Lesson 6: The Cycle of Matter

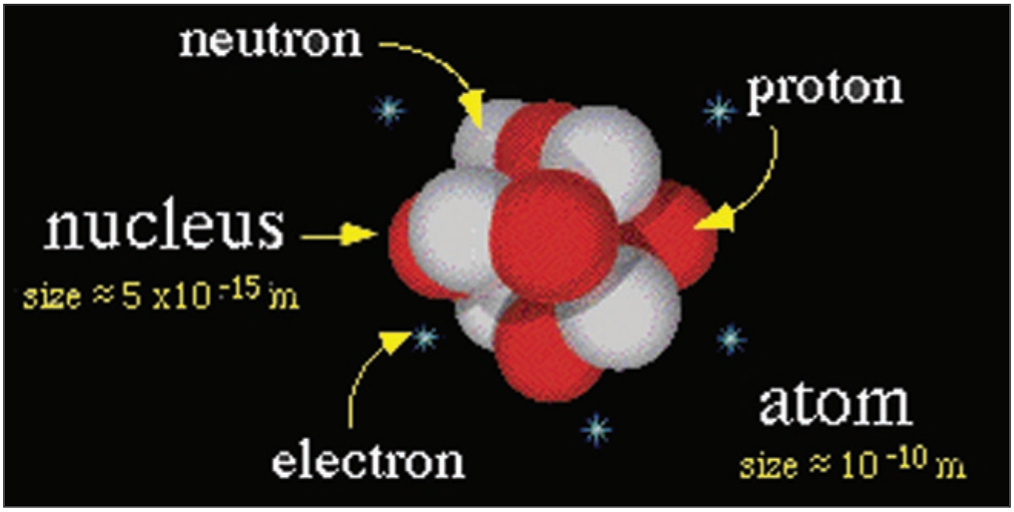


Illustration showing atom structure with distances and sizes exaggerated for clarity; Lawrence Berkeley National Laboratory, USDOE

Students trace the path that atoms take as they move throughout the cycle of matter and compare this to the flow of energy.

Main Lesson Concept:
Over a long time, matter is transferred from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change.

Scientific Question:
In food webs, is matter ever created or destroyed?

Objectives	Standards
• Students will draw and explain the cycle of matter, how matter is transferred in this cycle, changing location and form while maintaining the same number of atoms. • Students will draw and explain the flow of energy and will compare and contrast a cycle and a flow.	**Meets:** 2061: 5E (6-8) #2

Assessment	Abstract of Lesson
Cycle of Matter and Flow of Energy drawings and descriptions, and responses to questions in Astro Journal.	Students observe a model of the water cycle, discuss characteristics of cycles and review conservation of matter in chemical reactions and in digesting food. Students then read a story tracing the path of carbon and oxygen atoms as they change form and move in a cycle. Finally, students compare and contrast the cycle of matter with the flow of energy.

Prerequisite Concepts	Major Concepts
• Regardless of how substances within a closed system interact with one another, or how they combine or break apart, the total weight of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same. (2061: 4D (6-8) #7, Atmosphere Lesson 4) • All organisms, including the human species, are part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment. (2061: 5A (6-8) #5) • Food provides molecules that serve as fuel and building materials for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or material or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms. (2061: 5E (6-8) #1, Biology Lessons 2 thru 5)	• If the number of atoms stays the same, no matter how they are rearranged, the total mass stays the same. • As animals consume plants and then are consumed by living things, matter is transferred to other organisms and to the environment, and takes other forms in a series of chemical reactions. • As in all materials systems, the atoms change location and form different molecules, but the total number of atoms remains the same.

Suggested Timeline (45-minute periods):

Day 1: Engage, Explore – Part 1, and Explain – Part 1 sections
Day 2: Explore – Part 2, Explain – Part 2, and Extend sections
Day 3: Evaluate (approximately 15 minutes)

Materials and Equipment:

- Water cycle demonstration materials:
- 200 milliliters of water
- Burner or microwave to bring water to a boil
- Measuring cup
- Jar
- Lid or aluminum foil pan
- Ice cube
- Tape or marker than can write on jar
- Chart paper

Preparation:

- Duplicate a class set of Astro Journal Lesson 6.
- Gather materials for water cycle demonstration.
- Prepare water cycle demonstration just before the class period or right at the beginning of class using the procedures listed in the Engage section.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

Differentiation

Accommodations

For students who may have special needs:

Provide extra support for the reading assignment (e.g., partner, read aloud, etc.)

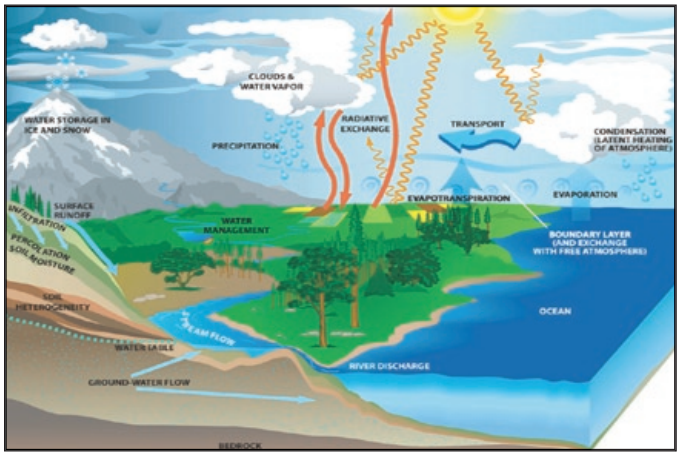
Advanced Extensions

For students who have mastered this concept:

Have students research and report on other cycles in nature and society. Have students compare the cycle of matter to recycling of newspaper and containers and what happens when people don't recycle. Based on what students know about how flows and cycles are different, have students draw conclusions about why it's important to conserve energy.

Engage

(approximately 20 minutes)



The Water Cycle; NASA

1. Draw on students' prior knowledge of the water cycle and how water is not lost, but simply changes form.

Note to Teacher: If the water cycle has been covered previously or if the materials below are difficult to obtain, simply review the water cycle and discuss how the amount of water does not change.

Procedure for water cycle demonstration:

1. Measure 200 milliliters of water.
2. Bring this water to a boil. (Some of the water will be lost to steam.)
3. Measure the remaining hot water. Write the amount on the board.
4. Fill a jar with the remaining hot water. Place an inverted lid or aluminum foil pan on top of the jar.
5. Next place an ice cube on the lid or pan.
6. Ask the students to watch the jar carefully. Encourage them to look for any changes that may occur in this demonstration.

- Question: What observations can you make about this demonstration?
- *Answer: (Accept all reasonable answers. Students may respond that the ice cube is melting and that there are water droplets on the inside of the jar.)*

- Question: How much water was in this jar when we started this demonstration?
- *Answer: (Answer is the number written on the board.)*

- Question: How much water do you think is in this jar now? Explain your reasoning.
- *Answer: (Allow students to share their ideas. Student responses will vary. Students that have knowledge of the water cycle will understand that the total amount of water in the jar has not changed.)*

Note to Teacher: You may want to use tape or a marker to label the water line when you first fill the jar with hot water. This will help students see the level change as the water evaporates. Be careful—the jar will be hot!

- Say: When I put the water in the jar, it was very hot.

- Question: What happens to water as the amount of heat is increased?
- *Answer: The water will evaporate as the amount of heat is increased.*

- Question: What happens to water when it evaporates?
- *Answer: When water evaporates, it changes from a liquid (water) into a gas (water vapor).*

- Question: Do you think that evaporation is occurring in this jar? Explain your answer.
- *Answer: Yes, due to the fact that the water is hot, there is evaporation occurring in this jar.*

- Question: What happens to water vapor when it loses heat energy?
- *Answer: When water vapor loses heat energy, it will change from a gas back to a liquid.*

- Question: Do you see this happening any place in the jar? Explain your answer.
- *Answer: Yes, there are water droplets on the inside of the jar. These water droplets are a result of water vapor losing heat energy and becoming water again.*

- Question: What do you think is causing water vapor to lose heat energy?
- *Answer: The ice cube on the aluminum foil pan or inverted lid causes the water vapor to lose heat energy.*

- Question: Do you think any of the water is lost from the jar?
- *Answer: No water is lost from the jar.*

- Question: If we drew a line at the beginning of our experiment to mark the amount of water and then drew a line now for the current amount of water, would the two lines be the same?
- *Answer: No, the two lines would not be the same.*

- Question: Explain how this is possible if the total amount of water in the jar has not changed.
- *Answer: The total amount of water in the jar has not changed, but the state of matter that the water is in has changed.*

- Question: Where is water located inside this jar? What state of matter is water in at each location?
- *Answer: Water is located in the bottom of the jar as a liquid, water is located in the air of the jar as a gas (water vapor), and water is located on the sides of the jar as a liquid.*

- Question: Has the amount of matter in this jar changed? Explain your answer.
- *Answer: No, the amount of matter in this jar has not changed. The matter has changed states and locations, but the amount is the same.*

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2. Discuss cycle information with students.

- Question: In general, how would you describe a cycle?
- *Answer: (Allow students to share their ideas. Students may respond that a cycle is something that repeats.)*

- Question: Do you think the amount of matter ever changes in a cycle?
- Say: No, the amount of matter does not change in a cycle.

- Question: Does the matter in a cycle always stay at the same location?
- Say: No, the matter in a cycle can change location.

- Question: Does the matter in a cycle stay in the same state?
- *Answer: No, matter in a cycle does not stay in the same state.*

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3. Review conservation of matter and relationship to chemical reactions from Atmosphere Lesson 4 and Biology Lesson 2.

- Say: In Biology Lesson 2, you ate a piece of a fruit or vegetable.

- Question: What happened to the size of the food as you ate it?
- *Answer: The food was broken into smaller pieces.*

- Question: Did the amount of food change while you were eating it? Explain your answer.
- *Answer: No, the amount of food did not change while I was eating it. The food was broken into smaller pieces, but the total amount of food remained the same.*

- Question: Once you eat food, what must your body do in order to release energy from the food?
- *Answer: Once I eat food, my body has to go through aerobic respiration/use oxygen to release energy from the food.*

- Say: Aerobic respiration is an example of a chemical reaction.

- Question: When a chemical reaction takes place, does the amount of matter change?
- *Answer: The amount of matter does not change during a reaction.*

- Question: In Atmosphere Lesson 4, you learned that there are three different kinds of changes that could happen to molecules. What are these?
- *Answer: The three different kinds of changes are: two molecules combining to make a new molecule, two molecules exchanging atoms to form two new molecules, and molecules breaking down into separate molecules and/or separate atoms.*

- Question: During any of these changes, did the number of atoms change?
- *Answer: No, the number of atoms did not change.*

- Question: Was matter created or destroyed in any of these changes?
- *Answer: No, matter was not created nor destroyed in any of these changes.*

- Question: How do you know?
- *Answer: The mass stayed the same, and the number of atoms stayed the same.*

- Say: During a chemical change just like during a cycle, the amount of substances involved does not change.

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4. Introduce the purpose of this lesson and the scientific question.

- Say: In Biology Lessons 3 through 5, we focused on the flow of energy. Today we are going to focus on the cycle of matter.

- Say: The Scientific Question we will be exploring is: In food webs, is matter ever created or destroyed?

- Have students complete the Hypothesis/Prediction section of their Astro Journals.

Explore – Part 1

(approximately 15 minutes)

Shovel of compost; National Resources Conservation Service, USDA

1. Discuss with students what they know about soil fertility from Geology Lesson 6 and Biology Lessons 2 through 5.

- Say: In Biology Lesson 5, you learned about decomposers.

- Question: When decomposers break down dead plants and animals, what happens to the materials in the dead plants and animals?
- *Answer: The decomposer may use the materials from the dead plants and animals, or they may be broken down into small parts in the environment.*

MISCONCEPTION: Students often think organisms and materials in the environment are very different types of matter. Students see these as fundamentally different and are not transferable into each other. The discussions and activities in this lesson will help students to see that the same atoms can make up different materials.

- Question: If the decomposer does not use these materials, what will happen to these materials?
- *Answer: The materials will become a part of the soil.*

- Say: We learned that this soil would be fertile.

- Question: What does soil provide for plants?
- Say: Two examples of substances that plants (and other living things) need to survive are carbon and nitrogen.

- Question: What do you know about carbon?
- *Answer: Students studied the carbon cycle in Geology Lesson 6, and they have also learned about carbon in carbon dioxide and glucose when they studied the photosynthesis and aerobic respiration equations in Biology Lessons 3 and 4.*

- Question: What do you know about nitrogen?
- *Answer: Students learned in Biology Lesson 2 that nitrogen is important to our bodies because it is a building block for proteins. Our skin and hair are made up of proteins.*

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2. Have the students read Part 1 of the Captain Carbon Story.

Explain – Part 1

(approximately 10 minutes)

Experiment to identify fundamental mechanisms contributing to acclimation of photosynthesis to elevated carbon dioxide, Agriculture Research Service, USDA

1. Have students discuss Part 1 of the story as well as the Cliffhanger Question in small groups.

- Once students have had a discussion in small groups, lead a class discussion.
- Have students explain what they learned during Part 1 of the Captain Carbon Story.
- Question: How was it possible that the Carbon Dioxide trio was formed again after being a part of Great Glucose and Oh Oxygen?
- *Answer: (Allow students to share their ideas. Students may use their knowledge of aerobic respiration to explain that animals took in the Great Glucose by eating the plant and breathed in Oh Oxygen.)*
- Question: What is the relationship between the photosynthesis and aerobic respiration equations?
- *Answer: The photosynthesis and aerobic respiration equations look like the opposite of each other.*

Note to Teacher: Students may look at the equation for photosynthesis and aerobic respiration and think they are opposites or are reversible; however this is not the case. There are very complex chemical processes involved with each, and these steps are not reversible. Also, energy is lost during these processes. This could be explained to students using the metaphor of one-way streets. You might start at point A and travel to point B using one route, but are unable to go from point B to point A using the reverse route because the one-way streets are traveling in the wrong direction.

Explore – Part 2

(approximately 20 minutes)

Preparing to study CO_2 exchange between lakes and the atmosphere to better define the carbon cycle and to improve our understanding of air-water gas transfer in oceans; USG

1. Have the students read Part 2 of the Captain Carbon Story.

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2. Have students draw a picture that shows the path that carbon took in the Captain Carbon Story.

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3. Have students answer the Captain Carbon questions that follow.

Explain – Part 2

(approximately 10 minutes)

Space Shuttle Crew testing oxygen masks; NASA

1. Discuss student conclusions from the Captain Carbon Activity.

- Question: Where did Captain Carbon start out his journey?
- *Answer: Captain Carbon started his journey as carbon dioxide in the atmosphere linked with two of his Oxygen Family friends.*

MISCONCEPTION: Students see only chains of events and pay little attention to the matter involved in the processes, such as plant growth or animals eating plants. The questions in this activity are designed to help students focus on the matter during the process.

- Question: During his journey, what substances did Captain Carbon make up?
- *Answer: He made up carbon dioxide, glucose, and then carbon dioxide again.*

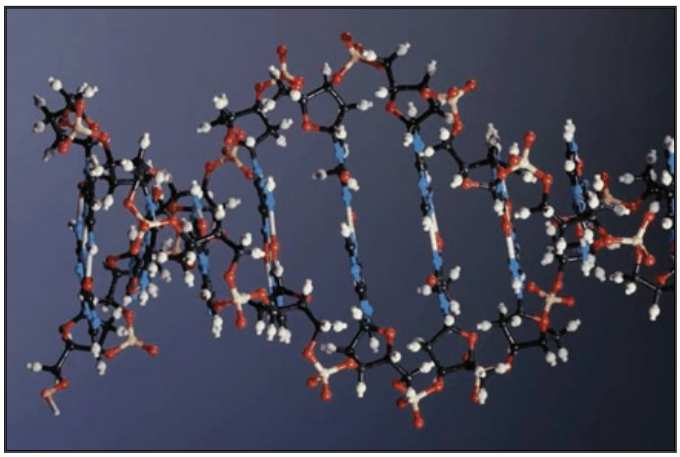
- Question: How is it possible that he was part of a gas, then a solid, and then a gas again?
- *Answer: (Allow students to discuss their ideas about this. This is a difficult concept but fundamental in understanding conservation of matter. Hopefully, students will conclude that when atoms rearrange to form new molecules, they can become a part of different kinds of substances in various states.)*

- Question: During Captain Carbon's journey, did the number of atoms change? Explain your answer.
- *Answer: No, the number of atoms did not change during Captain Carbon's journey. They simply rearranged and changed places.*

- Question: The number of atoms did not change, but the atoms did make some changes. What were these changes? Provide an example of each of these changes.
- *Answer: The atoms formed different molecules. An example of this is in photosynthesis where carbon dioxide and water triggered by solar energy formed glucose and oxygen. The atoms also changed location. In the story, the carbon dioxide trio started out in the atmosphere. The trio then entered the plant through a small opening in the leaf. Later in the story, the human breathed out the carbon dioxide.*

Extend/Apply

(approximately 15 minutes)



Model of DNA molecule; Lawrence Berkeley National Laboratory, USDOE

1. Discuss the comparison of the flow of energy and the cycle of matter.

- Question: What happened to carbon in the Captain Carbon Story?
- *Answer: Carbon traveled in a cycle, starting as carbon dioxide, becoming part of sugar in a plant during photosynthesis, then being broken down inside an animal, until it combined with oxygen to form carbon dioxide and was breathed out.*

- Question: What happened to other forms of matter, like oxygen atoms?
- *Answer: They also went through a similar process, being broken apart and combining with new molecules as they traveled from place to place.*

- Question: How is this process like the water cycle?
- *Answer: It is like the water cycle in that matter moves from place to place and changes form, but the amount of matter never changes. New matter is never created nor destroyed just like water changes form and travels, but there is always the same total amount.*

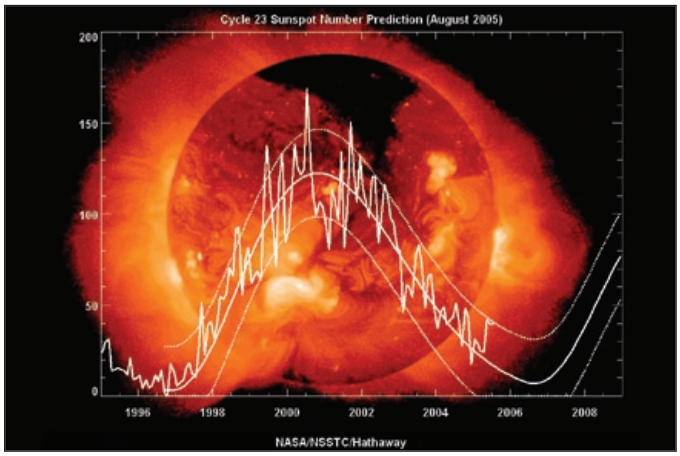
- Say: We call these cycles. Cycles are repetitive like a circle.

- Question: How does the flow of energy compare to the cycle of matter?
- *Answer: Both happen during the processes that living things use to get their energy. However, the cycle of matter focuses on where the matter (the actual atoms of carbon, oxygen, etc.) go in the process, while the flow of energy traces where the energy goes in the process.*

- Next to the carbon path that students drew for the Captain Carbon Story, have students draw a simple energy flow that involves the sun, the producer, and consumer described in the story. Have them add a decomposer. Also have students answer the Cycle and Flow questions and the Results and Conclusions in their Astro Journals.

Evaluate

(approximately 15 minutes)



Charting of sunspot cycle; NASA

1. Discuss students' Astro Journal Cycle and Flow conclusions.

- Question: How is the cycle of matter different from the flow of energy?
- *Answers may include: The cycle of matter repeats. Matter is recycled. But in the flow of energy, energy comes from the sun, but doesn't go back to the sun. The energy is released along the way, as living things use it to live. Moving, breathing, regulating body temperature, growing, reproducing, and digesting food are just some examples of how living things release energy into the environment.*

- Question: So what can you conclude is the difference between a flow and a cycle?
- *Answer: A cycle repeats, but a flow ends.*

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2. Discuss students' responses in their Astro Journals to ensure they have mastered the major concepts.

- Question: How does the cycle of matter apply to a forest?
- *Answer: As decomposers break down dead leaves and rotting dead trees, they release important substances back into the soil to become a part of new plants. In this way dead things are recycled and help new living things to grow.*

- Question: During this process, is matter created or destroyed? Explain.
- *Answer: Matter is neither created nor destroyed, because there are always the same number of atoms. These atoms break apart from one molecule to form new molecules and move from living things to become a part of the soil to then become part of a new living thing again, but they do not disappear or reappear. The total number of atoms is always the same.*

- Question: Based on what you've learned about the cycle of matter, could carbon dioxide be made of the same atoms that make up sugar or glucose?
- *Answer: Yes, since carbon dioxide is made of carbon and oxygen atoms, and sugar has carbon and oxygen atoms in it—the same atoms could make up both.*

- Question: But sugar is a solid and carbon dioxide is a gas. How is it possible that both could be made of the same atoms?
- *Answer: (Allow students to discuss their ideas about this. Hopefully, they will reason that atoms in different combinations of molecules, form different types of substances. Sometimes these substances are liquid, sometimes solid, and sometimes gas. From Atmosphere Lesson 4 they may recall that atoms rearrange to form new substances through chemical reactions).*

- Question: Why is the cycle of matter important to humans and other living things?
- *Answer: The cycle of matter is important because necessary substances and building materials can be used over and over so that the cycle of life can continue.*

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3. Collect students' Astro Journals and evaluate them to ensure that they have mastered the major concepts:

- If the number of atoms stays the same, no matter how they are rearranged, the total mass stays the same.

- As animals consume plants and then are consumed by living things, matter is transferred to other organisms and to the environment, and takes other forms in a series of chemical reactions.

- As in all materials systems, the atoms change location and form different molecules, but the total number of atoms remains the same.

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4. Bridge to next lesson.

- Say: Today, we learned that the total amount of matter remains constant, even though its form and location change. In the next lesson, we will use our knowledge from this unit to understand how food webs are important for human survival.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Biology Lesson 6: The Cycle of Matter

Name _____ Date _____ Class/Period _____

Scientific Question:
In food webs, is matter ever created or destroyed?

1. **Hypothesis/Prediction:** What happens to the matter that makes up the food you eat? Do you think matter disappears or is formed as it travels through a food chain?
2. Explain why you think that.

Astro Journal Biology Lesson 6: The Cycle of Matter

Name _____ Date _____ Class/Period _____

Part 1 – Cycle of Matter: • Draw a picture that shows the path that carbon took in the Captain Carbon Story. • Include descriptions of what is occurring during each step. • Leave "Part 2 – Flow of Energy" blank until later, but be sure to answer all of the Part 1 questions that continue on the next page.	**Part 2 – Flow of Energy** • Draw the path of energy including the sun, the producer and consumer described in the Captain Carbon Story. • Add a decomposer. • Describe what is happening at each step and when energy might be released as it is used.
Cycle of Matter	Flow of Energy
1. Explain your drawing of the path that carbon took in the Captain Carbon Story.	1. Explain your drawing of the path that energy takes in a food chain.
2. What different substances did Captain Carbon make up?	2. How is the cycle of matter different from the flow of energy?

Astro Journal Biology Lesson 6: The Cycle of Matter

Name _____ Date _____ Class/Period _____

Part 1 – Cycle of Matter	**Part 2 – Flow of Energy**
3. In the Captain Carbon Story, did the atoms go through any changes? Did the total number of atoms change? Explain your answer.	3. What can you conclude is the difference between a flow and a cycle?
	4. Imagine a forest scene that includes living trees, decomposers, dead leaves and dead logs. How is matter cycling in this scene?

Results and Conclusions

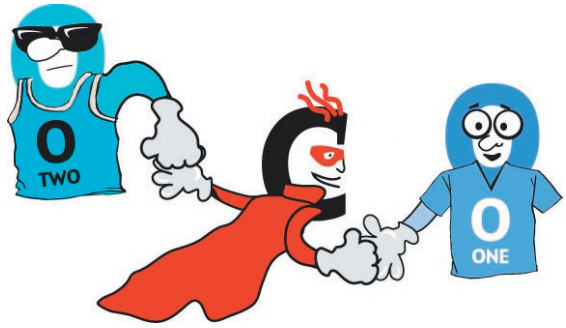
1. Is matter created or destroyed in the cycle of matter? Explain.

2. Why is the cycle of matter important to humans and other living things?

Captain Carbon Story

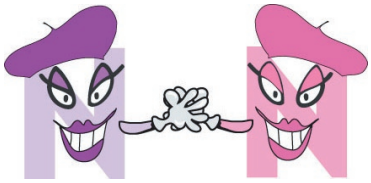
Part 1

Captain Carbon had many friends. He was often seen traveling with two members of the Oxygen Family. The three of them would float around linked arm and arm. It was difficult to separate them from each other. They were seen together so often that people gave them their very own name, "Cool Carbon Dioxide."



Cool Carbon Dioxide

Sometimes this trio would leave the atmosphere for a long time. Their friends would look all around for them, but they were difficult to find. One day, when the trio came back from being gone for a long time, the twins, Necessary Nitrogens, asked where they had been.



Necessary Nitrogens

Cool Carbon Dioxide responded that they had been performing a very important job. He explained that they had entered a plant leaf through a small hole. The twins were amazed, "What did you do in the plant?" The trio responded that they helped the plant go through photosynthesis. The twins responded, "What is that?"

Captain Carbon explained the process of photosynthesis to their friends.

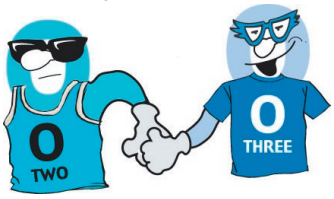
They said that they had been able to combine with the trio Wacky Water thanks to the Snazzling Solar Energy from the sun.

Wacky Water

They told their friend that they formed two new products, Great Glucose and Oh Oxygen.

Great Glucose

They explained that Captain Carbon and Oxygen One helped to form Great Glucose (along with many other team members), while Oxygen Two joined with Oxygen Three who was part of Wacky Water to form Oh Oxygen.



Oh Oxygen

The twins responded, "So you actually separated from each other and formed new products? Wow, that was so brave of you!" The trio explained that it was important that they formed these new products. Otherwise the plant could not survive. The twins said, "But, you are here today as a trio again. How did this happen?"

Cliffhanger Question: How did this happen? Discuss with your group how the Cool Carbon Dioxide trio was able to become a trio again instead of being a part of Great Glucose and Oh Oxygen. Use your knowledge from this unit to help you with this question.

Captain Carbon Story

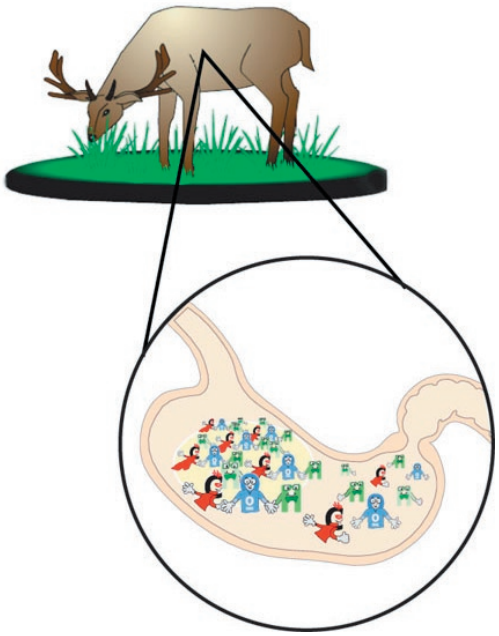
Part 2

The trio, Cool Carbon Dioxide, told their friends to be patient. They said, "We have only explained half of our journey."

The trio said that their journey got even more interesting after becoming Great Glucose and Oh Oxygen. Oh Oxygen was released from the plant through a small opening in the leaf, just like how Cool Carbon Dioxide had entered the plant. Once Oxygen Two was released from the plant as Oh Oxygen with his new Oxygen buddy, they became part of the atmosphere.

The twins said, "Well, where did the Great Glucose go?" Captain Carbon and Oxygen One explained that the plant used the Great Glucose for energy to grow and function. Then one day, Great Glucose was being broken apart in this long hollow tube. The twins said, "That sounds scary! Where were you?"

Captain Carbon explained that he, Oxygen One, and the rest of the Great Glucose team were inside an animal's digestive system. The twins said, "Wow!" Captain Carbon continued his explanation. He said that in the animal's digestive system the Great Glucose molecule was broken down into many parts.



Captain Carbon said, "While this was happening, the animal breathed in Oh Oxygen (including Oxygen Two) through her nose." "Now," Captain Carbon said, "do you see how Cool Carbon Dioxide was able to once again become a trio?"

The twins responded, "Yes! Captain Carbon, Oxygen One, and Oxygen Two were all able to recombine in the animal's body."

Captain Carbon said, "And how did we get back into the atmosphere?"

The twins said, "That is easy! The animal released you when he exhaled."