CHAPTER

2

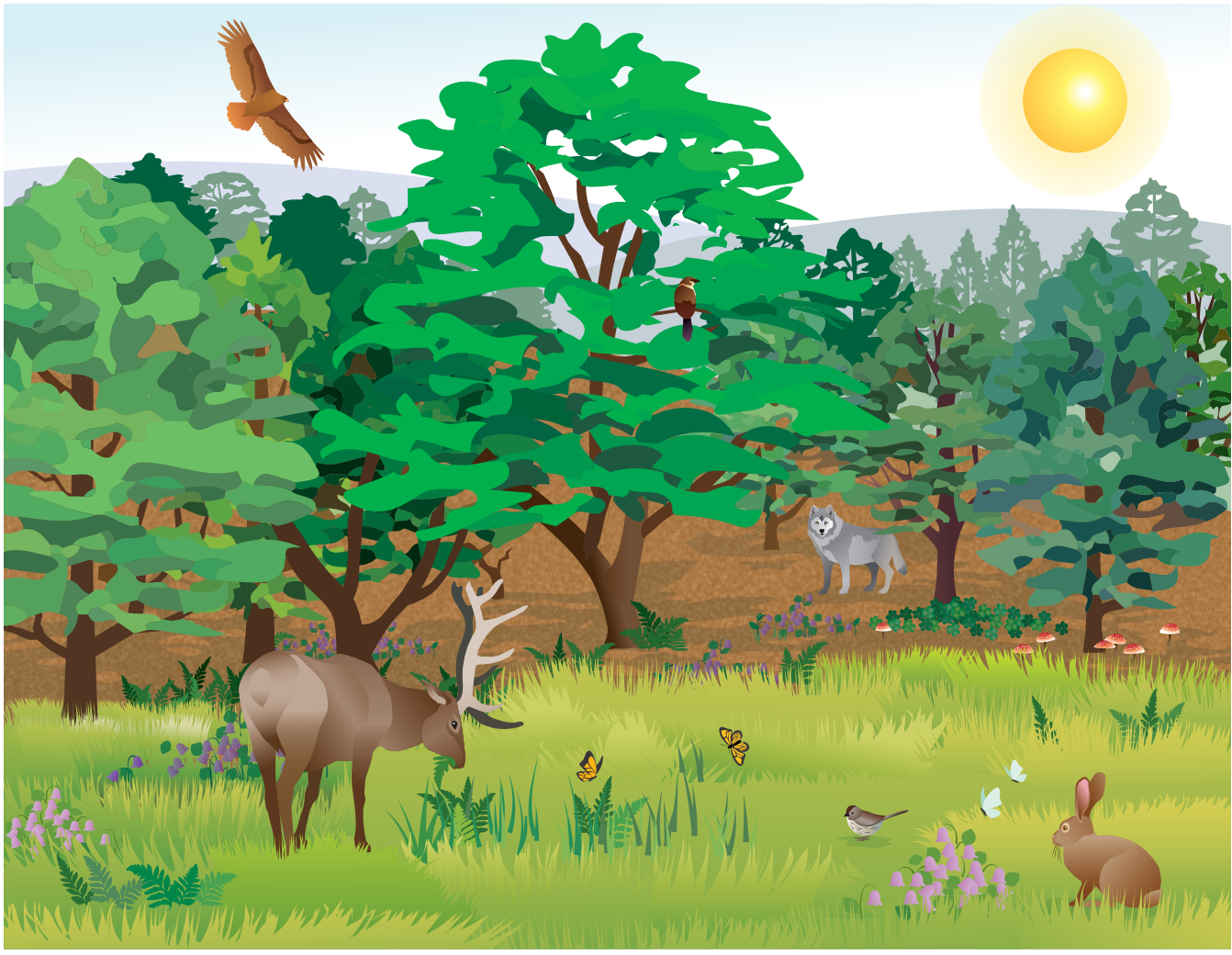
Ecosystem Models

In Chapter 1 you studied interactions between organisms, and developed food webs to model feeding relationships. Why do organisms need food? What does food provide? What else do organisms need to live, grow, and reproduce? And what happens to an organism when it dies? In Chapter 2 you will take a closer look at the roles of producers, consumers, and decomposers in the overall function of an ecosystem. The crosscutting concepts of energy and matter will be critical to thinking about interactions among organisms and between organisms and the abiotic parts of the environment.

You will use the scientific practice of developing and using models to understand and explain the movement of matter and energy in ecosystems. Scientists use models to show how things work, to construct explanations for why things happen, and to make predictions. You will use models to represent the movement of energy and matter in ecosystems. These models will help you describe, explain, and predict how ecosystems are affected by disruptions, such as forest fires or volcanic eruptions.

Engage: Ecosystem Changes

In the previous chapter, you developed food webs to model the feeding interactions in the Greater Yellowstone ecosystem. In this activity and this chapter, you will look more deeply at the interactions between the abiotic environment and organisms. You will use scientific models to represent these interactions and explain how they are affected by natural disasters.



Guiding Question

How do natural disasters affect ecosystems like the Yellowstone ecosystem?

Process & Procedure

Part One: Thinking About Ecosystems

1. Examine the illustration on the facing page of a forest and meadow in the Yellowstone Ecosystem. Discuss the following questions with your group of four students.

a. How do the plants in the illustration:

- get the energy they need to live, grow and reproduce?
- get the matter (stuff) they need to grow?

b. How do the animals in the illustration:

- get the energy they need to live, grow, and reproduce?
- get the matter (stuff) they need to grow?

c. When a plant or animal dies, what happens to it? Where does the matter it's made from go?

Part Two: Disruptions in an Ecosystem

2. Examine the photographs and read the captions for the four disasters described on the following page.

3. Your teacher will assign your group of four to discuss one of the four disasters. With your group, discuss the following questions.

- What effects do you think this disaster would be likely to have on abiotic (non-living) parts of the Yellowstone ecosystem?
- What effects do you think this disaster would be likely to have on the biotic (living) parts of the Yellowstone ecosystem?
- Would any organisms be killed by the disaster? If so, what do you think would happen to these dead organisms?

4. With the class, discuss the question: What similarities and differences are there in the effects of the four disasters on the ecosystems?

a. A severe drought is caused by several years of very little rainfall.
b. An area is flooded, and as it recedes, it washes away soil and plants.
c. A landslide covers a hillside and meadow with mud and debris.
d. A violent tornado tears a 1.5 mile wide path through the forest.

Part Three: What Happens to Dead Organisms and Wastes

5. Watch as your teacher sets up a compost bag with leftover plant material.

6. Discuss with your group:

- What do you predict will happen to the material in the bag in the next few days?
- What do you think will cause this to happen

Analysis

1. How do you think the disruption you discussed would affect the ability of organisms to get the energy they need to live?

2. How do you think the disruption you discussed would affect the ability of organisms to get the matter they need to live?

Explore: Life and Death in an Ecosystem

Ecosystems are always changing. For example, the type and number of organisms may change or the amount of available water may change. Sometimes these changes are small, and the levels of various biotic and abiotic factors in the ecosystem go back and forth within a range. Such an ecosystem is considered **stable**. At other times, biotic or abiotic factors undergo major changes, and an ecosystem becomes unstable. Events like the ones you discussed in the previous activity can cause ecosystems to become unstable. After these disruptions, the ecosystem may eventually return to the way it was before or change to a new stable system.

One disruption that can lead to large-scale changes is fire. In this activity, you will explore the changes that take place during and after a fire in Yellowstone.

Guiding Question

What happens over time after an ecosystem is disrupted by a fire?

Materials

For each group of four students:

- 1 set of six Forest Change cards
- 1 set of 13 Yellowstone Food Web Cards from Activity 1.2
- 1 badger card
- 1 bald eagle card

Process & Procedure

Part One: Matter and Energy for a Food Chain

1. Spread out the Yellowstone Food Web Cards. With your group of four students, create a food web that includes two additional animals—a badger and a bald eagle.
   - Badgers eat smaller animals such as hares.
   - Bald eagles eat badgers, beavers, and hares.
2. Work with your group of four to select four cards that you can arrange in a food chain with four levels.
3. In your science notebook, begin a simple diagram (drawing) of the food chain you just created. To make your diagram:
   a. Use a full sheet of paper for your diagram.
   b. Title the diagram "Yellowstone Ecosystem Model."
   c. Put the plant near the bottom of the page, and arrows to the organisms that eat them going up the page.
   d. Label the organisms on the diagram.
4. Discuss the following with your group. Then add your ideas to your diagram. Use labels and captions to help explain your thinking.
   - Where does each organism get the matter it needs to grow?
   - What happens to the matter in each organism when it dies?
   - Where does each organism get the energy it needs to grow?

Part Two: Fire in Yellowstone

5. Carefully examine the six Forest Change cards. They show a forest and a meadow at the forest's edge in the Yellowstone ecosystem. With your group, use words to:
   - **a.** identify or describe the plants and animals on the cards.
   - **b.** describe the abiotic factors in the forest.
6. The Forest Change cards show changes in a forest ecosystem. Discuss how the drawings are similar to and different from a real forest ecosystem.
7. Which card shows a forest ecosystem that has existed for a long time? Place it as the first card in your timeline.
8. Determine what happened in this forest over time. Place the remaining five cards in the order you think they happened. Record your sequence in your science notebook, skipping a few lines between the letter for each card.
9. Next to the letter for each card, write a brief description explaining:
   - why you placed the card where you did.
   - what is happening to the ecosystem in the card.
10. With your class, discuss the order of the cards and try to reach agreement on the order.

Analysis

1. What do you think happened to the matter and energy in the ecosystem during the fire?
2. Think about what might cause a major disruption.
   - **a.** Besides fire, what other factors in the abiotic environment could disrupt or cause major changes in an ecosystem?
   - **b.** What biotic factors could cause major disruptions in an ecosystem?
3. In what order did the animals return to the forest ecosystem? Why do you think they returned in that order?
4. Do you think large fires in national parks should be put out or left to burn? Explain your thinking.

5. Review the series of illustrations below of change in a pond ecosystem. Compare how change occurred in the forest and the pond. Be sure to describe similarities and differences in the causes and effects of the changes in the two ecosystems.

Explain: Matter in Ecosystems

You have used food webs to show feeding relationships between organisms in an ecosystem. These food webs are examples of scientific models.

A scientific **model** is a representation that can be used to explain and predict what happens in the natural world. Scientists use models to ask questions and develop explanations for how a system works. They also use them to communicate ideas and predict how a change in one part of a system might affect another part of the system. A model might be presented in a diagram, an arrangement of physical objects, a mathematical equation, or even a computer program.

In the previous activity, you added your ideas about the movement of matter and energy in ecosystems to your Yellowstone ecosystem model. In the next three activities, you will add to and revise your model as you learn more about matter and energy.

Plants (A) and decomposers (B) each play important roles in the movement of matter in ecosystems.

Guiding Question

How does matter move between biotic and abiotic parts of an ecosystem?

Materials

For each group of four students

- Chart paper
- Colored markers

For each student

- Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems"
- Handout 2.3-2, "Changes Due to Fire in a Forest Ecosystem"
- 1 copy of the Explanation Tool

Process & Procedure

Part One: Your Ideas About Energy and Matter in Ecosystems

1. Read the statements on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."
   - **a.** In the "Before" column, mark whether you think each statement is correct (+) or incorrect (-). You will have a chance to revise your answers after reading Part Two, "The Movement of Matter in Ecosystems."
   - **b.** Pick one statement from the handout that you think is incorrect. Write one sentence explaining why you think the statement is incorrect.

Part Two: Scientific Findings About Matter in Ecosystems

2. Review each of the scientific findings on the followng pages and discuss what each finding tells you about the where matter comes from and where it goes in an ecosystem.

Scientific Findings

A. Living things are made mostly of substances, like proteins, carbohydrates, and fats, that contain carbon.

Substances in organisms	Main elements in the substance
Carbohydrates	carbon, hydrogen, oxygen
Proteins	carbon, hydrogen, oxygen, nitrogen, sulfur
Fats	carbon, hydrogen, oxygen

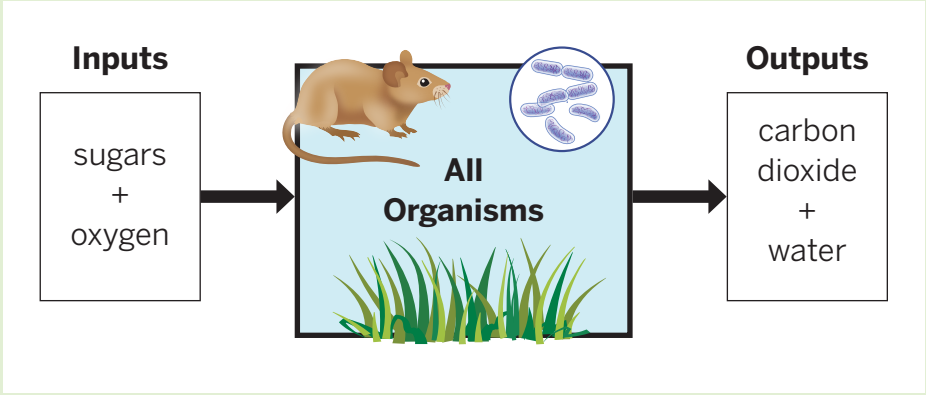
B. A scientist named Van Helmont weighed some soil and planted a willow tree in the soil. Over five years, the willow tree gained 74 kg (164 pounds). The soil lost only 0.05 kg (0.025 lb).

C. Plants can be grown in the presence of sunlight with only air plus water containing some dissolved minerals.

These plants are growing without soil.

D. All organisms—including both plants and animals—conduct a process called cellular respiration. They must do this all the time in order to use the energy stored in food. In this process, the organisms take in in oxygen and use it to break down sugars and other substances in food. They give off carbon dioxide and water.

Cellular Respiration



E. Plants conduct photosynthesis to make their own food. When they do this, they use carbon dioxide and water as the source of matter they need to make sugars. Plants that live on land get water from the soil, and carbon dioxide from the air. Plants that live in water use carbon dioxide that is dissolved in the water.

The data table below summarizes plants' uptake and release of carbon dioxide and oxygen based on the balance between cellular respiration and photosynthesis.

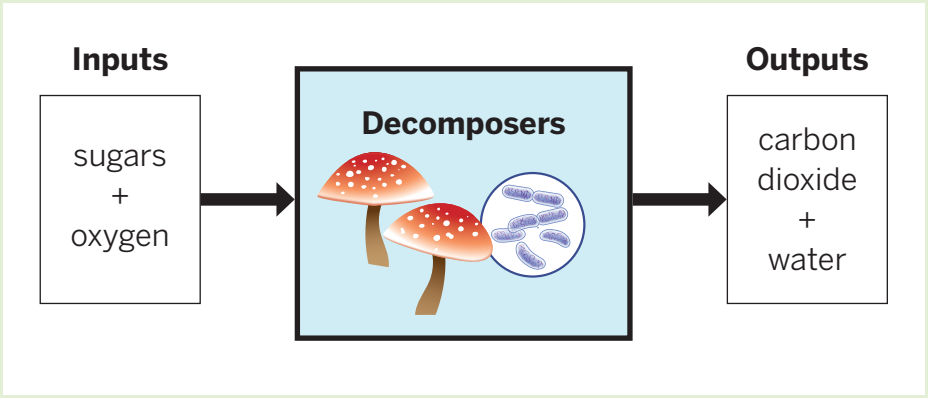
Conditions	Processes	Overall result
Dark	Respiration	oxygen in, carbon dioxide out
Low light	Respiration & photosynthesis	Amount of oxygen and carbon dioxide in and out cancel each other
Light	Respiration & photosynthesis	oxygen out, carbon dioxide in

F. Following your teacher's instructions, examine the contents of the compost bag that was set up in Activity 2.1. Record your findings in your science notebook.

G. Decomposers get food by consuming dead animals and plants. For example, scientists have shown that compost piles are full of many kinds of bacteria that break down the organisms and release heat.

H. Like plants and animals, decomposers respire all the time. As they respire, decomposers break the matter they eat from dead animals and plants into carbon dioxide and water.

Cellular Respiration

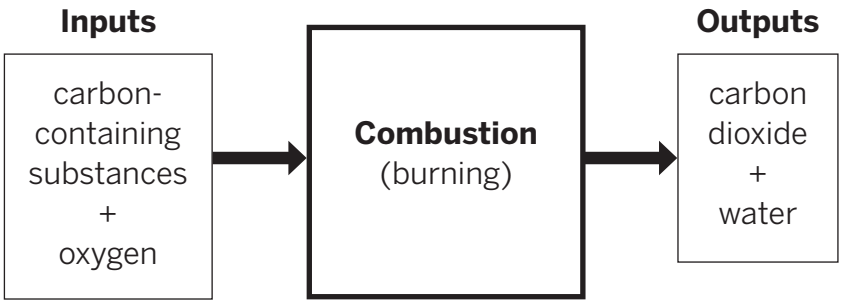


I. Dead organisms and their wastes will only rot if decomposers are present. For example, if food is sterilized to kill all decomposers it will not rot.

The berries on the left were treated to kill decomposers.

J. When an object that contains carbon burns in air (oxygen), carbon dioxide and water are given off. The outputs are the same as those from cellular respiration.

Combustion



K. The total amount of matter in a closed system is conserved, or stays the same. This means the matter can change, but it can't be created or destroyed.

3. Work with your group of four students, and use the chart paper provided, to develop a model for the movement of matter in an ecosystem. Use blue arrows to show the movement of matter. You can base your model on the diagrams you created for Activity 2.2, but be sure to add the details you have learned about in this activity. You will continue to revise this Yellowstone ecosystem model in the next two activities.

4. Use Handout 2.3-2, "Changes in a Forest Ecosystem," to write a caption describing what is happening to the matter in the forest in each diagram.

5. Discuss with your group how your ideas about matter in ecosystems have changed. Be prepared to share your ideas with the class.

Analysis

1. An animal dies. Explain:

a. What happens to the matter the animal was made of?

b. What happens to the energy stored in the animal?

2. Using the Explanation Tool, construct a scientific explanation that answers the question: Where does a plant get the matter it needs to grow? Use the steps below to guide you as you use the Explanation Tool.

- **Question:** Record the question "Where does a plant get the matter it needs to grow?"
- **Evidence:** Examine the data in the findings that help to answer this question. Include data (with units) as evidence to support your answer.
- **Science Concepts:** List any science concepts that are connected to the evidence and might help answer the question.
- **Scientific Reasoning:** Describe the scientific reasoning that connects the evidence and science concepts to the question you are trying to answer.
- **Claim:** Based on the evidence and on your scientific reasoning, state your claim about where plants get the matter they need to grow.

3. Complete the "After" Column for statements 1–3 on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."

a. In the "After" column, mark whether you think each statement is correct (+) or incorrect (-).

b. Under each statement, explain how the activity gave evidence to support or change your ideas. Cite specific evidence from the scientific findings that you used.

Explain: Energy Flow in Ecosystems

You have been learning that many ecological interactions are related to food. You have learned that food provides the matter that all organisms need to grow, survive and reproduce. Plants make their own food, while animals and decomposers get their food by eating other organisms, living or dead. You have discovered that all the matter that supports the ecosystem is present within the boundaries of that system because it keeps cycling throughout the biotic and abiotic components.

But what about energy? Without energy, animals wouldn't be able to grow muscles, digest food, or move. Plants wouldn't be able to produce leaves, move the sugars they make or make their own food in the first place. No organism would be able to reproduce. How do organisms get the energy they need? Where does it come from? Where does it go?

Guiding Question

How does energy flow in an ecosystem?

Materials

For each group of four students

- colored markers
- chart paper

For each group of four students

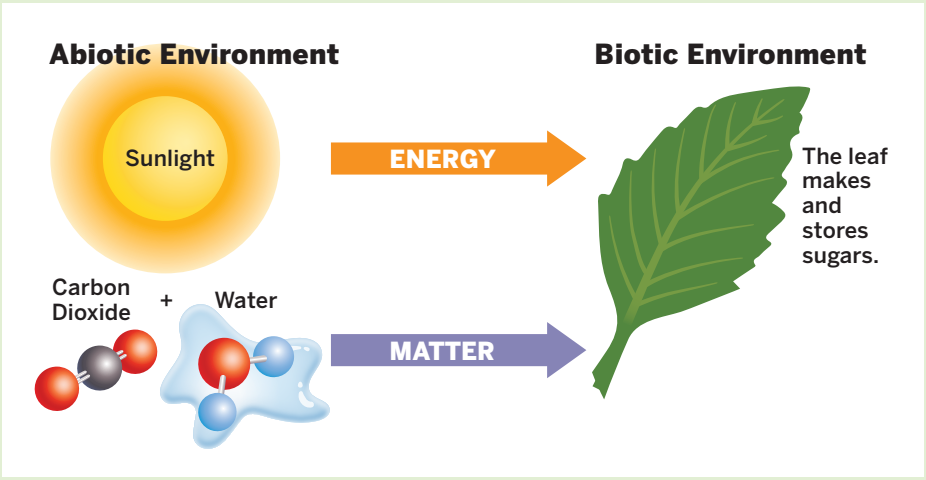
- Partially completed Handout 2.3-1 from previous activity
- Partially completed Handout 2.3-2 from previous activity

Process & Procedure

1. As you learned in the previous activity, plants make their own food through the process of photosynthesis. In order to carry out this process, plants require energy.
   - **a.** Discuss in your group: Where do plants get the energy for photosynthesis?
   - **b.** Record your preliminary ideas in your science notebook.
   - **c.** Follow your teacher's instructions for discussing your preliminary answer to this question.
   - **d.** After the discussion, record your revised answer to this question.
2. Discuss in your group: Where do animals and decomposers get the energy they need for life processes?
   - **a.** Record your preliminary ideas in your science notebook.
   - **b.** Follow your teacher's instructions for discussing your preliminary answer to this question.
   - **c.** After the discussion, record your revised answer to this question.
3. Return to your Yellowstone Ecosystem Model from the previous activity. Based on your current understanding, add red arrows to your model to show how you think energy is flowing in the ecosystem.
4. Read the following information to prepare you to check your model and revise it if necessary.

Plants need sunlight in order to make food. Plants are able to transform the energy in sunlight into chemical energy in sugars through photosynthesis. Without light energy from the Sun, the plants would be unable to make their own food in the form of sugars. For a while, they would use the food they have stored, but eventually they would die. This is because the food that plants make provides the chemical energy for their life processes.

Photosynthesis



The energy that flows from the Sun and is transformed by plants is in fact the source of energy for nearly all life on Earth, whether on land or in water. If all the plants died, the organisms in the rest of the food web that rely on them for food would die too. This is because the chemical energy stored in the food of plants is the only source of energy for plant-eating animals.

While all organisms require water and other substances, such as minerals (plants and animals) and vitamins (animals), these substances do not provide energy for organisms. Only substances that contain carbon (carbohydrates, proteins, and fats) can provide the kind of chemical energy useful to living organisms. They use this energy to move, grow, and carry out all of their activities.

Chemical energy only flows from the producers to the consumers and decomposers. It cannot flow to lower levels of the food chain. At each level of a food chain, organisms use some of their energy for their own maintenance and growth. When these organisms are eaten, chemical energy stored in the organisms moves to the next level. Plants never get energy from animals. Even Venus fly traps, which capture insects caught in their leaves, get only other kinds of nutrients from those animals, not energy.

5. Revisit question 1a: Where do plants get the energy for photosynthesis?
   - Follow your teacher's instructions for discussing your revised answer to this question.
   - After the discussion, record your final answer in your science notebook.
6. Revisit question 2: Where do all animals and decomposers get the energy they need for life processes?
   - Follow your teacher's instructions for discussing your final answer to this question.
   - After the discussion, record your revised answer in your science notebook.
7. Return to you Yellowstone Ecosystem Model from the previous activity. Based on your revised understanding, revise or add to your model to show how energy is flowing in the ecosystem.
8. Use Handout 2.3-2, "Changes in a Forest Ecosystem," to write a caption describing what is happening to the energy in the forest in each diagram.

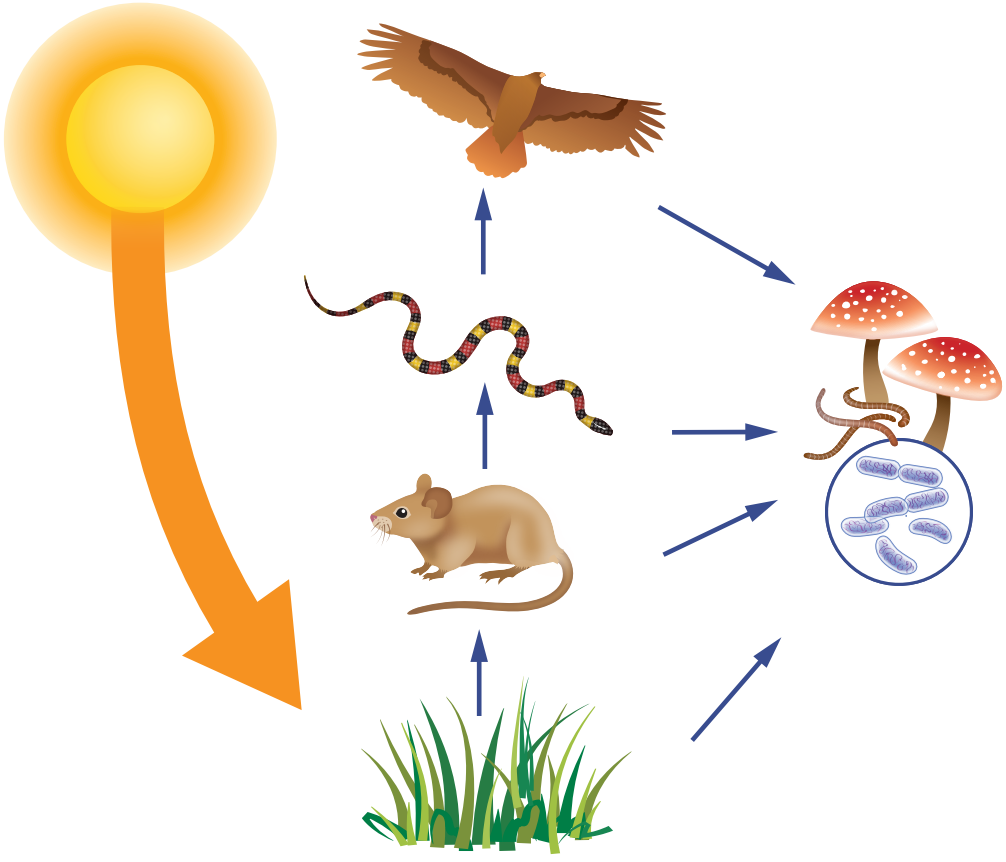
Analysis

1. Use your revised model to explain why sunlight is essential for the flow of energy throughout the ecosystem.
2. Explain what happens to the energy in an animal:
   a. while it is alive?
   b. when it is eaten by another animal?
   c. when it dies, but isn't eaten by another animal?
3. Complete the "After" Column for statements 4–7 on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."
   a. In the "After" column, mark whether you think each statement is correct (+) or incorrect (-).
   b. Under each statement, explain how the activity gave evidence to support or change your ideas. Cite specific evidence from the reading and anything you learned while revising your Yellowstone Ecosystem Model.

Elaborate: Energy Tracking

You have learned that matter cycles throughout an ecosystem, moving among biotic and abiotic components. You have also learned that the chemical energy in food flows in only one direction, from producers to consumers and decomposers; it never flows back to the producers. You have been making and revising a Yellowstone Ecosystem Model to explain these phenomena.

In this activity you will elaborate on your understanding of how energy flows throughout an ecosystem. You will utilize two models to understand what happens to that energy at each step.



Guiding Question

Where does all the energy transformed by producers go?

Materials

For each group of four students

- Handout 2.5-1, " Energy Units"
- Colored markers
- Scissors

For each student

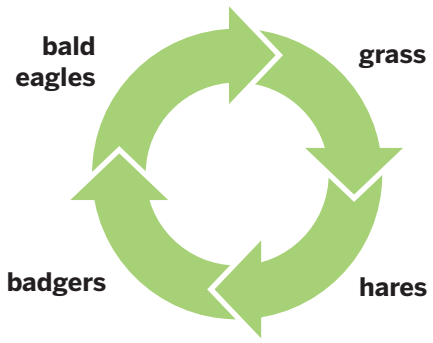
- Partially completed Handout 2.3-1 from Activity 2.3
- Partially completed Handout 2.3-2 from Activity 2.3

Process & Procedure

Part One: Energy Flow in the Biotic Components

1. Based on what you know so far, which of the following models is the best for describing the flow of energy among the biotic components in an ecosystem. Record your initial answer along with your reasoning in your science notebook.

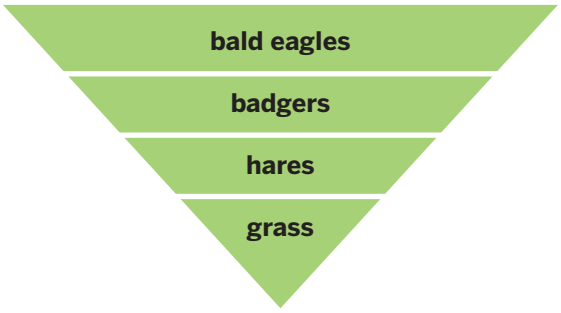
A.



B.

C.

D.



2. Read the following scientific findings.

- Heat is released when organisms use oxygen to break down sugars, as you learned in Activity 2.4.
- The heat that plants lose is given off to the environment.
- Heat and light are both forms of energy.
- Plants can use only light energy to make food during photosynthesis.
- Organisms can use only the chemical energy in food to support life processes.
- In most ecosystems, there is more total plant matter than there is animal matter. There is usually more total matter in the prey animals than in the predators.

3. Review your choice of models and explain whether your initial ideas are supported or you need to revise them based on the scientific findings. Record your revised explanation in your science notebook. Follow your teacher's instructions for discussing your explanation with others.

Part Two: Adding in the Abiotic Components

4. Read this additional scientific information.

While energy flows up the food web or food chain from one level to the next, at each level of the food web, about 10% of the energy taken in by organisms is stored within the organism's body as chemical energy, while about 90% is transformed into heat energy as the organism conducts activities like digesting food, respiring, growing, and moving.

5. In your groups of four, you will model this transformation of usable chemical energy into heat as follow:

a. Assign each person in the group to play the role of one level in the ecosystem:

- grass
- hares
- badgers
- bald eagles

b. Let the desktop or tabletop and all the items on the top represent the abiotic components of the ecosystem.

c. Let the tree begin with 100 energy units.

d. Following the information in Step 4 about the amount of energy that flows to the next level of the food chain, model how the energy units flow through the biotic and abiotic components of the environment.

e. The tree continues photosynthesizing, and it has another 100 energy units. Model what happens to these 100 units.

Part Three: Energy Flow in the Yellowstone Ecosystem

6. Return to your Yellowstone Ecosystem Model and revise it to show how energy flows among the biotic and abiotic components in the ecosystem. Be sure to account for the amount of energy that moves into each component of the ecosystem.

Analysis

1. Do you think there could be 10 levels in a food web or food web? Why or why not?

2. What happens to energy as it flows through an ecosystem?

3. Scientists describe the movement of energy with the word "flows" and the movement of matter with the word "cycles." Why do they use these two different words to describe the movement of energy and matter?

4. Complete the "After" Column for statement 8 on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."

a. In the "After" column, mark whether you think each statement is correct (+) or incorrect (-).

b. Under each statement, explain how the activity gave evidence to support or change your ideas. Cite specific evidence from the reading and anything you learned while revising your Yellowstone Ecosystem Model.

Evaluate: Modeling Energy Flow and Matter Cycling in an Ecosystem

So far in this unit, you have worked to develop models to explain the movement of energy and matter in the Yellowstone Ecosystem.

In this activity, you will construct a model of your local ecosystem to predict how the flow of energy and cycling of matter might be affected by various disruptions.

Challenge

How can a model be used to represent and make predictions about an ecosystem?

Materials

For each group of four students

A variety of materials, which might include:

- chart paper
- disposable containers (shoe boxes, aluminum trays, etc.)
- model organisms (simple sketches, stickers, buttons, plastic models, photos, etc.)
- clear plastic film
- sheets of stickers (dots, stars, etc.)
- different colors of construction paper
- yarn and/or string
- tape
- glue
- scissors
- colored markers or pencils

For each student

- 1 copy of the Explanation Tool

Process and Procedure

1. You will work with your group to construct a model of your local ecosystem. Your teacher will explain the materials available to you as you make your model.
2. Brainstorm organisms that live in your area, and use them to develop a food web that includes at least:
   - 2 producers
   - 2 level-1 consumers
   - 2 level-2 consumers
   - 1 level-3 consumer
   - 1 decomposer
   - the ultimate source of energy for your ecosystem

   You may include more organisms if there are available materials and you have enough time.

3. Gather the materials you need to create your model.
4. Record your food web in your science notebook. Be sure to include arrows showing what eats what.
5. Construct a 2- or 3-dimensional model of an ecosystem. Use the materials to:
   a. label producers, consumers, and decomposers.
   b. show the cycling of matter between the biotic and abiotic parts of your ecosystem.
   c. show the flow of energy between the biotic and abiotic parts of your ecosystem.
   d. include a key if needed.
6. Present your model to the class, making sure to:
   a. describe what happens to the total amount of matter within your ecosystem.
   b. describe what happens to energy after it enters the ecosystem.

Analysis

1. Imagine that a science museum is making a very large version of your model for a museum display. Write three captions explaining the model for members of the public who will view the display. The captions should describe:
   a. interactions between living organisms.
   b. the cycling of matter between abiotic and biotic parts of the ecosystem.
   c. the source, flow, and loss of energy from abiotic and biotic parts of the ecosystem.
   d. what would happen if a disease killed off the top level of your ecosystem.

2. Using the Explanation Tool, construct a scientific explanation for the following. A landslide occurs along the side of a mountain that causes the forest at the bottom to be covered with 20 meters of rocks and soil. Predict how the flow of energy and the cycling of matter would be affected both in the short term and in the long term. Use the steps below to guide you as you use the Explanation Tool.

- **Question:** Record the question "How would an ash cloud from a volcano affect the flow of matter, cycling of energy, and organisms in an ecosystem?
- **Evidence:** Use evidence from this chapter that helps you to answer this question.
- **Science Concepts:** List any science concepts that are connected to the evidence and might help answer the question.
- **Scientific Reasoning:** Describe the scientific reasoning that connects the evidence and science concepts to the question you are trying to answer.
- **Claim:** Based on the evidence of patterns in the data and on your scientific reasoning, state your claim about the effects of the ash cloud on matter, energy, and organisms in the ecosystem.