in using scientific language in their explanations.

Modifications