



Matter and Energy in Ecosystems:

Biodome Collapse



© 2018 by The Regents of the University of California. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage or retrieval system, without permission in writing from the publisher.

Teachers purchasing this Investigation Notebook as part of a kit may reproduce the book herein in sufficient quantities for classroom use only and not for resale.



These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, and ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.



Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify.

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

Matter and Energy in Ecosystems: Biodome Collapse
ISBN: 978-1-947002-97-5
AMP.NA18

Matter and Energy in Ecosystems:

Biodome Collapse

Table of Contents

Safety Guidelines for Science Investigations	1
<i>Matter and Energy in Ecosystems: Biodome Collapse Unit Overview</i>	3

Chapter 1: Photosynthesis

Chapter Overview	4
Lesson 1.2: Investigating a Biodome	5
Warm-Up	6
Examining the <i>Biodome Files</i>	7
Introducing the Simulation	8
Lesson 1.3: Sunlight and Life	9
Warm-Up	10
Reading <i>Sunlight and Life</i>	11
Homework: Reading “What Is Carbon?”	12
Lesson 1.4: How Energy Storage Molecules Are Made	13
Warm-Up	14
Revisiting <i>Sunlight and Life</i>	15
Observing Photosynthesis Close Up	16–17
Homework: <i>Elodea</i> Experiment	18
Homework: Reading “Where Did Chloroplasts Come From?”	19
Lesson 1.5: Photosynthesis in Ecosystems	20
Warm-Up	21
Modeling Energy Storage Molecules	22
Decreasing Energy Storage Molecules	23–24
Homework: Sim Mission: Determine Ways to Increase Energy Storage Molecules	25–26
Lesson 1.6: Examining Data from the Biodome	27–28
Warm-Up	29
Examining Data from the Biodome	30
Reasoning About Data from the Biodome	31
A Model for the Econauts	32
Homework: Check Your Understanding	33

Table of Contents (continued)

Chapter 2: Cellular Respiration in Ecosystems

Chapter Overview	34
Lesson 2.1: Carbon Dioxide in Ecosystems	35
Warm-Up	36
Carbon Dioxide in Ecosystems	37
The Snail and <i>Elodea</i> Experiment	38
Introduction to <i>A Feast for Decomposers</i>	39
Homework: Reading <i>A Feast for Decomposers</i>	40
Lesson 2.2: How Carbon Dioxide Enters the Air	41
Warm-Up	42
Observing Cellular Respiration	43
Modeling How Organisms Give Off Carbon Dioxide	44
Sharing Models	45
Homework: Photosynthesis and Cellular Respiration in Producers	46
Lesson 2.3: An Explanation for the Econauts	47
Warm-Up	48
Testing a Claim in the Sim	49
Word Relationships Routine	50
Homework: Writing to the Econauts	51
Lesson 2.4:	
Homework: Reading “How Did We Get Mitochondria?”	52
Lesson 2.5: Investigating Econauts’ Claims	53–54
Purple Group: Warm-Up	55
Purple Group: Investigating Ecosystem Claims	56–57
Blue Group: Warm-Up	58
Blue Group: Investigating Ecosystem Claims	59–60
Green Group: Warm-Up	61
Green Group: Investigating Ecosystem Claims	62–64
Word Relationships Routine	65
Homework: Reading “Glacier Mice: Living Arctic Tumbleweeds”	66
Homework: Check Your Understanding	67

Table of Contents (continued)

Chapter 3: Carbon Movement in Ecosystems

Chapter Overview	68
Lesson 3.1: “Carbon in the Global Ecosystem”	69
Warm-Up	70
Reading “Carbon in the Global Ecosystem”	71
Homework: Increasing Carbon in the Atmosphere	72
Lesson 3.2: Total Carbon in an Ecosystem	73
Warm-Up	74
Revisiting “Carbon in the Global Ecosystem”	75
The Carbon Game Instructions	76
The Carbon Game	77
Homework: Making Connections	78
Lesson 3.3: Looking for the Missing Carbon	79
Warm-Up	80
Finding the Missing Carbon	81–82
Researching the <i>Biodome Files</i>	83
Homework: Movement of Carbon in the Biodome	84
Lesson 3.4: Explaining What Happened in the Biodome	85
Warm-Up	86
Cause and Effect in the Biodome	87
Biodome Model	88
Homework: Writing a Recommendation to the Econauts	89
Homework: Check Your Understanding	90

Chapter 4: Science Seminar

Chapter Overview	91
Lesson 4.1: Analyzing Claims and Evidence	92
Warm-Up	93
Discussing Deforestation Claims	94
Annotating and Discussing Evidence	95
Sorting the Evidence	96
Homework: Choosing a Claim	97
Lesson 4.2: Science Seminar	98
Warm-Up	99

Table of Contents (continued)

Preparing Your Science Seminar Argument	100
Science Seminar Observations	101
Homework: Reflecting on the Science Seminar	102
 Lesson 4.3: Writing a Scientific Argument	 103
Warm-Up	104
Using the Reasoning Tool	105
Preparing to Write	106
Writing a Scientific Argument	107–108
Homework: Revising Your Argument	109
Homework: Check Your Understanding	110
 Matter and Energy in Ecosystems Glossary	 111–113

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____

Date: _____

Matter and Energy in Ecosystems: Biodome Collapse **Unit Overview**

What caused the failure of the biodome? Five years ago, a local group called the Econauts began an ambitious project to determine if humans could survive on another planet. They constructed a biodome, an ecosystem inside a glass dome larger than a football field. The ecosystem was filled with plants, animals, and a volunteer group of eight humans. Recently, the group noticed a problem: animals were getting skinny, plants were not growing, and many organisms stopped reproducing. The organisms were safely removed from the biodome, but the cause of these changes is still a mystery. You have been hired to join the team of expert ecologists to investigate the failed biodome and determine what went wrong. The team has already concluded that organisms ran out of the energy storage molecules they need for survival, but why? As a student ecologist working for the Biodome Investigation Team, it's your job to find out what caused the biodome to fail so future biodome experiments can be more successful.

Name: _____

Date: _____

Chapter 1: Photosynthesis

Chapter Overview

Why didn't the plants and animals in the biodome have enough energy storage molecules? You'll start your investigation by exploring what affects the amount of energy storage molecules in ecosystems.



Lesson 1.2: Investigating a Biodome

Welcome to your assignment as student ecologists! Five years ago, a group called the Econauts began an ambitious project to determine if humans could survive on another planet. They constructed a biodome, an ecosystem inside a glass dome that is larger than a football field. The ecosystem was filled with plants, animals, and eight humans. Recently, the group noticed that the organisms were unhealthy and failing to reproduce. The organisms were saved, but the cause of the problem is a mystery. Now, the Econauts need you to investigate and determine what went wrong.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 1 Question

- Why didn't the plants and animals in the biodome have enough energy storage molecules?

Vocabulary

- abiotic matter
- biotic matter
- claim
- ecosystem
- energy storage molecule
- system

Digital Tool

- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Warm-Up



What is one thing you found interesting about this biosphere?

What questions do you have about living in a biosphere?

Name: _____ Date: _____

Examining the *Biodome Files*

Dr. Corry left some of the Econauts' files about the biodome for you to examine. Take a few minutes to read at least one of these files. You may want to annotate the articles as you read. Once you're finished reading, record your ideas that might answer the Chapter 1 Question and share them with your partner.

Chapter 1 Question: *Why didn't the plants and animals in the biodome have enough energy storage molecules?*

Introducing the Simulation

Part 1: Exploring the Simulation

Talk with your partner as you explore the *Matter and Energy in Ecosystems* Sim. Share what you both notice.

- What do you notice about changes you can make in the Sim?
- What questions do you have about the Sim?

Part 2: Observing Energy Storage Molecules in an Ecosystem

With a partner, observe the Sim and see if you can get any evidence to help you answer the question *Where do the energy storage molecules in an ecosystem come from?*

1. Observe the Sim, paying attention to the movement of the energy storage molecules throughout the ecosystem.
2. In the table below, record what you observe about the flow of energy storage molecules into and out of different parts of the ecosystem.
3. After you complete the table, answer the discussion questions with your partner.

Part of ecosystem	Contains energy storage molecules? (yes or no)	Energy storage molecules flowing in? (yes or no)	Energy storage molecules flowing out? (yes or no)
Producers			
Consumers			
Decomposers			
Dead matter			
Abiotic matter			

Discussion Questions

- Where do energy storage molecules first appear in the ecosystem?
- What ideas do you have about where energy storage molecules in an ecosystem come from?

Lesson 1.3: Sunlight and Life

After the failure of their biodome, the Econauts are searching for answers. Why do some ecosystems support so much life, while others are relatively lifeless? As student ecologists, you know that organisms need energy to survive and that this energy comes from energy storage molecules. But where do the energy storage molecules themselves come from? In order to help the Econauts, you'll need to find out. Today, you'll learn the answers to these questions and others in *Sunlight and Life*, a set of articles about the key ingredients that make some ecosystems livelier than others.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 1 Question

- Why didn't the plants and animals in the biodome have enough energy storage molecules?

Vocabulary

- | | | |
|------------------|---------------------------|------------|
| • abiotic matter | • consumer | • producer |
| • biotic matter | • ecosystem | • system |
| • carbon | • energy storage molecule | |
| • carbon dioxide | • photosynthesis | |

Name: _____ Date: _____

Warm-Up

Think about the different types of plants found in an ecosystem and respond to the questions below.

Could you have an ecosystem without plants? (check one) ☐ yes ☐ no

Explain your answer.

Name: _____

Date: _____

Reading *Sunlight and Life*

1. Choose one of the *Sunlight and Life* articles, then read and annotate the article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement.

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____

Date: _____

Homework: Reading “What Is Carbon?”

Before you read the article, read the focus question. Keep the question in mind, as you read "What Is Carbon?" Highlight or annotate any information that might help you answer the focus question. When you are finished, answer the reading focus question below.

Reading Focus Question: *Which parts of the biodome contain carbon?*

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Lesson 1.4: How Energy Storage Molecules Are Made

The Econauts are counting on you to discover why the organisms in the biodome did not have enough energy storage molecules. As you investigate today, you'll find out more about what these molecules are and how they are made. Soon, you'll be able to explain to the Econauts where these energy storage molecules come from, bringing you one step closer to solving the mystery of the failed biodome.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 1 Question

- Why didn't the plants and animals in the biodome have enough energy storage molecules?

Vocabulary

- | | | |
|------------------|----------------------------|------------------|
| • abiotic matter | • connect | • photosynthesis |
| • biotic matter | • consumer | • producer |
| • carbon | • energy storage molecules | • system |
| • carbon dioxide | • ecosystem | |

Digital Tool

- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Warm-Up

Part 1

Read the information on your Energy Storage Molecule card.

In the article set, *Sunlight and Life*, you learned that organisms need many types of energy storage molecules to help them survive in their ecosystems. Answer the following questions after you read your card.

1. Which energy storage molecule is on your card? (check one)

☐ glucose

☐ starch

☐ fat

☐ glycogen

2. What did you learn about the type of energy storage molecule on your card?

3. What questions do you have about this type of energy storage molecule?

Part 2: Learning More About Energy Storage Molecules

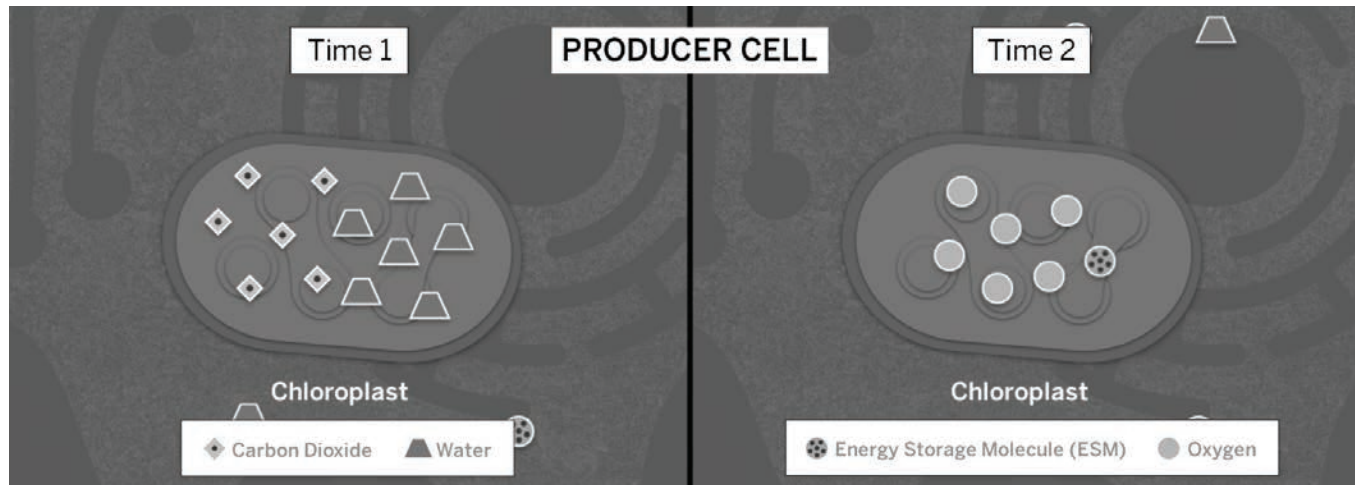
In order to figure out where energy storage molecules come from, you'll need to know more about what they are made of and how they are used.

Present your card to the rest of your group. Then, work together to decide how energy storage molecules are (a) **similar** and (b) **different**.

Revisiting *Sunlight and Life*

Part 1: Thinking More About Producers

These images from the Sim show the same cell of a producer, but at two different times.



Write a caption for this diagram to describe why you think the chloroplast at Time 1 is different from the same chloroplast at Time 2.

Part 2: Taking a Closer Look at *Sunlight and Life*

Investigation Question: *Where do the energy storage molecules in an ecosystem come from?*

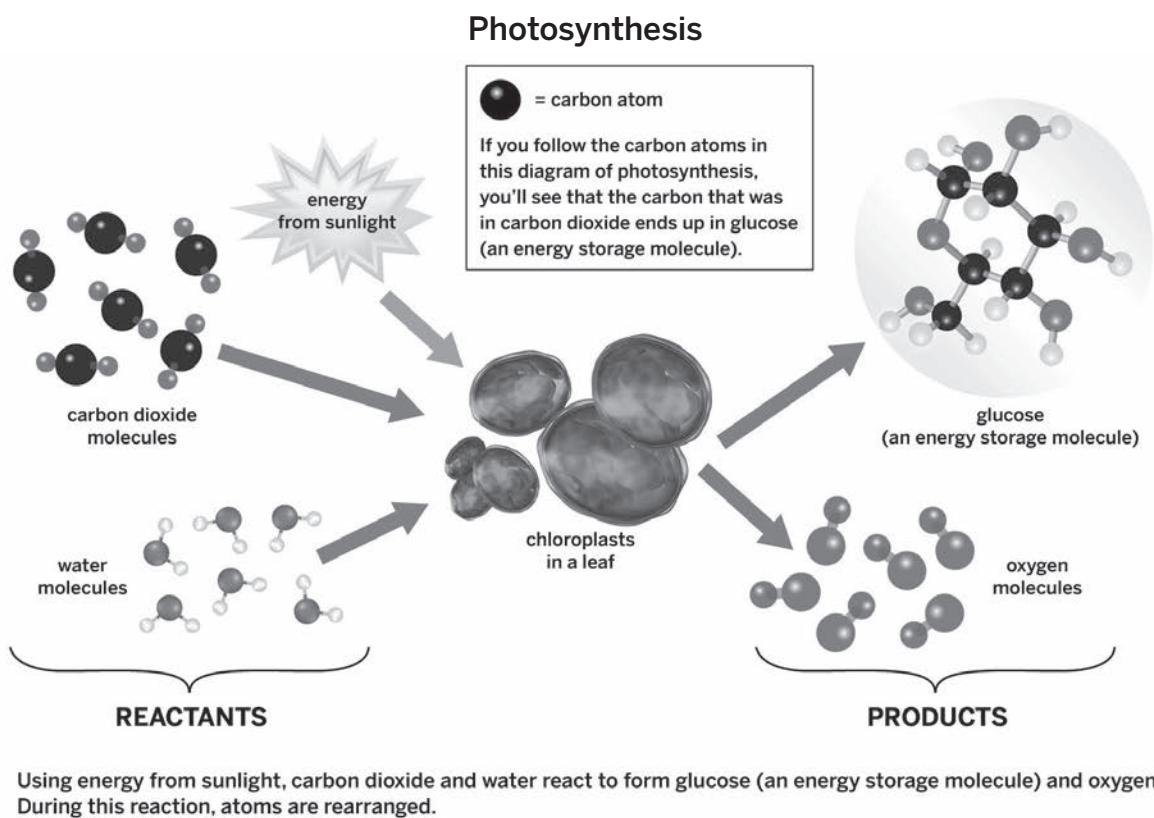
Read and annotate paragraphs 3 and 4 from the introduction to *Sunlight and Life*. As you read, highlight any information that might help you answer the Investigation Question.

Observing Photosynthesis Close Up

Part 1

The Sim and the diagram from the article are both types of models to help you understand more about the process of photosynthesis. Compare the close-up view from the Sim (press VIEW CELL) and the diagram below to help you gather more evidence about the process of photosynthesis and where energy storage molecules come from.

1. Open the Sim and run it with the default settings. To see a model of photosynthesis, press VIEW CELL in the box labeled Producers.
2. Compare what you see in the Sim to the diagram below, and discuss the questions that follow with your partner.



Discussion Questions

- How are these models (the Sim and the diagram) similar and how are they different?
- What do these models show about where energy storage molecules come from?
- Which organisms in an ecosystem produce energy storage molecules?

Name: _____ Date: _____

Observing Photosynthesis Close Up (continued)

Part 2: Revising Initial Ideas

Turn back to the Sim screenshot on page 15. Using what you learned in the reading and the Sim, write a new caption or revise your first caption to describe what you now think about why the chloroplast looks different at Time 1 than at Time 2.

Complete the following sentences about photosynthesis, using words from the Word Bank. (Not all words will be used.)

Photosynthesis is done by _____. This process requires _____ from sunlight and _____ from abiotic matter. Photosynthesis makes _____ for an ecosystem.

Word Bank

producers	consumers	biotic	abiotic	
energy storage molecules	carbon dioxide	energy	oxygen	carbon

Homework: *Elodea* Experiment

Elodea is a producer that lives in freshwater. It is a popular choice as a plant for aquariums. Learn more about what can affect the process of photosynthesis by watching the video, *Photosynthesis and Elodea*, which you can find in Digital Resources. After watching the video, answer the question below.

In the experiment, what factors affected the number of energy storage molecules that the *Elodea* plant can make?

Name: _____

Date: _____

Homework: Reading “Where Did Chloroplasts Come From?”

You have learned that photosynthesis takes place inside the chloroplasts of producers, but where did chloroplasts come from and how did they end up in producers? Read and annotate the "Where Did Chloroplasts Come From?" article. Then, answer the questions below.

1. What are organelles?

2. What are some of the organelles in a plant cell?

3. How did chloroplasts end up in producer's cells?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Lesson 1.5: Photosynthesis in Ecosystems

Student ecologists, you've learned so far that producers are important because they are the only organisms that perform photosynthesis, the process of making the energy storage molecules that all living organisms need to survive. To explain the failed biodome to the Econauts, however, you'll need to dig deeper into what factors affect how many energy storage molecules can be produced in an ecosystem. Today, you'll use the Sim to see how some different changes can affect an entire ecosystem.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 1 Question

- Why didn't the plants and animals in the biodome have enough energy storage molecules?

Key Concepts

- Carbon is part of carbon dioxide, which is *abiotic* matter. Carbon is also part of energy storage molecules, which are *biotic* matter.
- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.

Vocabulary

- | | | |
|------------------|---------------------------|------------|
| • abiotic matter | • claim | • producer |
| • biotic matter | • ecosystem | • system |
| • carbon | • energy storage molecule | |
| • carbon dioxide | • photosynthesis | |

Digital Tools

- *Matter and Energy in Ecosystems* Modeling Tool activity: Energy Storage Molecules
- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Warm-Up

Chapter 1 Question: *Why didn't the plants and animals in the biodome have enough energy storage molecules?*

We know the biodome was shut down because there weren't enough energy storage molecules in the ecosystem. Based on what you have learned so far, what do you think happened in the ecosystem?

1. Write a claim that answers the chapter question, based on what you have learned so far.

2. Why do you think this claim is correct?

3. How has your thinking changed since the beginning of the unit?

Modeling Energy Storage Molecules

Part 1: Exploring the Modeling Tool

Today's new tool will help you display your understanding of where energy storage molecules come from.

1. Open the *Matter and Energy in Ecosystems* Modeling Tool activity: Energy Storage Molecules.
2. Explore the Modeling Tool to help you learn how it works.

Part 2: Modeling Energy Storage Molecules

You have been investigating the process of photosynthesis to help you answer the Investigation Question: *Where do the energy storage molecules in an ecosystem come from?*

Return to the *Matter and Energy in Ecosystems* Modeling Tool activity: Energy Storage Molecules, and make a model that shows where the energy storage molecules in an ecosystem come from.

Goal: Show where the energy storage molecules in an ecosystem come from.

Do:

- Drag items from the Ecosystem and Matter categories into your model.
- Add Movement arrows to show how matter moves through the ecosystem.
- Drag one or more Process editors to your model. Use them to show the process that makes energy storage molecules. Name the process and show the input(s) and output(s).

Tip:

- You do not have to include all the items in your model. Only include items that will help you meet the goal.

Name: _____

Date: _____

Decreasing Energy Storage Molecules

Part 1

You just made a model showing where energy storage molecules come from. Refer to your model and think back to what you know about how energy storage molecules are made and the factors that affect photosynthesis. Write a claim that can answer the new Investigation Question: *What factors affect how many energy storage molecules producers are able to make?*

Part 2: Sim Mission: Determine Ways to Decrease Energy Storage Molecules

Investigation Question: *What factors affect how many energy storage molecules producers are able to make?*

We know that energy storage molecules decreased in the biodome. What could have caused a change in the amount of energy storage molecules that producers were making? Use the *Matter and Energy in Ecosystems* Sim to help you find out.

Mission: Find at least two ways to **decrease** the amount of energy storage molecules producers can make, without using the kill buttons.

Plan 1: One way I will try to decrease the number of energy storage molecules that producers can make is to: (check one) ☐ increase sunlight. ☐ decrease sunlight. ☐ burn dead matter. ☐ bury dead matter. ☐ trap carbon dioxide.	Plan 2: Another way I will try to decrease the number of energy storage molecules that producers can make is to: (check one) ☐ increase sunlight. ☐ decrease sunlight. ☐ burn dead matter. ☐ bury dead matter. ☐ trap carbon dioxide.
--	--

Decreasing Energy Storage Molecules (continued)

Steps to Complete Your Mission:

1. Open the *Matter and Energy in Ecosystems* Simulation.
2. Without changing any of the starting values, press PLAY. Run the Sim for at least 20 time units.
3. Make *only one* change to the ecosystem. Do not use the kill buttons.
4. Observe the ecosystem for an additional 50 time units. Look for evidence that your mission is complete. (**Hint:** Look at the graphs of energy storage molecules and photosynthesis.)
5. If your change does not decrease the energy storage molecules in living things, reset the Sim and try changing something else after 20 time units. (**Hint:** Make a BIG change in the ecosystem so it is easier to see the effects.)
6. Remember, find *two* ways to decrease energy storage molecules:

One change I made in the Sim that decreased energy storage molecules was: (check one)

- ☐ increase sunlight.
- ☐ decrease sunlight.
- ☐ burn dead matter.
- ☐ bury dead matter.
- ☐ trap carbon dioxide.

Another change I made in the Sim that decreased energy storage molecules was: (check one)

- ☐ increase sunlight.
- ☐ decrease sunlight.
- ☐ burn dead matter.
- ☐ bury dead matter.
- ☐ trap carbon dioxide.

7. Why did the changes you made result in fewer energy storage molecules? Discuss this with your partner.

Homework: Sim Mission: Determine Ways to Increase Energy Storage Molecules

We know that energy storage molecules decreased in the biodome, and you investigated how that might have happened. Another way to learn more about the biodome is to investigate the opposite—an *increase* in energy storage molecules. Use the Sim to find out what changes will increase energy storage molecules.

Mission: Find at least two ways to **increase** the amount of energy storage molecules producers can make, without using the kill buttons.

Plan 1: One way I will try to increase the number of energy storage molecules that producers can make is to: (check one) ☐ increase sunlight. ☐ decrease sunlight. ☐ burn dead matter. ☐ bury dead matter. ☐ trap carbon dioxide.	Plan 2: Another way I will try to increase the number of energy storage molecules that producers can make is to: (check one) ☐ increase sunlight. ☐ decrease sunlight. ☐ burn dead matter. ☐ bury dead matter. ☐ trap carbon dioxide.
---	---

Steps to Complete Your Mission:

1. Open the *Matter and Energy in Ecosystems* Simulation.
2. Without changing any of the starting values, press PLAY. Run the Sim for at least 20 time units.
3. Make *only one* change to the ecosystem. Do not use the kill buttons.
4. Observe the ecosystem for an additional 50 time units. Look for evidence that your mission is complete. (**Hint:** Look at the graphs of energy storage molecules and photosynthesis.)
5. If your change does not increase the energy storage molecules in living things, reset the Sim and try changing something else after 20 time units. (**Hint:** Make a BIG change in the ecosystem so it is easier to see the effects.)

Name: _____

Date: _____

Homework: Sim Mission: Determine Ways to Increase Energy Storage Molecules (continued)

6. Remember, find *two* ways to increase energy storage molecules:

One change I made in the Sim that increased energy storage molecules was: (check one)

- ☐ increase sunlight.
- ☐ decrease sunlight.
- ☐ burn dead matter.
- ☐ bury dead matter.
- ☐ trap carbon dioxide.

Another change I made in the Sim that increased energy storage molecules was: (check one)

- ☐ increase sunlight.
- ☐ decrease sunlight.
- ☐ burn dead matter.
- ☐ bury dead matter.
- ☐ trap carbon dioxide.

7. Why did the changes you made result in more energy storage molecules?

Lesson 1.6: Examining Data from the Biodome

Why did the biodome fail? The Econauts need answers from the Biodome Investigation Team in order to begin planning for their next biodome. Today, you'll get some new evidence that will help you figure out what went wrong. Then, it will be up to you to explain the decrease in energy storage molecules to the Econauts. Good luck, student ecologists!

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 1 Question

- Why didn't the plants and animals in the biodome have enough energy storage molecules?

Key Concepts

- Carbon is part of carbon dioxide, which is *abiotic* matter. Carbon is also part of energy storage molecules, which are *biotic* matter.
- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.
- If one part of a system changes, this affects the rest of the system.
- When there is *more* carbon (in the form of carbon dioxide) in abiotic matter, *more* carbon is available to producers for making energy storage molecules.
- When there is *less* carbon (in the form of carbon dioxide) in abiotic matter, *less* carbon is available to producers for making energy storage molecules.
- When there is *more* sunlight, producers can make *more* energy storage molecules from the carbon in carbon dioxide.
- When there is *less* sunlight, producers cannot make as many energy storage molecules from the carbon in carbon dioxide.

Name: _____

Date: _____

Lesson 1.6: Examining Data from the Biodome (continued)

Vocabulary

- abiotic matter
- biotic matter
- carbon
- carbon dioxide
- claim
- ecosystem
- energy storage molecule
- evidence
- photosynthesis
- producer
- reasoning
- scientific argument
- system

Digital Tool

- *Matter and Energy in Ecosystems* Modeling Tool activity: Energy Storage Molecules

Name: _____

Date: _____

Warm-Up

Jaime is using the Sim and asks you for advice. He says, “I want an ecosystem that makes as many energy storage molecules as possible! What should I do to increase the number of energy storage molecules that producers can make?”

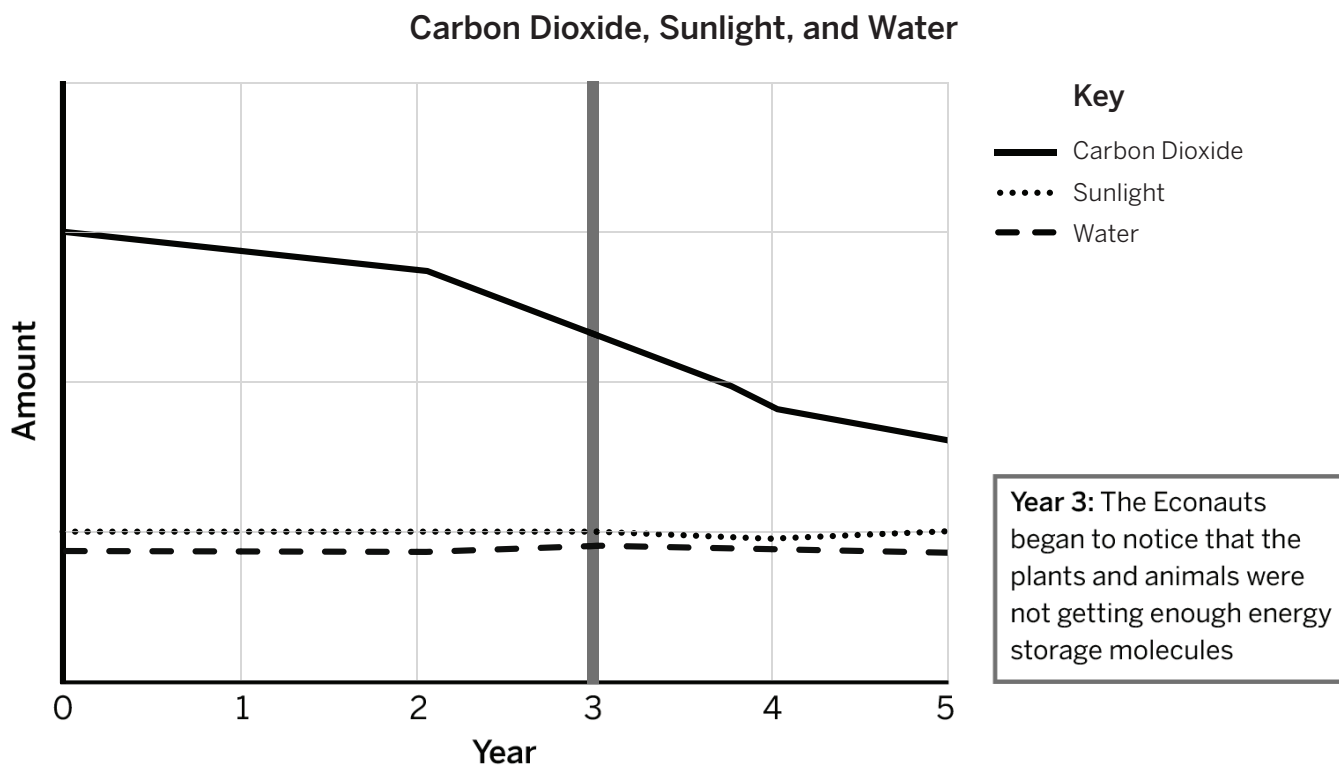
1. What should Jaime do to increase the number of energy storage molecules that producers can make? You may choose more than one answer.

- ☐ Decrease the amount of carbon dioxide in the ecosystem.
- ☐ Increase the amount of carbon dioxide in the ecosystem.
- ☐ Decrease the amount of sunlight in the ecosystem.
- ☐ Increase the amount of sunlight in the ecosystem.

2. Explain your choice(s).

Examining Data from the Biodome

Dr. Corry has given you some data about the biodome that will help you write your explanation to the Econauts. Examine this graph and use the questions to discuss it with your partner. (Note: Your teacher will project a color version of this graph.)



Discuss the following questions with your partner:

- How has the amount of carbon dioxide changed over time?
- How has the amount of sunlight changed over time?
- How has the amount of water changed over time?
- Does this data help in understanding why the plants and animals in the biodome were not getting enough energy storage molecules? Why or why not?

Name: _____ Date: _____

Reasoning About Data from the Biodome

Use the Reasoning Tool to connect a piece of evidence from the graph (on page 30) to the claim you think is best.

Claim 1: A change in the amount of *carbon dioxide* led to a decrease in the amount of energy storage molecules made by producers in the biodome.

Claim 2: A change in the amount of *sunlight* led to a decrease in the amount of energy storage molecules made by producers in the biodome.

Evidence	This matters because . . .	Therefore, . . . (Claim 1 or Claim 2)

A Model for the Econauts

You are now ready to send a model and a written explanation to the Econauts. Your model will help them understand where energy storage molecules in an ecosystem come from. Your written explanation should help them understand why the plants and animals in the biodome were not getting enough energy storage molecules.

1. Look back at your *Matter and Energy in Ecosystems* Modeling Tool activity: Energy Storage Molecules. If your thinking has changed, revise your model to reflect your new ideas.

Goal: Show where the energy storage molecules in an ecosystem come from.

Do:

- Drag items from the Ecosystem and Matter categories into your model.
- Add Movement arrows to show how matter moves through the ecosystem.
- Drag one or more Process editors to your model. Use them to show the process that makes energy storage molecules. Name the process and show the input(s) and output(s).

Tip:

- You do not have to include all the items in your model. Only include items that will help you meet the goal.

2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

3. Use your model and the data from Dr. Corry (on page 30) to write your explanation.

Explain to the Econauts why the plants and animals in the biodome were not getting enough energy storage molecules. Use your Reasoning Tool and your model to help you as you write.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

1. I understand where carbon can be found in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

2. I understand how having less carbon dioxide available in the biodome led to fewer energy storage molecules being made in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

3. I understand why the carbon dioxide in the biodome decreased.

☐ yes ☐ not yet (check one and explain your answer choice)

4. I understand why changing the amount of carbon in one part of the biodome affected the rest of the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

5. I understand that scientists assume that if there is a pattern in their observations of natural systems, the same thing will be true of similar natural systems.

☐ yes ☐ not yet (check one and explain your answer choice)

6. What are you still wondering about the biodome?

Chapter 2: Cellular Respiration in Ecosystems

Chapter Overview

You've determined that the amount of carbon dioxide in the biodome's air decreased. What could have caused this? Your next step is to find out what parts of an ecosystem give off carbon dioxide, and this will help you think about what went wrong in the biodome.



Lesson 2.1: Carbon Dioxide in Ecosystems

Last chapter, you discovered that decreased carbon dioxide in the air of the biodome may have prevented producers from making enough energy storage molecules for the ecosystem. However, your work as student ecologists is far from over. The Econauts are now wondering why the amount of carbon dioxide in the air of the biodome went down. To answer this question and help the Econauts build a better biodome, you'll need to figure out how that carbon dioxide gets into the air in the first place.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 2 Question

- What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?

Vocabulary

- | | | |
|------------------|----------------------------|------------------|
| • abiotic matter | • consumer | • photosynthesis |
| • biotic matter | • decomposer | • producer |
| • carbon | • ecosystem | • system |
| • carbon dioxide | • energy storage molecules | |
| • claim | | |

Digital Tool

- *Matter and Energy in Ecosystems* Sorting Tool activity: Carbon Dioxide in Ecosystems

Name: _____

Date: _____

Warm-Up

Chapter 2 Question: *What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?*

At the end of the last lesson, you learned there was not enough carbon dioxide in the biodome's air, which led to a decrease in energy storage molecules inside the biodome. What are some ideas you have about what might have caused the decrease in carbon dioxide? Record some initial claims. You will have an opportunity to revise them after you learn more.

Name: _____

Date: _____

Carbon Dioxide in Ecosystems

Launch the *Matter and Energy in Ecosystems* Sorting Tool activity: Carbon Dioxide in Ecosystems and follow the instructions. Talk to a partner about your ideas as you work.

Goal: Show your ideas about which parts of an ecosystem give off carbon dioxide and which parts do not give off carbon dioxide.

Do:

- Complete the table by placing each card into one of the categories.

Discuss:

After you finish sorting, discuss the following questions with your partner:

- Did you place any parts of the ecosystem in a different category than your partner? Why?
- Were you or your partner unsure about where to place any parts of the ecosystem? Why?

Class Poll:

After completing the sorting activity, choose the parts of the ecosystem that you think give off carbon dioxide to the air.

- ☐ decomposers
- ☐ producers
- ☐ consumers
- ☐ dead matter
- ☐ abiotic matter

The Snail and *Elodea* Experiment

Investigation Question: *Where does the carbon dioxide in abiotic matter come from?*

Do producers give off or take in carbon dioxide? What about consumers? Can producers and consumers do both? Gather evidence by watching the video of an experiment with a snail and some *Elodea*.

1. Record your predictions for which organisms will give off carbon dioxide in the table below.
2. Observe the color of the BTB solution in the video to figure out which organisms give off carbon dioxide.
3. Record the results in the table below.

BTB Solution Experiment Key:

The color of BTB changes depending on how much carbon dioxide is added:

- blue = no carbon dioxide
- green = low carbon dioxide
- yellow = high carbon dioxide

	Prediction: Will the organism give off carbon dioxide during the experiment? (yes or no)	Results: Did the organism give off carbon dioxide during the experiment? (yes or no)
Snail (dark)		
<i>Elodea</i> plant (dark)		

4. Discuss the discussion questions with your partner.

Discussion Questions

- How well did your predictions match the actual results of the experiment?
- Do producers give off or take in carbon dioxide? How do you know?
- Do consumers give off or take in carbon dioxide? How do you know?
- Reflect on what you learned from the video that might help you answer today's Investigation Question.

Introduction to *A Feast for Decomposers*

Investigation Question: *Where does the carbon dioxide in abiotic matter come from?*

Part 1: Reading *A Feast for Decomposers*

At the start of the lesson, you used the Sorting Tool to make predictions about which parts of an ecosystem give off carbon dioxide. In the video, you got evidence about whether producers and consumers give off carbon dioxide. Now, you will learn more about a third type of organism in ecosystems—decomposers. Read the the first two paragraphs of the article set, *A Feast for Decomposers*, and highlight any information that helps you determine whether decomposers give off carbon dioxide.

Part 2: Revisiting the Sorting Tool: Carbon Dioxide in Ecosystems

After watching the video experiment and reading the excerpt from *A Feast for Decomposers*, revisit your first ideas.

1. Open the Sorting Tool activity: Carbon Dioxide in Ecosystems. Do you agree with how you sorted the parts of the ecosystem? If not, move cards to reflect your new understanding of which parts of an ecosystem give off carbon dioxide to abiotic matter.
2. When you are done sorting the parts of the ecosystem, press HAND IN. If you worked with a partner, write their name here: _____

Goal: Show your ideas about which parts of an ecosystem give off carbon dioxide and which parts do not give off carbon dioxide.

Do:

- Complete the table by placing each card into one of the categories.

After completing the sorting activity, choose the parts of the ecosystem that you think give off carbon dioxide to the air.

- ☐ decomposers
- ☐ producers
- ☐ consumers
- ☐ dead matter
- ☐ abiotic matter

Name: _____

Date: _____

Homework: Reading *A Feast for Decomposers*

Return to the article set, *A Feast for Decomposers*. You've already read the introduction; now choose one of the articles to learn more about a particular decomposer and how it affects ecosystems. Read and annotate the article you chose. Record the article (or articles) you read below.

Which article did you read?

- ☐ "Wonderful Worms"
- ☐ "Insects Break Down the Big Stuff"
- ☐ "Soil Bacteria by the Billions"
- ☐ "Surprising Soil Fungus"
- ☐ "Fungi That Feast on Wood"
- ☐ "Mold Makes Fuzzy Fruit"
- ☐ "Aquatic Bacteria Bonanza"

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Lesson 2.2: How Carbon Dioxide Enters the Air

By now, you've seen that organisms like *Elodea* plants (producers), snails (consumers), and decomposers all give off carbon dioxide, but how does this happen? Today, you'll use the Sim to look inside a single cell as you search for clues about how living things give off carbon dioxide. Student ecologists, keep investigating! With each step, the Biodome Investigation Team gets closer to finding out why the amount of carbon dioxide in the biodome decreased.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 2 Question

- What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?

Vocabulary

- | | | |
|------------------------|----------------------------|------------------|
| • abiotic matter | • consumer | • photosynthesis |
| • biotic matter | • decomposer | • producer |
| • carbon | • ecosystem | • system |
| • carbon dioxide | • energy storage molecules | |
| • cellular respiration | | |

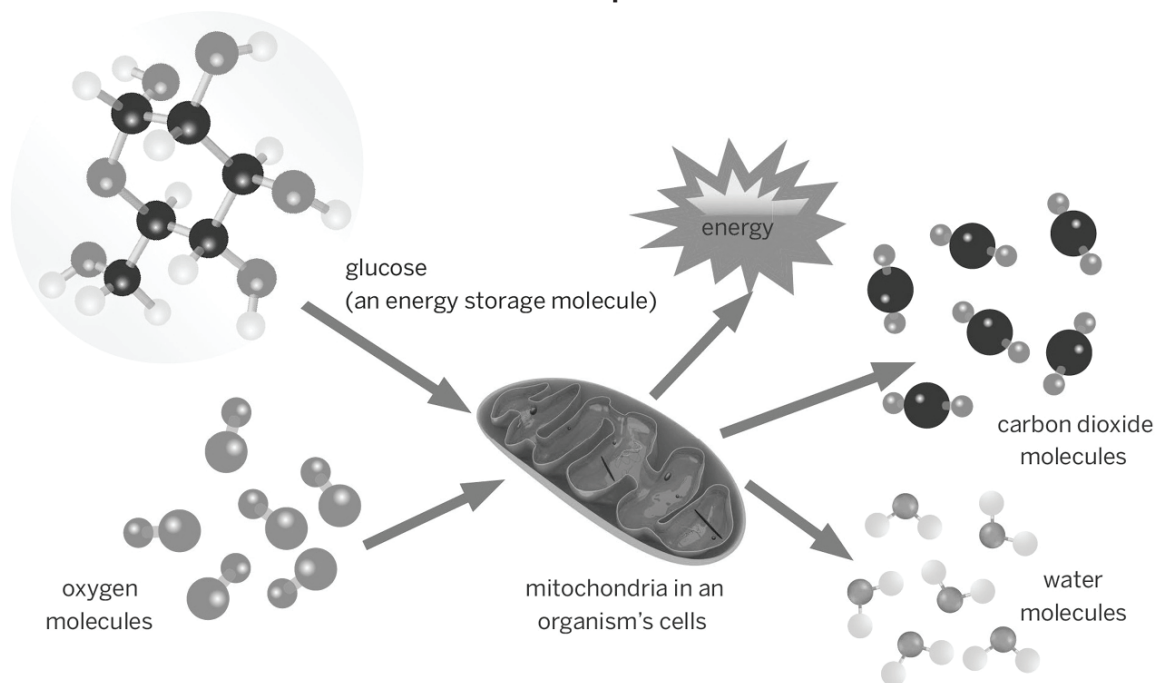
Digital Tools

- *Matter and Energy in Ecosystems* Modeling Tool activity: Carbon Dioxide in Air
- *Matter and Energy in Ecosystems* Simulation

Warm-Up

In *A Feast for Decomposers*, you read a bit about cellular respiration. Now, look carefully at this diagram and write what you think it shows about cellular respiration.

Cellular Respiration



In cell parts called the mitochondria, glucose (an energy storage molecule) plus oxygen combine to make carbon dioxide plus water, releasing energy. This process is called cellular respiration.

What do you think this diagram shows about cellular respiration?

Observing Cellular Respiration

Part 1: Observing Cellular Respiration in the Sim

With a partner, you will observe the Sim. You will use what you see when you press VIEW CELL along with the diagram below to learn more about cellular respiration. These two models will help you answer the Investigation Question: *How do organisms give off carbon dioxide?*

1. Press VIEW CELL for all the different organisms.
2. Compare what you see in the Sim to the diagram from the article (on page 42), using the following questions as a discussion guide:
 - What is similar about cells in the Sim and the article diagram?
 - What is different about cells in the Sim and the article diagram?
 - What do both models tell you about how organisms give off carbon dioxide?

Part 2: Revising Your Answer

Now that you've gathered evidence about cellular respiration in the Sim, look at the diagram (on page 42) again. Revise your answer by recording your new ideas about cellular respiration.

Part 3: Observing Cellular Respiration in the Sim

Does cellular respiration require energy from the sun?

1. Open the Sim.
2. Click PLAY to run the Sim with the default settings.
3. Observe the Sim. Which parts of an ecosystem perform cellular respiration?
4. Turn off sunlight in the ecosystem. Observe whether the amount of sunlight affects which parts of an ecosystem perform cellular respiration.
5. Discuss the following two questions with your partner, and then record your answers.
 - A. Which parts of an ecosystem perform cellular respiration? Check all the answers you think are correct.
 - ☐ producers
 - ☐ primary consumers
 - ☐ secondary consumers
 - ☐ decomposers
 - ☐ dead matter
 - B. Does the amount of sunlight affect which parts of an ecosystem perform cellular respiration? (check one) ☐ yes ☐ no

Name: _____

Date: _____

Modeling How Organisms Give Off Carbon Dioxide

Make a model with the Modeling Tool that answers the Investigation Question: *How do organisms give off carbon dioxide?* Remember to use what you saw when you compared the Sim and the diagram.

1. Launch the *Matter and Energy in Ecosystems* Modeling Tool activity: Carbon Dioxide in Air.
2. In your model, show (a) which organisms give off carbon dioxide, and (b) how this happens.
3. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

4. Then, use your model to answer the question below.

Goal: Show where carbon dioxide in the air comes from.

Do:

- Drag items from the Ecosystem and Matter categories into your model.
- Add Movement arrows to show how matter or energy moves through the ecosystem.
- Drag one or more Process editors to your model. Use them to show the process that gives off carbon dioxide. Name the process and show the input(s) and output(s).

Tips:

- You do not have to include all the items in your model.
- Carbon dioxide has already been added to the air of the ecosystem.

Explain how your model answers the Investigation Question.

Name: _____

Date: _____

Sharing Models

Share your model with another pair of students:

- Display your model.
- Use the vocabulary terms in the Word Bank to help you and your partner explain to the other pair of students how your model answers the Investigation Question: *How do organisms give off carbon dioxide?*
- When you are finished, switch roles with the other pair of students.

Word Bank

abiotic matter	carbon dioxide	ecosystem	biotic matter	cellular respiration
energy storage molecule	carbon	consumer	producer	decomposer

Name: _____

Date: _____

Homework: Photosynthesis and Cellular Respiration in Producers

Producers make energy storage molecules during photosynthesis, and then they use them during cellular respiration. Do producers make just enough energy storage molecules for themselves or do they make enough for the ecosystem? Read this short article and use the Sim to find out.

Part 1

1. Read and annotate the article “The Mulberry Tree and the Silkworm.”
2. Use the information in the article to make a prediction.

My Prediction: I think producers do: (check one)

- ☐ the same amount of photosynthesis as cellular respiration.
- ☐ more photosynthesis than cellular respiration.
- ☐ less photosynthesis than cellular respiration.

Explain your answer.

Part 2

Test your ideas in the *Matter and Energy in Ecosystems* Sim:

1. Without making any changes, start the Sim.
2. Observe Info view by pressing the / symbol.
3. Observe producer photosynthesis and compare it to producer cellular respiration. Write your observations below.

What do you notice?

Lesson 2.3: An Explanation for the Econauts

Student ecologists, it is almost time to write the next part of your explanation to the Econauts. First, however, you'll need to review some new data about the biodome that Dr. Corry sent. Using the data and some evidence from the Sim, you'll be able to explain to the Econauts why the carbon dioxide in the air of the biodome decreased. Let's get to work!

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 2 Question

- What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?

Key Concept

- As organisms release energy during cellular respiration, carbon dioxide is produced from the carbon in energy storage molecules. This process moves carbon from biotic to abiotic matter.

Vocabulary

- | | | |
|------------------------|--------------|---------------------------|
| • abiotic matter | • claim | • energy storage molecule |
| • biotic matter | • connect | • evidence |
| • carbon | • consumer | • photosynthesis |
| • carbon dioxide | • decomposer | • producer |
| • cellular respiration | • ecosystem | • system |

Digital Tool

- *Matter and Energy in Ecosystems* Simulation

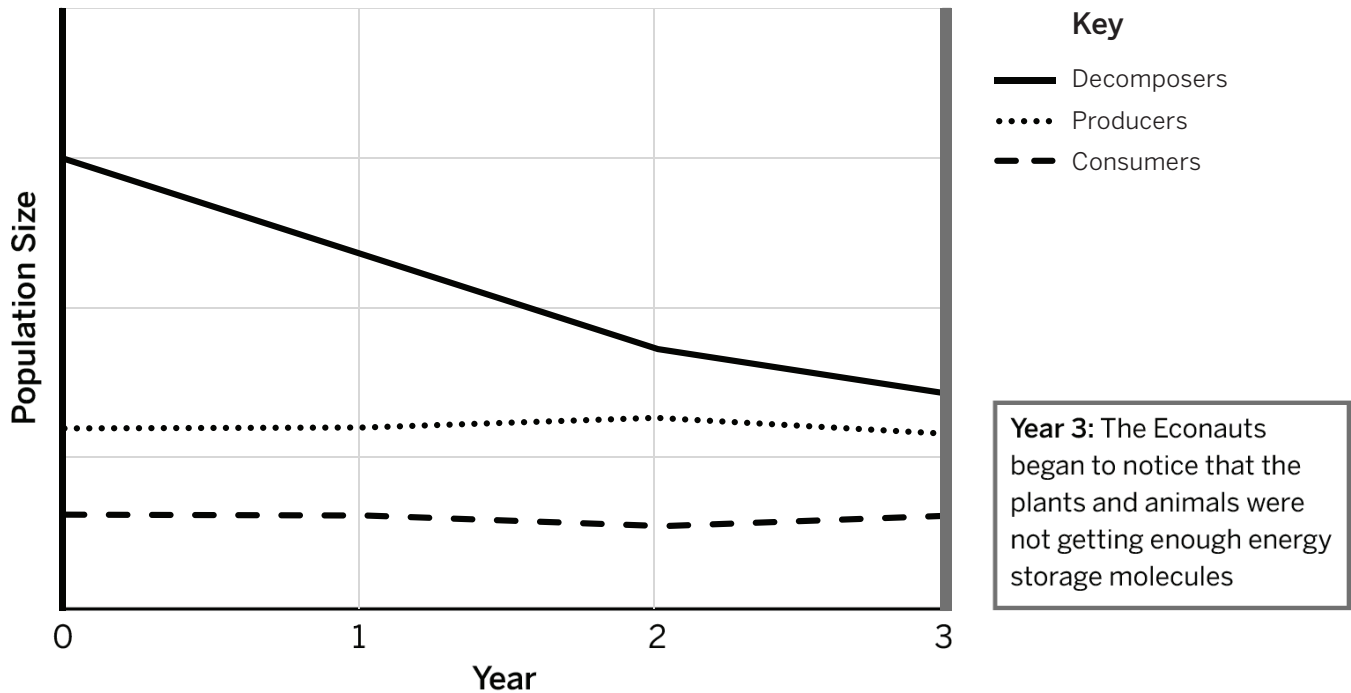
Name: _____

Date: _____

Warm-Up

Based on your recent work, Dr. Corry sent you a graph showing the populations of producers, consumers, and decomposers in the biodome. Examine this graph and think about what it shows you. Then, answer the questions below.

Biodome Population Data



Can this graph help you explain why the amount of carbon dioxide in the air of the biodome decreased? (check one)

☐ yes ☐ no

Explain your answer.

Name: _____ Date: _____

Testing a Claim in the Sim

Claim: A decrease in decomposers led to a decrease in carbon dioxide in the air (abiotic matter) of the biodome.

With a partner, use the *Matter and Energy in Ecosystems* Sim to test the claim.

1. Open the Sim and run it with default settings for 20 time units.
2. After 20 time units, pause the Sim. Use the KILL button to remove all decomposers. Press PLAY.
3. Open the graph and observe how the decrease in decomposers affects the ecosystem. Be sure CELLULAR RESPIRATION and CARBON DIOXIDE are selected so you can observe these graph lines.
4. With your partner, discuss what you observe about carbon dioxide in the graph. Note your observations in the space below.

Observations:

Explain how your observations are evidence either for or against the claim.

Word Relationships Routine

- Use the Word Relationships cards to create sentences that answer the Chapter 2 Question: *What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?*
- Use at least two different Word Relationships cards in each sentence. In your group of four, take turns as both the speaker and the listener.
 - Your group may use the same word more than once. You do not need to use all the vocabulary words.
 - There are many different ways to answer the Chapter 2 Question, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

abiotic matter	cellular respiration	energy storage molecule	biotic matter
consumer	photosynthesis	carbon	decomposer
producer	carbon dioxide	ecosystem	system

Date: _____

Last time you wrote to the Econauts, you explained that living organisms in the biodome were not getting enough energy storage molecules because the amount of carbon dioxide in the air decreased. Now, the Econauts want to know, *What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?*

abiotic matter	carbon dioxide	decomposer	photosynthesis
biotic matter	cellular respiration	ecosystem	producer
carbon	consumer	energy storage molecule	system

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins or other markings on the paper.

Homework: Reading “How Did We Get Mitochondria?”

You have been learning about how organisms release energy through the process of cellular respiration. To learn more about the part of the cell that performs cellular respiration, read and annotate the “How Did We Get Mitochondria?” article. Then, answer the questions below.

1. What are mitochondria, and why are they an important part of cells?

2. How did mitochondria become part of the cell?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Lesson 2.5: Investigating Econauts' Claims

The Econauts are at it again! In order to learn more about how to design their next biodome, they have been exploring different ecosystems: a cave, a coastal prairie, and an area of volcanic activity deep in the ocean. They have made some claims and are wondering if you can help them find evidence to support or refute these claims. Start by reading about an ecosystem, and then use the Sim to gather evidence. Help these Econauts with their research so their next biodome will, hopefully, be more successful.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 2 Question

- What caused carbon dioxide to decrease in the air (abiotic matter) of the biodome?

Key Concepts

- Carbon is part of carbon dioxide, which is *abiotic* matter. Carbon is part of energy storage molecules, which are *biotic* matter.
- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.
- If one part of a system changes, this affects the rest of the system.
- When there is *more* carbon (in the form of carbon dioxide) in abiotic matter, *more* carbon is available to producers for making energy storage molecules.
- When there is *less* carbon (in the form of carbon dioxide) in abiotic matter, *less* carbon is available to producers for making energy storage molecules.
- When there is *more* sunlight, producers can make *more* energy storage molecules from the carbon in carbon dioxide.
- When there is *less* sunlight, producers cannot make as many energy storage molecules from the carbon in carbon dioxide.
- As organisms release energy during cellular respiration, carbon dioxide is produced from the carbon in energy storage molecules. This process moves carbon from biotic to abiotic matter.

Name: _____

Date: _____

Lesson 2.5: Investigating Econauts' Claims (continued)

Vocabulary

- abiotic matter
- biotic matter
- carbon
- carbon dioxide
- claim
- cellular respiration
- consumer
- decomposer
- ecosystem
- energy storage molecule
- evidence
- photosynthesis
- producer

Digital Tool

- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Purple Group: Warm-Up

Read the following message from Econaut Keith Yoo, then respond to the question below about his claim.

To: Biodome Investigation Team

From: Keith Yoo, Econaut

Subject: Cave Ecosystem Claim

Recently, I was hiking in a dark cave and was so surprised at what I saw! As I shined my flashlight, I couldn't believe the variety and number of organisms. The organisms seemed healthy, so they must be able to get enough energy storage molecules. I'd like your help with a claim that I developed based on the cave ecosystem: ***Populations in the cave ecosystem can get energy storage molecules without sunlight.***

Please investigate this claim and let me know what you find.



Claim: Populations in the cave ecosystem can get energy storage molecules without sunlight.

Do you agree or disagree with this claim? Explain your answer.

Purple Group: Investigating Ecosystem Claims

Claim: Populations in the cave ecosystem can get energy storage molecules without sunlight.

Part 1: Reading About Your Ecosystem

Read and annotate Dr. Corry's short article, "Getting Energy in a Cave Ecosystem." Look for information that will help you either support or go against the claim.

Part 2: Finding Evidence in the Sim

Gather more evidence in the Sim by following the directions and answering the questions. You will first observe the system with sunlight to see a normally functioning ecosystem. Then, you will look at the system without sunlight to help determine whether populations in an ecosystem can get energy storage molecules without sunlight.

Ecosystem With Sunlight

1. Press PLAY and run the Sim on the default settings for 20 time units.

2. Observe the energy storage molecules in the ecosystem.

Where do energy storage molecules first appear in the ecosystem? (circle one)

consumers

producers

decomposers

dead matter

abiotic matter

3. Observe the energy storage molecules in producer cells by pressing VIEW CELL. How are they made? (Circle your answers to complete the sentence.)

Energy storage molecules are made by combining (**oxygen** / **water** / **carbon from carbon dioxide**) and (**oxygen** / **water** / **carbon from carbon dioxide**) using energy from the sun.

4. What happens to the energy storage molecules *after* they are produced? (Circle your answers to complete the sentence.)

After they are produced, energy storage molecules are turned into

(**oxygen** / **water** / **carbon dioxide**) and (**oxygen** / **water** / **carbon dioxide**) during the process of releasing energy in the mitochondrion. The (**oxygen** / **water** / **carbon dioxide**) then moves into the air (abiotic matter).

Purple Group: Investigating Ecosystem Claims (continued)

Ecosystem Without Sunlight

1. Reset the Sim.
2. Set Sunlight to NONE.
3. Press VIEW CELL for Producers. Observe the energy storage molecules in this view.

Explain what is happening.

4. Let the Sim run for at least 100 time units.

What eventually happens to the ecosystem? Why did this happen?

Part 3: Writing to the Econauts

After visiting a cave, Econaut Keith Yoo made the following claim: Populations in the cave ecosystem can get energy storage molecules without sunlight.

Write a short message to Keith and explain whether you agree with his claim or not. Be sure to use evidence from the article and the Sim in your explanation. Remember, the Econauts do not know as much about ecosystems as you do, so you should explain your ideas fully and clearly.

Name: _____

Date: _____

Blue Group: Warm-Up

Read the following message from Econaut Tess Ames, then respond to the question below about her claim.

To: Biodome Investigation Team

From: Tess Ames, Econaut

Subject: Coastal Prairie Ecosystem Claim

Recently, I was walking through the coastal prairie near my city and saw plants all around for miles, but no animals at all. I'd like your help with a claim that I developed based on what I saw in the coastal prairie ecosystem: ***An ecosystem can survive with only producers.***

Please investigate this claim and let me know what you find.



Claim: An ecosystem can survive with only producers.

Do you agree or disagree with this claim? Explain your answer.

Blue Group: Investigating Ecosystem Claims

Claim: An ecosystem can survive with only producers.

Part 1: Reading About Your Ecosystem

Read and annotate Dr. Corry's short article, "Getting Energy in a Coastal Prairie Ecosystem." Look for information that will help you either support or go against the claim.

Part 2: Finding Evidence in the Sim

Dr. Corry's information about the coastal prairie ecosystem told you about one specific ecosystem, but the claim refers to ecosystems in general. Use the Sim to help you find evidence that could apply to all ecosystems. Observe a normally functioning ecosystem first, and then compare it to an ecosystem without consumers and decomposers. Look for evidence that will either support or go against the claim.

Ecosystem with Producers, Consumers, and Decomposers

1. Press PLAY and run the Sim on the default settings.
2. Press VIEW CELL in producers, consumers, and decomposers. Observe the energy storage molecules in each.

What happens to energy storage molecules when they are used to release energy? (Circle your answers to complete the sentence.)

After they are produced, energy storage molecules are turned into

(**oxygen / water / carbon dioxide**) and (**oxygen / water / carbon dioxide**) during the process of releasing energy in the mitochondrion. The (**oxygen / water / carbon dioxide**) then moves into the air (abiotic matter).

3. What do producers, consumers, and decomposers have in common? (check one.)

- ☐ They do photosynthesis.
- ☐ They do cellular respiration.
- ☐ They do both photosynthesis and cellular respiration.
- ☐ They do not do photosynthesis or cellular respiration.

4. What happens to the carbon from energy storage molecules? **Hint:** First, VIEW CELL, and then look at the full ecosystem. (Circle your answers to complete the sentence.)

The carbon in energy storage molecules is turned into (**oxygen / water / carbon dioxide**).

When it leaves producers, consumers, and decomposers, it goes to (**biotic / abiotic**) matter.

Blue Group: Investigating Ecosystem Claims (continued)

Ecosystem with Only Producers

- 1. Reset the Sim.
- 2. Set primary and secondary consumer and decomposers to zero.
- 3. Play the Sim for 250 time units. You may want to run the Sim at 2x or 4x speed.

Explain what happened to the producer population over time.

Explain why having an ecosystem without any consumers or decomposers caused the producer population to change. **Hint:** Observe the graph of carbon dioxide in abiotic matter.

Part 3: Writing to the Econauts

After visiting a coastal prairie, Econaut Tess Ames made the following claim: An ecosystem can survive with only producers.

Respond to Econaut Tess Ames by explaining whether or not the evidence you found will support her claim. Be sure to include evidence from the article, the Sim, and anything else you learned in the unit. Remember, the Econauts do not know as much about ecosystems as you do, so you should explain your ideas fully and clearly.

Name: _____

Date: _____

Green Group: Warm-Up

Read the following email from Econaut Kate Jones, then respond to the question below about her claim.

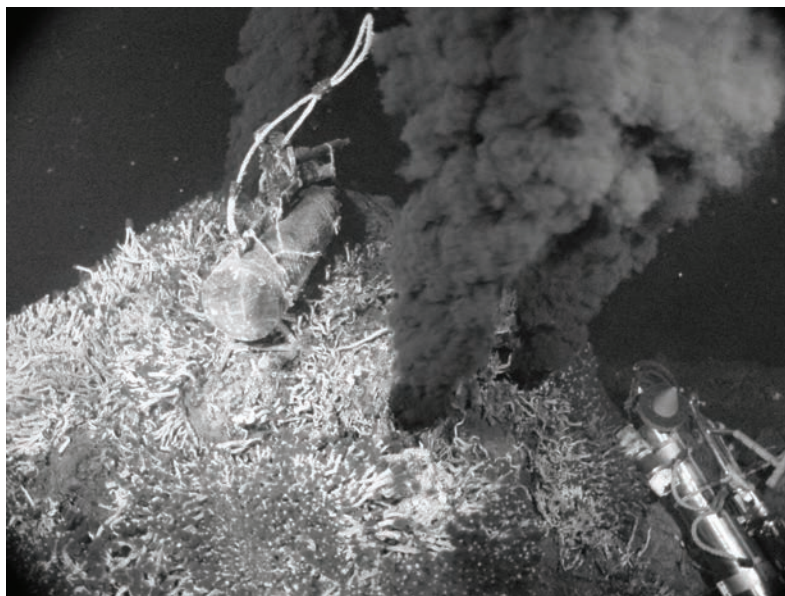
To: Biodome Investigation Team

From: Kate Jones, Econaut

Subject: Deep-Sea Vent Ecosystem Claim

I recently watched an interesting video about a deep-sea probe that took images of organisms living far below the ocean surface where there is no sunlight. I'd like your help with a claim that I developed from watching this video: ***Populations in the deep-sea vent ecosystem can get energy storage molecules without sunlight.***

Please investigate this claim and let me know what you find.



Claim: Populations in the deep-sea vent ecosystem can get energy storage molecules without sunlight.

Do you agree or disagree with this claim? Explain your answer.

Green Group: Investigating Ecosystem Claims

Claim: Populations in the deep-sea vent ecosystem can get energy storage molecules without sunlight.

Part 1: Reading About Your Ecosystem

Read and annotate Dr. Corry's short article, "Getting Energy Near a Deep-Sea Vent." Look for information that will help you either support or go against the claim.

Part 2: Finding Evidence in the Sim

Gather more evidence in the Sim by following the directions and answering the questions. See if the evidence supports or refutes the claim.

Ecosystem Without Sunlight

1. Open the Sim.
2. Set Sunlight to NONE.
3. Observe what happens to the ecosystem. Can the ecosystem survive without light? Why or why not?

Represent a Deep-Sea Vent Ecosystem in the Sim

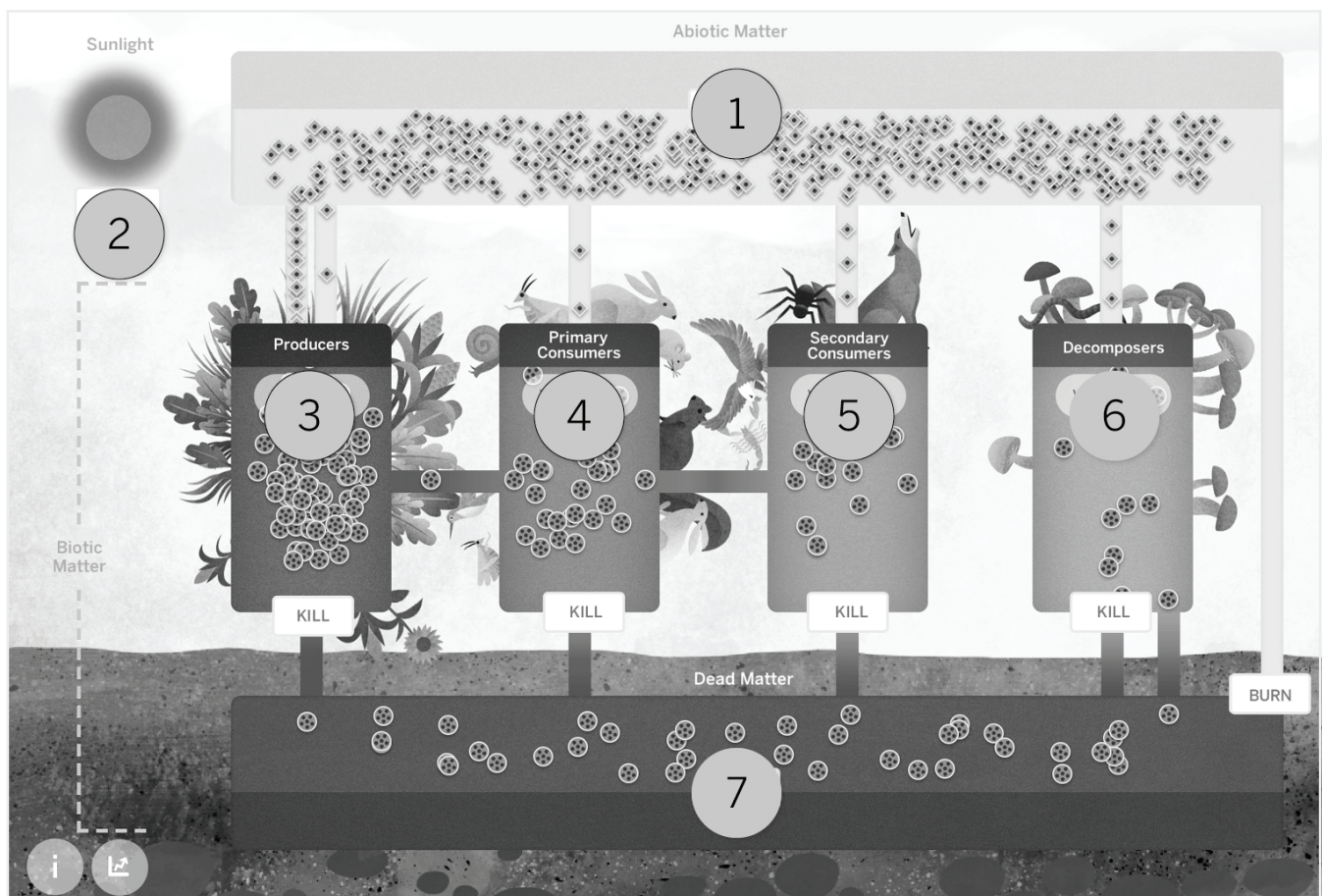
1. How does the ecosystem in the Sim compare to a deep-sea vent ecosystem? Fill in the table with key features of the Sim Ecosystem (left) and Deep-Sea Vent Ecosystem (right). Use the middle column to note features of both that are similar. Refer to the idea bank below if it helps.

Idea Bank: *producers, consumers, decomposers, energy storage molecules, carbon dioxide, sunlight, photosynthesis, hydrogen sulfide, chemosynthesis.*

Features of the Sim ecosystem	Features of both ecosystems	Features of the deep-sea vent ecosystem

Green Group: Investigating Ecosystem Claims (continued)

2. The Sim ecosystem depends on photosynthesis for energy storage molecules. *How would you change the Sim to represent an ecosystem that depends on chemosynthesis?* Describe your changes by telling how the parts of the ecosystem would be different. To make it easier, refer to the numbered parts of the Sim ecosystem (see the diagram below) in your explanation. However, you do not have to write about every part. If needed, return to your article to review information about deep-sea vent ecosystems.



Name: _____

Date: _____

Green Group: Investigating Ecosystem Claims (continued)

Part 3: Writing to the Econauts

Econaut Kate Jones made the following claim: Populations in the deep-sea vent ecosystem can get energy storage molecules without sunlight.

Use what you learned to write a short message to Econaut Kate Jones and explain whether you found evidence to support her claim or not. Be sure to include evidence from the article, the Sim, and any other information from the unit in your explanation. Remember, the Econauts do not know as much about ecosystems as you do, so you should explain your ideas fully and clearly.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Name: _____

Date: _____

Word Relationships Routine

Form a group with two students who investigated a different ecosystem. Use the Word Relationships cards to create sentences that will explain what you learned about your ecosystem to the other students in your group.

- Use at least two different Word Relationships cards in each sentence. In your group, take turns as both the speaker and the listener.
- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different things to share about your ecosystem. Create sentences that describe the claim you investigated, the organisms that live in your ecosystem, and any evidence you found for or against the claim.

Word Bank

abiotic matter	cellular respiration	energy storage molecule	biotic matter
consumer	photosynthesis	carbon	decomposer
producer	carbon dioxide	ecosystem	system

Homework: Reading “Glacier Mice: Living Arctic Tumbleweeds”

Every ecosystem is different. To learn about a unique ecosystem that scientists are just beginning to understand, read and annotate the “Glacier Mice: Living Arctic Tumbleweeds” article. Then, answer the questions below.

1. Describe how glacier mice are complete ecosystems, even though they are tiny.

2. What does it mean to define the “boundaries” of an ecosystem?

3. What is one way that the surrounding ecosystem can affect the glacier mouse ecosystem?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand where carbon can be found in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

2. I understand how having less carbon dioxide available in the biodome led to fewer energy storage molecules being made in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

3. I understand why the carbon dioxide in the biodome decreased. (check one)

☐ yes ☐ not yet (check one and explain your answer choice)

4. I understand why changing the amount of carbon in one part of the biodome affected the rest of the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

5. What are you still wondering about the biodome?

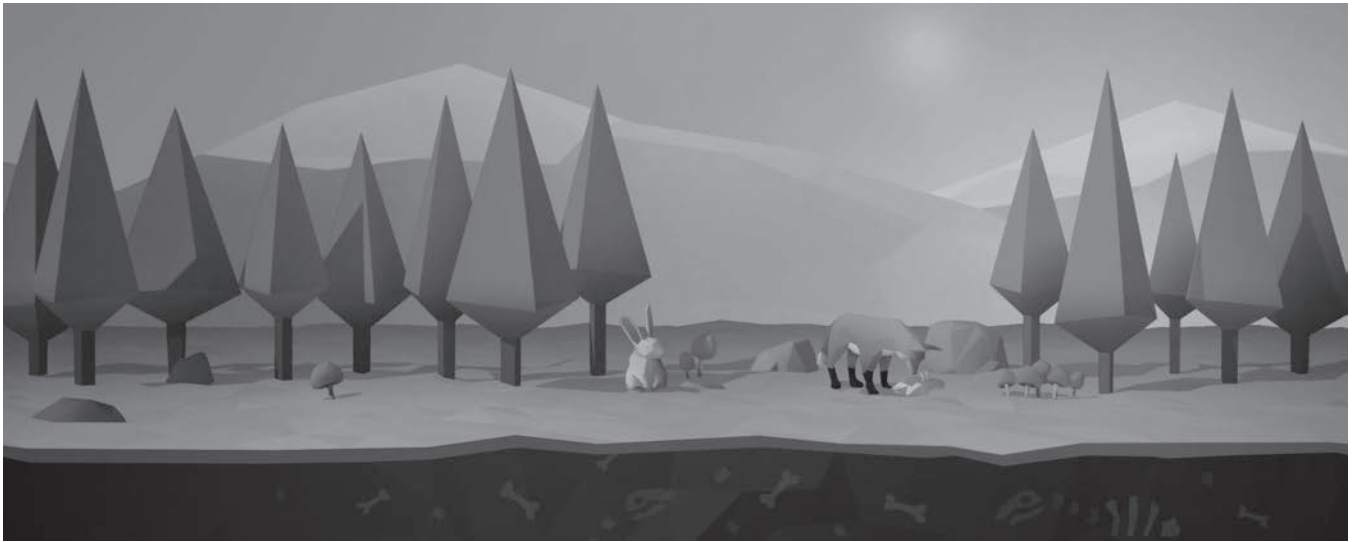
Name: _____

Date: _____

Chapter 3: Carbon Movement in Ecosystems

Chapter Overview

By now, you have enough information to understand why the living things in the biodome did not have enough energy storage molecules. The question remains: *What happened to the carbon that used to be in the air of the biodome?* To find out, you will learn more about how carbon moves through ecosystems.



Lesson 3.1: “Carbon in the Global Ecosystem”

Student ecologists, you’ve discovered that a decrease in the number of decomposers prevented the producers in the biodome from making enough energy storage molecules for all the plants and animals. Before you congratulate yourselves on a job well done, the Econauts have one more question: If the decrease in decomposers caused the decrease in carbon dioxide that shut down the biodome, then what happened to the carbon that used to be in the air? Today, you’ll begin to investigate by reading an article about the movement of carbon through Earth’s global ecosystem.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 3 Question

- What happened to the carbon that used to be in the air (abiotic matter) of the biodome?

Vocabulary

- | | | |
|------------------------|----------------------------|------------------|
| • abiotic matter | • connect | • photosynthesis |
| • biotic matter | • consumer | • producer |
| • carbon | • decomposer | • system |
| • carbon dioxide | • ecosystem | |
| • cellular respiration | • energy storage molecules | |

Digital Tool

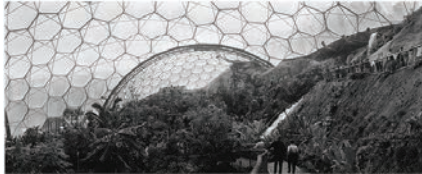
- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Warm-Up

Read the new message from Dr. Corry and answer the question.



To: Student Ecologists
From: Dr. Bryan Corry
Subject: One More Assignment

Great work, student ecologists! The Econauts had not realized that a change in the population of decomposers could have such a dramatic effect on the other organisms in the biodome. Before they plan their next biodome, they have one more question—they want to know what happened to the carbon that used to be in the air of the biodome.

We know that the decrease in the decomposer population caused the carbon dioxide in the air of the biodome to decrease, but the Econauts need to know what happened to all that carbon. This is your last mission for the Biodome Investigation Team, so we're hoping you give it your best.

Bryan

Dr. Bryan Corry, Head Ecologist
Biodome Investigation Team

What do you think happened to the carbon that used to be in the air of the biodome?

Name: _____

Date: _____

Reading "Carbon in the Global Ecosystem"

1. Read and annotate the "Carbon in the Global Ecosystem" article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

When you use the strategies that are part of Active Reading, which type(s) of annotations have you found to be most helpful for better understanding science texts? (circle all that apply)

recording questions

recording connections

summarizing

identifying unfamiliar words

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Homework: Increasing Carbon in the Atmosphere

In “Carbon in the Global Ecosystem,” you read that—unlike what happened in the biodome—the amount of carbon in Earth’s atmosphere is increasing. Your mission is to use the Sim to model the global ecosystem by increasing the amount of carbon dioxide in abiotic matter as much as possible.

1. Open the Sim.
2. Press PLAY to run the Sim with the default settings.
3. Make a change to increase the carbon dioxide in abiotic matter as much as possible.
4. Open Info view to find out how much carbon dioxide is in the ecosystem. Record the amount below.

Amount of Carbon Dioxide: _____

5. Answer the question.

As you increased the amount of carbon dioxide in the air, what happened to the amount of carbon in other parts of the ecosystem? Explain your answer.

Lesson 3.2: Total Carbon in an Ecosystem

We've seen that processes like photosynthesis and cellular respiration change the amount of carbon in different parts of an ecosystem. But when the amount of carbon in one part of the ecosystem goes up or down, what does that mean for the rest of the ecosystem? Today, we're going to consider how these changes affect the different parts of an ecosystem as they did in the biodome.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 3 Question

- What happened to the carbon that used to be in the air (abiotic matter) of the biodome?

Vocabulary

- | | | |
|------------------------|----------------------------|------------------|
| • abiotic matter | • consumer | • photosynthesis |
| • biotic matter | • decomposer | • producer |
| • carbon | • ecosystem | • system |
| • carbon dioxide | • energy storage molecules | |
| • cellular respiration | | |

Name: _____

Date: _____

Warm-Up

Gabriela read in the newspaper that the amount of carbon in the atmosphere is increasing and that humans are responsible. She said, "If carbon in the atmosphere is increasing, the total amount of carbon on Earth must also be increasing."

Do you agree or disagree with Gabriela's statement? (check one)

☐ agree ☐ disagree

Explain your answer.

Name: _____

Date: _____

Revisiting “Carbon in the Global Ecosystem”

1. Read paragraphs 4 and 5 of "Carbon in the Global Ecosystem." As you read, highlight pieces of evidence that will help you answer the Investigation Question.
2. After reading and annotating, answer the question below, using the evidence you found in the article.

Investigation Question: *If the amount of carbon changed in one part of a closed ecosystem, what happened to the carbon in the rest of the ecosystem?*

Name: _____ Date: _____

The Carbon Game Instructions

Goal: Work with your partner to keep producers, consumers, and decomposers in this ecosystem from running out of carbon for as many rounds as you can.

Materials (team of two players)

- 1 ecosystem game board
- 30 carbon tokens
- 12 Event cards: *natural events that affect the ecosystem*
- 15 Action cards: *ways YOU change the ecosystem*

Before the Game

1. Place six tokens in each region of the ecosystem (air, producers, consumers, decomposers, dead matter).

ANSWER THE QUESTION ON PAGE 77 BEFORE CONTINUING.

2. Shuffle both sets of cards (Action and Event), and place the decks facedown near the board.
3. Each player should draw an Action card and place it faceup in front of both players.

Playing the Game (each round)

- 1. Effects:** Follow the Effects of High and Low Carbon instructions for each part of the ecosystem. If more than one effect applies, go in order from the top of the board to the bottom, and then from left to right within each row.
- 2. Events:** Draw an Event card and place it faceup next to the board. Follow the instructions on the card. Wait till the beginning of the next round to apply any ecosystem effects.
- 3. Action:** Choose one of the faceup Action cards and follow the instructions **OR** discard one of the faceup Action cards. After you follow the instructions or discard, draw a new card, turn it faceup, and wait till the next round to play your new Action card. *This round is now over.*

Winning and Losing

If your ecosystem survives, you win! If any organisms (producers, consumers, or decomposers) run out of carbon, you lose.

Effects of High and Low Carbon

Air (Abiotic Matter)

High carbon (more than 8)
Producers have more carbon from carbon dioxide to perform more photosynthesis.
• Move 1 carbon from air to producers.

Low carbon (fewer than 4)
Producers do not have enough carbon from carbon dioxide to make energy storage molecules.
• Move 1 carbon from producers to dead matter.

Producers

High carbon (more than 8)
Producers provide extra food for consumers.
• Move 1 carbon from producers to consumers.

Low carbon (fewer than 4)
Consumers do not have enough food to survive.
• Move 1 carbon from consumers to dead matter.

Consumers

High carbon (more than 8)
More consumers eat producers and perform cellular respiration.
• Move 1 carbon from producers to consumers.

• Move 1 carbon from consumers to air.

Decomposers

High carbon (more than 8)
More decomposers eat dead matter and perform cellular respiration.
• Move 1 carbon from dead matter to decomposers.

• Move 1 carbon from decomposers to air.

Dead Matter

High carbon (more than 8)
Food supply for decomposers has increased.
• Move 1 carbon from dead matter to decomposers.

Low carbon (fewer than 4)
Decomposers do not have enough carbon from dead matter to survive.
• Move 1 carbon from decomposers to dead matter.

Name: _____ Date: _____

The Carbon Game

After you complete step #1 in Before the Game, report your carbon numbers.

- The total amount of carbon in the ecosystem is _____.
- The total amount of carbon in biotic matter is _____.
- The total amount of carbon in abiotic matter is _____.

At the end of the game, count again and report your carbon numbers.

- The total amount of carbon in the ecosystem is _____.
- The total amount of carbon in biotic matter is _____.
- The total amount of carbon in abiotic matter is _____.

Based on the game, discuss with your partner what you have learned that can help you answer the Investigation Question: *If the amount of carbon changed in one part of a closed ecosystem, what happened to the carbon in the rest of the ecosystem?*

Name: _____ Date: _____

Homework: Making Connections

Think of another science topic you studied earlier. How does that topic connect to what we are learning about carbon and energy in ecosystems? Be creative! Consider how carbon in ecosystems might affect or be affected by molecules, energy, forces, Earth—either its atmosphere or oceans.

Other science topic: _____

Connect the science topic you suggested to something you have been learning in this unit.

Lesson 3.3: Looking for the Missing Carbon

You are almost finished with your investigation into what happened to the carbon that used to be in the air (abiotic matter) of the biodome and why the population of decomposers decreased. Are these two things related? Investigate the final pieces of the puzzle to help figure out what caused the biodome ecosystem to fail. The Econauts are counting on you to help them understand what went wrong!

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 3 Question

- What happened to the carbon that used to be in the air (abiotic matter) of the biodome?

Vocabulary

- | | | |
|------------------------|---------------------------|------------------|
| • abiotic matter | • claim | • evidence |
| • biotic matter | • consumer | • photosynthesis |
| • carbon | • decomposer | • producer |
| • carbon dioxide | • ecosystem | • system |
| • cellular respiration | • energy storage molecule | |

Digital Tools

- *Matter and Energy in Ecosystems* Sorting Tool activity: Carbon in the Biodome
- *Matter and Energy in Ecosystems* Simulation

Name: _____

Date: _____

Warm-Up

In Chapter 2, you learned that the decomposer population in the biodome decreased. This meant that fewer organisms were doing cellular respiration. As a result, less carbon dioxide was given off, so the amount of carbon dioxide in the air decreased. If the carbon is no longer in the air (abiotic matter), where could it be?

Based on what you learned about carbon movement in ecosystems, which claim best answers the Chapter 3 Question? (check one)

What happened to the carbon that used to be in the air (abiotic matter) of the biodome?

- ☐ **Claim 1:** The carbon that used to be in the air (abiotic matter) is no longer in the biodome, so total carbon *decreased*.
- ☐ **Claim 2:** The carbon that used to be in the air (abiotic matter) is now in another part of the ecosystem, so total carbon *stayed the same*.

Briefly explain your claim choice.

Finding the Missing Carbon

What Happened to Abiotic Carbon in the Biodome?

When the decomposer population decreased, the amount of carbon dioxide in the biodome went down. We know that the carbon that used to be in the air (abiotic matter) is now in another part of the ecosystem, because the total carbon stayed the same. But where is the carbon now? In order to plan their next biodome experiment, the Econauts need to know. Use the Sim to help you find the answer!

What happened to the carbon that used to be in the air (abiotic matter) of the biodome? Where did the carbon go? (Check one of the options to predict where the carbon went.)

- ☐ The carbon is now in the producers of the ecosystem.
- ☐ The carbon is now in the consumers of the ecosystem.
- ☐ The carbon is now in the decomposers of the ecosystem.
- ☐ The carbon is now in the dead matter of the ecosystem.

Use the Sim to test your prediction.

1. Open the *Matter and Energy in Ecosystems* Sim.
2. Press PLAY and run the Sim using the default settings for 20 time units.
3. Pause the Sim and kill all the decomposers.
4. Press PLAY to run the Sim for at least 100 more time units.
5. As the Sim runs, observe what happens to the carbon in the different parts of the ecosystem. *Where did the carbon that used to be in abiotic matter go?* **Hint:** Check Info view and look at how the amount of energy storage molecules changes in each part of the ecosystem or look at the graph and use the Graph Molecule preset.

Name: _____ Date: _____

Finding the Missing Carbon (continued)

In the space below, provide evidence from Info view or Graph view that shows what happened to the carbon that used to be in the abiotic part of the ecosystem. You may write or draw.

Was your prediction correct? Explain why or why not.

Name: _____

Date: _____

Researching the *Biodome Files*

To: Student Ecologists

From: Dr. Bryan Corry

Subject: *The Biodome Files*

I've been reading through the *Biodome Files* to try and get a better sense of what went wrong in the biodome. You've been focusing a lot on decomposers in this chapter, so I left some notes in the files. I'd like you to look at these files again, and use my notes to help you think about what might have caused the decomposer population to decrease. With any luck, we might be able to come up with a good explanation for the biodome's failure.

Bryan

Dr. Bryan Corry, Head Ecologist

Biodome Investigation Team

1. Read through the *Biodome Files* and look for Dr. Corry's notes. Start by looking at the files where Dr. Corry left notes—Files 2 and 3. Look at the other files if you have time.

- "Biodome File 1: News Stories"
- "Biodome File 2: Econaut Biographies & Job Descriptions"
- "Biodome File 3: Recommended Organisms to Include in the Biodome"
- "Biodome File 4: Biodome Water System Diagram"
- "Biodome File 5: Goatherd's Journal"

2. Annotate places you see evidence that indicates what caused the decomposer population to decrease.

3. Answer the questions below.

Review your annotations in the *Biodome Files*. Based on your evidence, write a claim that can explain what caused the decomposer population to decrease.

Describe the evidence you found in the *Biodome Files* that supports your claim.

Name: _____

Date: _____

Homework: Movement of Carbon in the Biodome

The Econauts had to shut down the biodome after the amounts of carbon dioxide in the air and energy storage molecules in living things decreased. In this chapter, you've learned about how carbon moves between the biotic and abiotic parts of ecosystems. Help the Econauts understand more about what happened to the carbon in the biodome by using the Sorting Tool as well as all that you learned from your reading, the Carbon Game, and the Sim.

1. Open the *Matter and Energy in Ecosystems* Sorting Tool activity: Carbon in the Biodome.
2. Press HAND IN once you have completed the diagram. If you worked with a partner, write their name here: _____
3. Answer the question below.

Goal: Show what happened to the amount of carbon in different parts of the biodome ecosystem.

Do:

- Complete the diagram. Drag increased, decreased or stayed-the-same cards next to carbon in dead matter and total carbon in the ecosystem.

Tip:

- Cards have already been placed next to carbon in abiotic matter and carbon in living things to show that carbon decreased in these parts of the biodome ecosystem.

Explain how your diagram shows what happened to the carbon in the biodome.

Lesson 3.4: Explaining What Happened in the Biodome

The Econauts are preparing to begin their next biodome experiment. First, however, they need advice about how to avoid the problems that forced the early shutdown of the last biodome experiment. Today, you'll help the Econauts by connecting the series of causes and effects that led to problems in the biodome. Think carefully! Your advice could determine the fate of the next biodome experiment.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 3 Question

- What happened to the carbon that used to be in the air (abiotic matter) of the biodome?

Key Concepts

- Since carbon cannot be produced or used up, the total amount of carbon in a closed ecosystem does not change.
- If the amount of carbon increased in abiotic matter, then it also decreased in biotic matter. If the amount of carbon decreased in abiotic matter, then it also increased in biotic matter.

Vocabulary

- | | | |
|------------------------|---------------------------|------------------|
| • abiotic matter | • connect | • photosynthesis |
| • biotic matter | • consumer | • producer |
| • carbon | • decomposer | • system |
| • carbon dioxide | • ecosystem | |
| • cellular respiration | • energy storage molecule | |

Digital Tools

- *Matter and Energy in Ecosystems* Sorting Tool activity: Cause and Effect Example and Cause and Effect in the Biodome
- *Matter and Energy in Ecosystems* Modeling Tool activity: Biodome Model

Name: _____

Date: _____

Warm-Up

Today, Quincy was late to his first period class, but what caused him to be late?

A cause is WHY something happened. An effect is WHAT happened. Sometimes, a cause makes an effect happen, and that effect makes something else happen.

1. Open the *Matter and Energy in Ecosystems* Sorting Tool activity: Cause and Effect Example.
2. Look at the pictures and order them so they show what caused Quincy to be late to his first period class.
3. When you finish ordering the cards, press HAND IN. If you worked with a partner, write their name here: _____

Goal: Show the series of causes and effects that made Quincy late to first period.

Do:

- Order the cards in a way that shows the reason Quincy was late to first period.

Tip:

- The last card for this chain of events is already in the correct location.

Name: _____ Date: _____

Cause and Effect in the Biodome

1. Open the *Matter and Energy in Ecosystems* Sorting Tool activity: Cause and Effect in the Biodome, and follow the instructions.
2. Talk to a partner about your ideas as your work. Use the words from the Word Bank to explain how one cause leads to another.
3. When you finish ordering the cards, press HAND IN. If you worked with a partner, write their name here: _____

Goal: Show the series of causes and effects that happened in the biodome ecosystem.

Do:

- Order the cards in a way that shows how buried dead matter was the cause of the plants and animals in the biodome not having enough energy storage molecules.

Tip:

- The first and last cards for this chain of events are already in the correct locations.

Word Bank

abiotic matter	carbon dioxide	decomposer	photosynthesis
biotic matter	cellular respiration	energy storage molecule	producer
carbon	consumer	ecosystem	system

Name: _____

Date: _____

Biodome Model

1. Open the *Matter and Energy in Ecosystems* Modeling Tool activity: Biodome Model.
2. Make a model that shows the Econauts how carbon moves through the biodome ecosystem.
3. When you finish your model, press HAND IN. If you worked with a partner, write their name here:

Goal: Show how carbon moves through the different parts of the biodome ecosystem.

Do:

- Drag Matter items into your model.
- Add Movement arrows to show how matter or energy moves through the ecosystem.
- Drag one or more Process editors to your model. Use them to show processes that involve carbon. Name the process and show the input(s) and output(s).

Tip:

- The different parts of the ecosystem have already been added to the model.

Date: _____

Use your cause-and-effect analysis and your Biodome Model to make a recommendation to the Econauts about how their plans for the next biodome should be different. Be sure to fully explain your recommendation so it is easy for the Econauts to understand how these new ideas will improve their next biodome. Use the Word Bank to help you write.

abiotic matter	carbon dioxide	decomposer	photosynthesis
biotic matter	cellular respiration	energy storage molecule	producer
carbon	consumer	ecosystem	system

[illegible]

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

1. I understand where carbon can be found in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

2. I understand how having less carbon dioxide available in the biodome led to fewer energy storage molecules being made in the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

3. I understand why the carbon dioxide in the biodome decreased.

☐ yes ☐ not yet (check one and explain your answer choice)

4. I understand why changing the amount of carbon in one part of the biodome affected the rest of the biodome.

☐ yes ☐ not yet (check one and explain your answer choice)

5. What are you still wondering about the biodome?

Name: _____

Date: _____

Chapter 4: Science Seminar

Chapter Overview

A group of farmers noticed that after clearing a forest to create farmland, carbon dioxide increased in the air. Take what you've learned during your biodome investigation and analyze the evidence to help these farmers figure out why this is happening.



Lesson 4.1: Analyzing Claims and Evidence

Great work on your research and recommendations to the Econauts about the biodome! Now, Dr. Corry needs your help with a new problem. He has been contacted by a group of farmers who want to know more about why deforestation in their area has caused carbon dioxide in the air to increase. What does cutting down trees have to do with an increase in carbon dioxide in the air? Today you'll work with your partner to analyze evidence and discuss how it might support or go against two claims about photosynthesis and cellular respiration.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 4 Question

- Why does deforestation lead to increased carbon dioxide in the air?

Key Concepts

- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.
- If one part of a system changes, this affects the rest of the system.
- When there is *more* carbon (in the form of carbon dioxide) in abiotic matter, *more* carbon is available to producers for making energy storage molecules.
- As organisms release energy during cellular respiration, carbon dioxide is produced from the carbon in energy storage molecules. This process moves carbon from biotic to abiotic matter.
- Since carbon cannot be produced or used up, the total amount of carbon in a closed ecosystem does not change.
- If the amount of carbon increased in abiotic matter, then it also decreased in biotic matter. If the amount of carbon decreased in abiotic matter, then it also increased in biotic matter.

Vocabulary

- | | | |
|------------------------|----------------------------|------------------|
| • carbon | • consumer | • evidence |
| • carbon dioxide | • decomposer | • photosynthesis |
| • cellular respiration | • ecosystem | • producer |
| • claim | • energy storage molecules | • system |
| • connect | | |

Date: _____

Warm-Up

Deforestation is when all the trees in an area are cut down or burned.

Deforestation



Why might people want to remove all the trees from an area of land? List two or three reasons.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

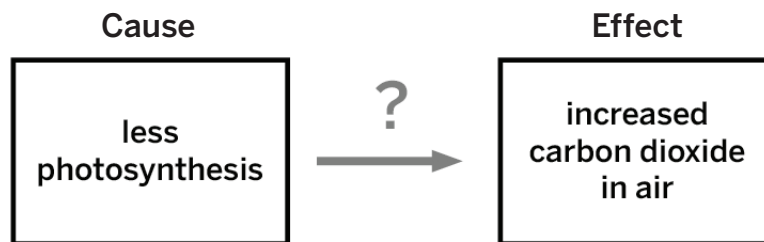
Discussing Deforestation Claims

Why does deforestation lead to increased carbon dioxide in the air?

Read each claim and review the diagrams. Think about all you have learned in this unit as you discuss each situation with your partner.

Claim 1: There is *less photosynthesis*, so carbon dioxide increases in the air.

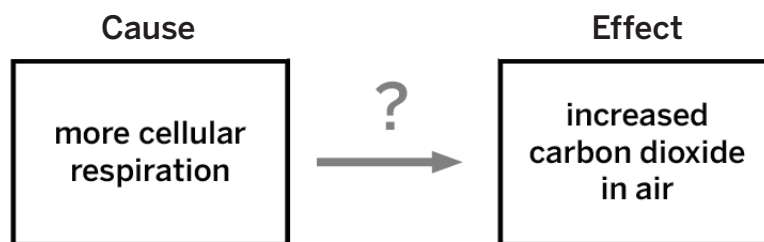
Discuss with your partner how less photosynthesis could lead to increased carbon dioxide in the air.



Why would less photosynthesis lead to an increase in carbon dioxide?

Claim 2: There is *more cellular respiration*, so carbon dioxide increases in the air.

Discuss with your partner how more cellular respiration could lead to increased carbon dioxide in the air.



Why would more cellular respiration lead to an increase in carbon dioxide?

Name: _____

Date: _____

Annotating and Discussing Evidence

Why does deforestation lead to increased carbon dioxide in the air?

1. Read each evidence card carefully.
2. Make annotations on each card. Consider the following:
 - What questions do you have about the evidence?
 - How is the evidence connected to what you have been learning about carbon and energy in ecosystems?
 - How does the evidence help you answer the question about deforestation?

Partner Discussion:

- Talk with your partner about your evidence card questions. See if you can help each other answer them.
- Looking at the evidence cards, are there any two pieces of evidence that you think could work together? How do you think the two cards are connected to each other?

Sorting the Evidence

1. With a partner, discuss whether each piece of evidence supports or goes against a claim. Use the sentence starters to help you talk with your partner.
2. Make annotations on each card:
 - If the evidence supports a claim, write "Supports Claim [1 or 2]" on that card.
 - If the evidence refutes a claim, write "Goes Against Claim [1 or 2]" on that card.
 - If the evidence connects with another evidence card, write "Connects with Evidence Card [A, B, C, or D]" on that card.
3. Sort the evidence by placing the cards underneath the claim they support.

Sentence Starters
I think this piece of information supports this claim because . . .
I don't think this piece of information supports this claim because . . .
I agree because . . .
I disagree because . . .
Why do you think that?

Name: _____ Date: _____

Homework: Choosing a Claim

Based on your analysis of the evidence in today's lesson, choose the claim that you think is best supported right now. You will have time in the upcoming lesson to revise your ideas.

Right now, the claim that I think is best supported by evidence is: (check one)

☐ **Claim 1:** There is *less photosynthesis*, so carbon dioxide increases in the air.

☐ **Claim 2:** There is *more cellular respiration*, so carbon dioxide increases in the air.

Explain your claim choice.

Lesson 4.2: Science Seminar

Why does cutting down trees increase the amount of carbon dioxide in the air? In today's Science Seminar, you and your fellow student ecologists will discuss this question, using the evidence to make the best case you can for why deforestation causes increased carbon dioxide. By the end of the lesson, you'll be ready to write a convincing scientific argument to the farmers.

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 4 Question

- Why does deforestation lead to increased carbon dioxide in the air?

Key Concepts

- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.
- If one part of a system changes, this affects the rest of the system.
- When there is *more* carbon (in the form of carbon dioxide) in abiotic matter, *more* carbon is available to producers for making energy storage molecules.
- As organisms release energy during cellular respiration, carbon dioxide is produced from the carbon in energy storage molecules. This process moves carbon from biotic to abiotic matter.
- Since carbon cannot be produced or used up, the total amount of carbon in a closed ecosystem does not change.
- If the amount of carbon increased in abiotic matter, then it also decreased in biotic matter. If the amount of carbon decreased in abiotic matter, then it also increased in biotic matter.

Vocabulary

- | | | |
|------------------------|----------------------------|-----------------------|
| • carbon | • decomposer | • reasoning |
| • carbon dioxide | • ecosystem | • scientific argument |
| • cellular respiration | • energy storage molecules | • system |
| • claim | • evidence | |
| • connect | • photosynthesis | |
| • consumer | • producer | |

Name: _____

Date: _____

Warm-Up

Take out your envelope from the last lesson. Look at the evidence cards and review your annotations. Then, use the evidence cards to answer the questions below.

Why does deforestation lead to increased carbon dioxide in the air?

Which claim do you think is the most convincing? (check one)

☐ **Claim 1:** There is *less photosynthesis*, so carbon dioxide increases in the air.

☐ **Claim 2:** There is *more cellular respiration*, so carbon dioxide increases in the air.

Draw a star on the evidence card that best supports your claim. Why did you choose this piece of evidence?

Name: _____

Date: _____

Preparing Your Science Seminar Argument

1. Take turns with your partner, and share which claim you think is most convincing.
2. Use your Warm-Up responses and the Argumentation Sentence Starters to help you share ideas.
3. Refer to the claims and evidence cards as needed.

Why does deforestation lead to increased carbon dioxide in the air?

☐ **Claim 1:** There is *less photosynthesis*, so carbon dioxide increases in the air.

☐ **Claim 2:** There is *more cellular respiration*, so carbon dioxide increases in the air.

Name: _____ Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	Check marks
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is: _____ _____ _____ _____	

Name: _____

Date: _____

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, think back on the claim you selected at the beginning of the lesson. After participating in the discussion, you may have changed your mind about which claim you think is best supported. Show your current thinking by answering the questions below.

Why does deforestation lead to increased carbon dioxide in the air?

- ☐ **Claim 1:** There is *less photosynthesis*, so carbon dioxide increases in the air.
- ☐ **Claim 2:** There is *more cellular respiration*, so carbon dioxide increases in the air.

Did you change your thinking about the claims after participating in the Science Seminar? Explain your answer.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Lesson 4.3: Writing a Scientific Argument

What explains the increase in the amount of carbon dioxide in the air that happens after deforestation? Is it less photosynthesis or more cellular respiration? Student ecologists, it's time for you to write your scientific argument. Today, you'll review the evidence and use the Reasoning Tool to organize your thinking. Then, you'll get to make your case to the farmers about why deforestation leads to increased carbon dioxide. How convincing can you make your argument?

Unit Question

- How do all the organisms in an ecosystem get the resources they need to release energy?

Chapter 4 Question

- Why does deforestation lead to increased carbon dioxide in the air?

Key Concepts

- During the process of photosynthesis, producers make energy storage molecules, using carbon from carbon dioxide and energy from sunlight. This moves carbon from abiotic to biotic matter.
- If one part of a system changes, this affects the rest of the system.
- When there is *more* carbon (in the form of carbon dioxide) in abiotic matter, *more* carbon is available to producers for making energy storage molecules.
- As organisms release energy during cellular respiration, carbon dioxide is produced from the carbon in energy storage molecules. This process moves carbon from biotic to abiotic matter.
- Since carbon cannot be produced or used up, the total amount of carbon in a closed ecosystem does not change.
- If the amount of carbon increased in abiotic matter, then it also decreased in biotic matter. If the amount of carbon decreased in abiotic matter, then it also increased in biotic matter.

Vocabulary

- | | | |
|------------------------|----------------------------|-----------------------|
| • carbon | • consumer | • photosynthesis |
| • carbon dioxide | • decomposer | • producer |
| • cellular respiration | • ecosystem | • reasoning |
| • claim | • energy storage molecules | • scientific argument |
| • connect | • evidence | • system |

Warm-Up

Making a Convincing Argument

Yuki and Ahmed are students studying about matter, energy, and ecosystems at another school. Below are their arguments about the biodome problem. Read and compare the two arguments, and then answer the questions.

Yuki's argument	Ahmed's Argument
Energy storage molecules in producers and consumers decreased because the Econauts buried the dead matter in the biodome. Burying the dead matter caused the population of decomposers in the biodome to decrease. This caused energy storage molecules in producers and consumers to go down.	Energy storage molecules in producers and consumers decreased because the Econauts buried the dead matter in the biodome. Burying dead matter caused the population of decomposers in the biodome to decrease. This matters because decomposers give off carbon dioxide and producers need carbon dioxide to make energy storage molecules. After the decomposer population decreased, there wasn't as much carbon dioxide in the air, so the producers couldn't make as many energy storage molecules. This caused energy storage molecules in producers and consumers to go down.

Which argument is more convincing? (circle one)

Yuki's argument

Ahmed's argument

What makes one argument more convincing than the other?

Name: _____

Date: _____

Using the Reasoning Tool

After scientists state a claim, they connect evidence to the claim in the reasoning process. This makes their argument convincing.

Use the Reasoning Tool to explain how your evidence relates to the claim you think is most convincing. Follow the instructions below.

1. Record the claim that you think is best supported by the evidence (in the **Therefore**, column). If you prefer, you can also write and record your own claim.
2. Tape the evidence cards that support your claim to the Reasoning Tool (in the **Evidence** column). You do not need to use all the cards, but you can use more than one to support your claim.
3. Use the middle column (**This matters because . . .**) to record how the evidence in the left column connects to the claim in the right column.

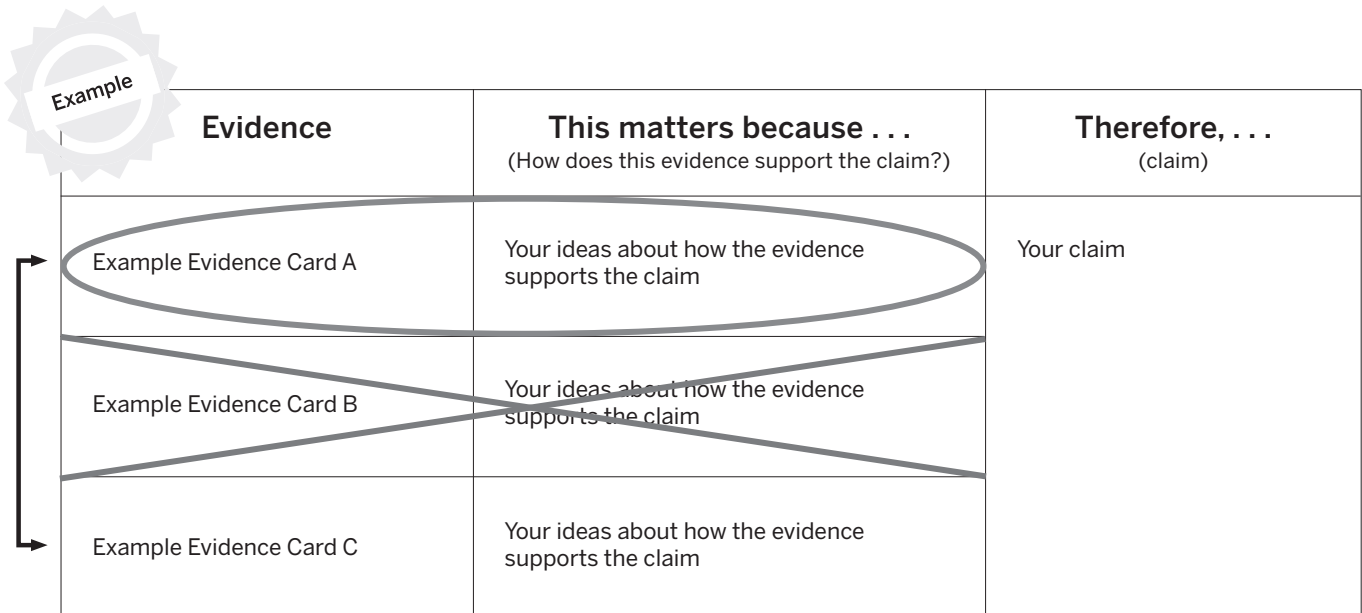
Evidence	This matters because . . . (How does this evidence support the claim)	Therefore, . . . (claim)

Preparing to Write

Using the Reasoning Tool to Support Your Claim

Plan how you will use your Reasoning Tool to write your argument. Use the example to guide you.

- Draw a circle around your strongest piece of evidence.
- Draw an X over a piece of evidence if you do not plan to use it in your argument.
- Draw an arrow to connect pieces of evidence that go together.



Evidence	This matters because . . . (How does this evidence support the claim?)	Therefore, . . . (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Writing a Scientific Argument

Write a scientific argument that addresses the question *Why does deforestation lead to increased carbon dioxide in the air?*

Claim 1: There is *less photosynthesis*, so carbon dioxide increases in the air.

Claim 2: There is *more cellular respiration*, so carbon dioxide increases in the air.

1. State your claim and explain how it could cause carbon dioxide to increase.
2. Then, use evidence to support your claim. For each piece of evidence, explain how the evidence supports your claim.
 - Review your Reasoning Tool. Include your strongest piece of evidence and make a connection between pieces of evidence that go together.
 - Use the Scientific Argument Sentence Starters to help you explain your thinking.

Scientific Argument Sentence Starters	
Describing evidence: The evidence that supports my claim is . . . My first piece of evidence is . . . Another piece of evidence is . . . This evidence shows that . . .	Describing how the evidence supports the claim: If _____, then . . . The change caused . . . The effect of this change was . . . This is important because . . . Since . . . Based on the evidence, I conclude that . . . This claim is stronger because . . .

Name: _____

Date: _____

Writing a Scientific Argument (continued)

[illegible]

Homework: Revising Your Argument

1. Reread the scientific argument you wrote in class.

2. Complete your argument, if needed.

3. Look for ways you could make your argument clearer or more convincing.

4. Consider reading your argument aloud or having another person read it.

5. Consider the following questions as you review your argument:

• Does your argument clearly explain how deforestation causes carbon dioxide to increase in the air?

• Do you describe your supporting evidence?

• Do you thoroughly explain how the evidence supports your claim?

6. Rewrite any sections of your argument that could be clearer or more convincing.
- _____

- Matter and Energy in Ecosystems—Lesson 4.3—Activity 5

© 2018 The Regents of the University of California. All rights reserved. Permission granted to photocopy for classroom use.

109

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

- 1. What are the most important things you have learned in this unit about how all the organisms in an ecosystem get the resources they need for energy?

- 2. What questions do you still have?

Matter and Energy in Ecosystems Glossary

abiotic matter: matter that makes up the nonliving parts of an ecosystem, such as air, water, and rocks

materia abiótica: materia que constituye las partes no vivientes de un ecosistema, como el aire, el agua y las rocas

atoms: the tiny pieces that all matter—all the stuff in the world—is made of

átomos: los pedacitos diminutos de los cuales toda la materia del mundo está hecha

biodome: a closed ecosystem made by humans

biodomo: un ecosistema cerrado hecho por humanos

biotic matter: matter that makes up the living and dead organisms in an ecosystem

materia biótica: materia que constituye los organismos vivos y muertos en un ecosistema

carbon: a type of atom (a tiny piece) that makes up molecules such as carbon dioxide and energy storage molecules

carbono: un tipo de átomo (un pedazo diminuto) que constituye moléculas como el dióxido de carbono y moléculas de almacenamiento de energía

carbon dioxide: a molecule made of carbon and oxygen atoms

dióxido de carbono: una molécula hecha de átomos de carbono y oxígeno

cellular respiration: the chemical reaction between oxygen and glucose that releases energy into cells

respiración celular: la reacción química entre oxígeno y glucosa que libera energía en las células

chloroplast: the part of a cell where photosynthesis happens

cloroplasto: la parte de una célula donde ocurre la fotosíntesis

connect: to link two or more things

conectar: unir o relacionar dos o más cosas

consumer: an organism that needs to eat in order to get energy storage molecules (such as starch and fat)

consumidor: un organismo que necesita comer para obtener moléculas de almacenamiento de energía (por ejemplo, almidón y grasa)

Matter and Energy in Ecosystems Glossary (continued)

decomposer: an organism that gets energy storage molecules (such as glucose) by breaking down dead matter

descomponedor: un organismo que consigue moléculas de almacenamiento de energía (por ejemplo, la glucosa) al desintegrar materia muerta

ecosystem: all the living and nonliving things interacting in a particular area

ecosistema: todos los seres vivos y no vivos que interactúan en un área específica

energy: the ability to make things move or change

energía: la capacidad de hacer que las cosas se muevan o cambien

energy storage molecule: a molecule that organisms can use to release the energy they need to survive

molécula de almacenamiento de energía: una molécula que los organismos pueden usar para liberar la energía que necesitan para sobrevivir

fat: a type of energy storage molecule

grasa: un tipo de molécula de almacenamiento de energía

glucose: a molecule that organisms can use to release energy, and that is made of carbon, hydrogen, and oxygen atoms

glucosa: una molécula que los organismos pueden usar para liberar energía y que está hecha de átomos de carbono, hidrógeno y oxígeno

glycogen: a type of energy storage molecule

glucógeno: un tipo de molécula de almacenamiento de energía

input: something that is required for a process

insumo: algo que se requiere para un proceso

mitochondrion: the part of a cell where cellular respiration happens

mitocondria: la parte de una célula donde ocurre la respiración celular

molecule: a group of atoms joined together in a particular way

molécula: un grupo de átomos unidos de una manera particular

organisms: living things, such as plants, animals, and bacteria

organismos: seres vivos, como plantas, animales y bacterias

Matter and Energy in Ecosystems Glossary (continued)

output: something that results from a process

egreso: algo que resulta de un proceso

photosynthesis: the process by which plants and other producers use energy from sunlight to change carbon dioxide and water into oxygen and glucose (an energy storage molecule)

fotosíntesis: el proceso por el cual las plantas y otros productores usan energía de la luz del sol para cambiar dióxido de carbono y agua en oxígeno y glucosa (una molécula de almacenamiento de energía)

producer: an organism that can make its own energy storage molecules (such as glucose)

productor: un organismo que puede hacer sus propias moléculas de almacenamiento de energía (por ejemplo, la glucosa)

product: an ending substance that is made during a chemical reaction

producto: una sustancia final que se crea durante una reacción química

reactant: a starting substance that is part of a chemical reaction

reactivo: una sustancia inicial que es parte de una reacción química

starch: a type of energy storage molecule made of many glucose molecules connected together

almidón: un tipo de molécula de almacenamiento de energía hecha de muchas moléculas de glucosa unidas

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

Lawrence Hall of Science:**Program Directors:** Jacqueline Barber and P. David Pearson**Curriculum Director, Grades K–1:** Alison K. Billman**Curriculum Director, Grades 2–5:** Jennifer Tilson**Curriculum Director, Grades 6–8:** Suzanna Loper**Assessment and Analytics Director:** Eric Greenwald**Learning Progressions and Coherence Lead:** Lauren Mayumi Brodsky**Operations and Project Director:** Cameron Kate Yahr**Student Apps Director:** Ari Krakowski**Student Content Director:** Ashley Chase**Leadership Team:** Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm***Matter and Energy in Ecosystems: Biodome Collapse Unit Team:***

Stacy Au-yang	Barbara Clinton	M. Lisette Lopez	Lauren Wielgus
Elizabeth Ball	Kristina M. Duncan	Deirdre MacMillan	Joshua A. Willis
Whitney Barlow	Jennifer B. Garfield	Amybeth O'Brien	
Candice Bradley	Brandon Hutchens	Patrice Scinta	
Benton Cheung	Nadja Lazansky	Claire Spafford	

Amplify:

Irene Chan	Charvi Magdaong	Matt Reed
Samuel Crane	Thomas Maher	Eve Silberman
Shira Kronzon	Rick Martin	Steven Zavari

Credits:

Illustration: Cover: Tory Novikova

Photographs: Page 6: Emily Riddell/First Light/Getty Images; Pages 16, 55, 93: Shutterstock; Page 42: David Marchal/E+/Getty Images; Page 58: Sebastian Kennerknecht/Minden Pictures/Getty Images; Page 61: NOAA PMEL EOI Program; Page 70: Holger Leue/Getty Images

Matter and Energy in Ecosystems:

Biodome Collapse

Table of Contents: Articles

Biodome Files	A1-A12
What Is Carbon?	B1-B2
Sunlight and Life	C1-C8
Where Did Chloroplasts Come From?	D1-D2
A Feast for Decomposers	E1-E9
The Mulberry Tree and the Silkworm	F1
How Did We Get Mitochondria?	G1-G2
Getting Energy in a Cave Ecosystem	H1-H2
Getting Energy in a Coastal Prairie Ecosystem	I1-I2
Getting Energy Near a Deep-Sea Vent	J1-J2
Glacier Mice: Living Arctic Tumbleweeds	K1-K2
Carbon in the Global Ecosystem	L1-L4



A biodome is a large glass dome with a human-made ecosystem inside.

Biodome File 1: News Stories

Group Builds Ecosystem from Scratch

The Econauts, a local group of space fans, have built a glass dome bigger than a football field. Inside, they have installed their very own ecosystem, complete with trees, plants, and animals. The dome is completely enclosed, but the plants and animals inside should have all the air and water they need to survive. This type of enclosed ecosystem is known as a biodome.

Members of the group plan to live sealed inside this biodome for several years. Their aim is to find out whether humans could build domes like this on the Moon, Mars, or other planets, creating livable spaces and food sources out in space.

The members of Econauts are not astronauts or scientists, just space fans who hope to live in space someday. Group members have varied backgrounds, including careers in business, advertising, gardening, medicine, and goat farming.

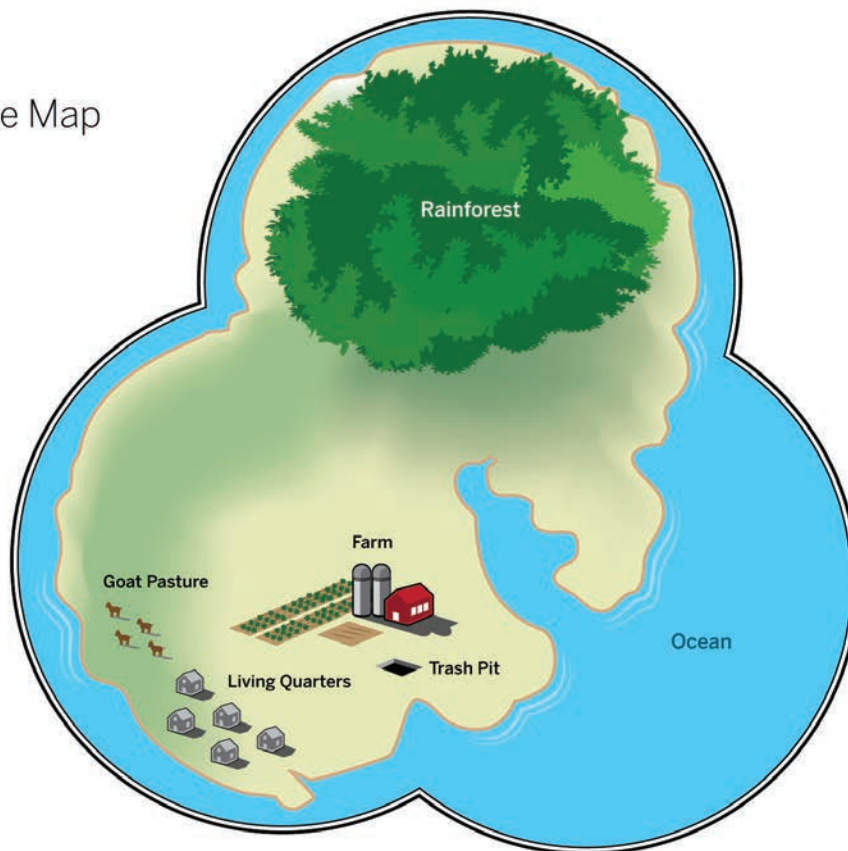
Other organizations have attempted to build biodomes in the past, with little long-term success. Ecosystems are complicated, and it's not so easy to create one that can survive in a sealed glass dome. In order to design their biodome, the Econauts group has hired expert ecologists to give their advice on what kinds of plants and animals to include, and how many of each. With the advice of these ecologists, the group members hope their constructed ecosystem will be self-sustaining, with plenty of plants for the animals to eat, plenty of sunlight and water for the plants, and plenty of air for both.

The human occupants will also be eating food farmed and raised in the biodome. Econaut Sarah Willard stated, “I’m really excited to live inside this biodome and help take care of the animals and plants. It will feel like being one of the first humans to live in a colony on another planet.”

Biodome Fails: Ecologists to Determine Why

Five years ago, a local group of space fans called the Econauts constructed an ecosystem sealed under glass—a biodome. Recently, the group noticed an ominous decrease in the populations of organisms: the ecosystem appeared to be in the process of collapsing. The occupants were safely removed from the biodome, but the cause of the crash is still a mystery. A group of expert ecologists has been hired to investigate the failed biodome and try to determine what went wrong. They will advise the Econaut group on how a second attempt could be improved.

Biodome Map



The failed biodome included an ocean and an area of land with a rain forest and a living area for the Econauts. The living area had a farm, living quarters, a goat pasture, and a pit for burying all trash and dead matter.

Biodome File 2:

Econaut Biographies & Job Descriptions

Each of the eight Econauts has been assigned a specific job based on his or her work and interests outside the biodome. They are expected to perform the requirements listed in the descriptions of their jobs, as well as record their activities at least once per season.

The Econauts



Water Maintenance:
Harrison Grant



Doctor : Ana Lopez



Goatherd: Sarah Willard



Hunter: Erica Li



Gardener: Jeff Anderson



Chef: Gabriel Gutierrez



Groundskeeper: Keith Yoo



Computer System
Operator: Celeste Parker

Why didn't
they include an
ecologist on the
team? Ecologists
understand how
ecosystems work

Each Econaut has a job to do in the biodome.

Econaut Biographies

Harrison Grant is a 26-year-old water technician from Phoenix, Arizona, who has taken responsibility for the Econauts' water system. He has loved space since he was a little boy and has thought a great deal about possible water systems for use in space, though he isn't a professional space scientist.

Erica Li is a 22-year-old college student from Kihei, Hawaii. She is working toward a career in advertising. Erica grew up hunting wild pigs with her family and getting oysters and crabs from the ocean. She learned about the biodome while taking astronomy classes in college, and she can't wait to bring her hunting and foraging skills into the dome.

Sarah Willard is a 29-year-old goat farmer from Wenatchee, Washington, and she'll be caring for the Econauts' herd of twenty goats. Sarah has been an amateur astronomer since she was a teenager, and she never expected that her goat-farming skills would help people learn how to live in space. She's looking forward to keeping the biodome goats happy and healthy.

Jeff Anderson is a 28-year-old gardener from Fort Collins, Colorado, who is responsible for growing all of the Econauts' food. Jeff became interested in space on an eighth-grade trip to the Kennedy Space Center in Florida, and has dreamed since then of contributing to the future of humans in space. He hopes his work in the biodome will help future generations learn to grow food if they settle on other planets.

Ana Lopez is a 52-year-old doctor from Greenville, South Carolina, who will provide medical care in the biodome. Ana is fascinated by the idea of living in space, and has studied the medical needs of people living in enclosed spaces so she is prepared to take great care of the Econauts during their project.

Keith Yoo is a 24-year-old banker from Pittsburgh, Pennsylvania, who will serve as the Econauts' groundskeeper. Keith has no experience with maintaining an ecosystem, but he's interested in the psychology of people living in confined spaces, so he's excited to offer his services to the team.

Gabriel Gutierrez is the Econauts' chef. He is 35 years old and comes from Oklahoma City, where he specializes in farm-to-table cooking. Gabriel works with a local university to study ways of introducing more natural food into the diets of people in space, and he is excited about the challenge of cooking good food from limited sources.

Celeste Parker is a 38-year-old computer network administrator from Minneapolis, Minnesota. She has dreamed of living in space since she was a girl, and hopes to buy a ticket for one of the first commercial flights in space. She will run all of the technology required for the Econauts' biodome.

Econaut Job Assignments

Gardener: Jeff Anderson

Pick fruits and vegetables and deliver them to the chef. Make sure all plants are receiving enough water. Plant new fruits and vegetables as necessary.

Groundskeeper: Keith Yoo

Maintain biodome buildings and grounds. Rake up dead leaves, place them in sealed garbage bags, and bury them at least 6 feet underground.

Computer Systems Operator: Celeste Parker

Make sure all computer equipment is working properly, and enter all biodome data for graphing.

Water Maintenance: Harrison Grant

Check and maintain the water system so there is enough water available to all organisms.

Chef: Gabriel Gutierrez

Prepare breakfast, lunch, and dinner for each of the residents. Make sure food provides what the Econauts' bodies need.

Hunter: Erica Li

Hunt rabbits with bow and arrow and deliver to chef. Search for fruits and edible plants in the forest area.

Goatherd: Sarah Willard

Care for goats, making sure they have plenty to eat and drink. Milk goats and deliver milk to chef.

Doctor: Ana Lopez

Provide basic medical care and regular checkups to all biodome residents.

Burial Duty: All (this job rotates monthly)

In order to keep the biodome looking orderly and full of life, we will bury any animals or plants that die. They will be placed in sealed garbage bags and buried at least 6 feet underground. We will bury all garbage as well.



The Econauts will take turns burying all dead matter, droppings, and garbage deep underground.

Biodome File 3: List of Recommended Organisms to Include in the Biodome

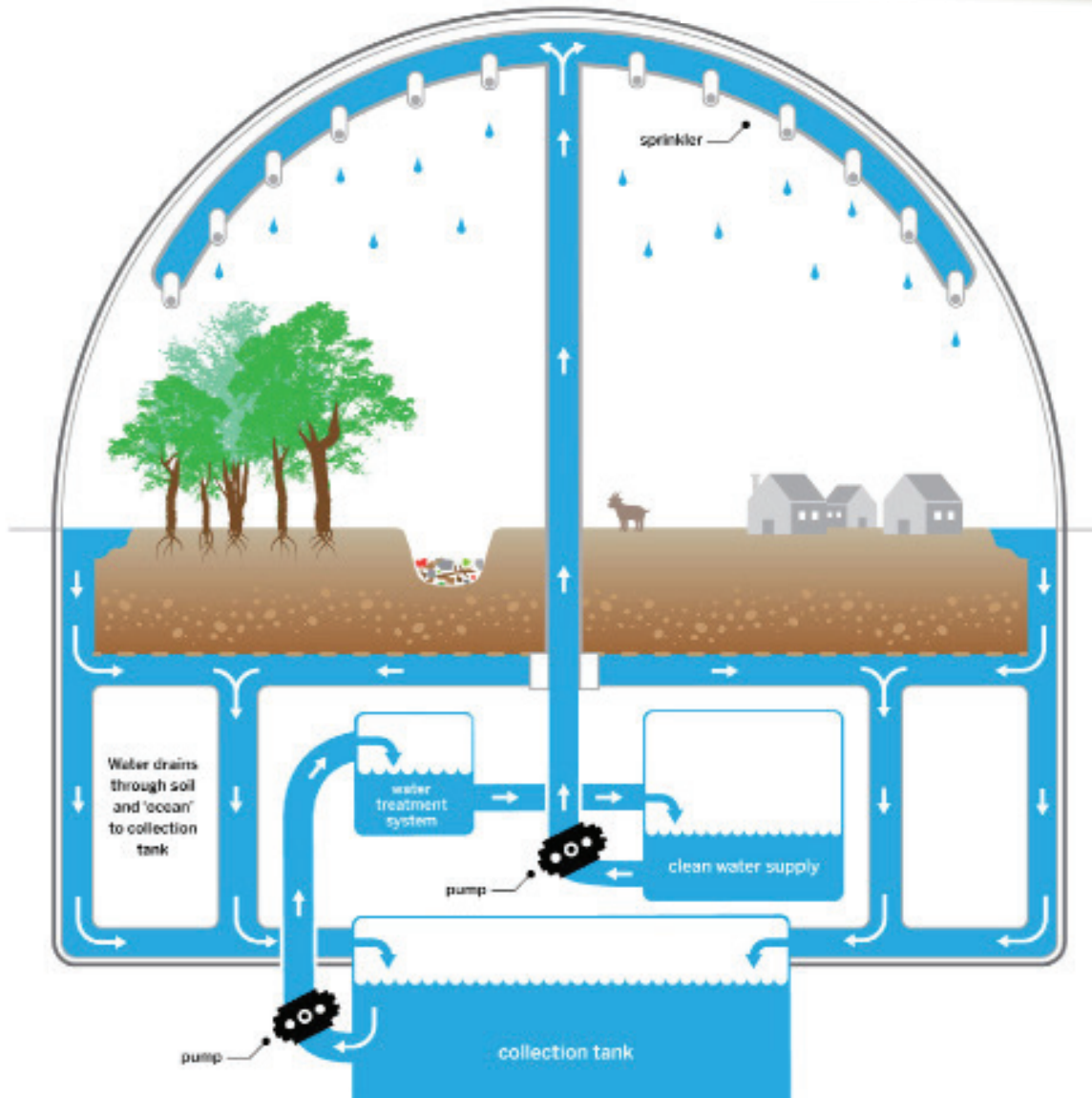
Producers	Primary Consumers	Secondary Consumers	Decomposers
bananas	pygmy goats	boars	worms
papayas	billy goats	tilapia (fish)	soil bacteria
sweet potatoes	chickens	spiders	soil fungus
beets	cockroaches	snakes	pill bugs
peanuts	ants	oysters	beetles
cowpea beans	bees	crabs	
rice	hummingbirds	reptiles	
wheat	bats	scorpions	
morning glories	moths		
phytoplankton (tiny algae)	zooplankton (tiny aquatic animals)		
rubber trees	butterflies		
mosses	termites		
ferns	turtles		
elodea (aquatic plant)	brine shrimp		
	rabbits		

I wonder why they decided not to include worms. Bacteria need worms to break dead matter into smaller pieces so bacteria can feed on it.

It's a good thing that they included producers for both land and water ecosystems.

Biodome File 4: Biodome Water System Diagram

Looks like the water system in the biodome was well designed. I can't see anything here that would cause the ecosystem to have problems.





Baby goats are so cute!

Biodome File 5: Goatherd's Journal

Year 1

Winter:

Today was the first day of my dream job: my first day herding goats in the Econauts' biodome! I'm so glad I got to join the team on this great adventure. I'm taking care of a herd of twenty adult goats between the ages of three and eight years. Most goats don't live longer than ten years, so I might lose a few before we leave the biodome. Still, I'm looking forward to what this experience holds for all of us.

Spring:

To keep our biodome environment neat and clean, the team is taking turns burying all trash, droppings, dead animals, and dead

plant matter. Guess whose turn it is this month? Mine! I've been raking up all the dead leaves and plants I can find, putting them into garbage bags, and tying the bags tightly before I bury them deep in the ground. At least there haven't been any dead animals this month! This isn't my favorite job here in the biodome, but I guess we all have to help out.

Summer:

Summer in the biodome is beautiful! The sun is shining, the birds are singing, and the goats are enjoying all the lush, green grass they can eat. Everybody seems happy and healthy.

Fall:

It's goat-breeding season here in the biodome. Fingers crossed that we'll have baby goats—we goatherds call them kids—in the spring! The vet came today for the goats' annual checkups, and said they're healthy.

Year 2

Winter:

The winter days are short and cold...and the winter nights are long and cold! There isn't much food available at this time of year, so I feed the goats hay from the alfalfa we grew last summer. At least they have thick winter coats to keep them warm. Four of our female goats are pregnant and should have their kids when spring comes! Until then, we just have to bundle up and try not to freeze.

Spring:

Our kids were born last week, and they sure are cute! The kids are eating well and growing quickly. It's such a wonder to watch these new little goats every day. My job is the best!

Summer:

It's my turn to bury our dead matter again. Burying our dead matter is never my favorite job, but it's especially tough this month because one of my older goats died last week. I sealed the body in a plastic bag and buried it along with all the dead leaves and plants, droppings, and trash. At least we have kids to help keep our goat population up. Otherwise, everybody in the biodome seems to be doing well.

Fall:

It's breeding season again! The vet visited for the goats' yearly checkup and said they're in good health. Looks like we're in for another good year in the biodome.



The goats are getting a nice, healthy diet of grass here in the biodome.

Year 3

Winter:

Winter again, and one of the goats died. I'm not sure what happened—she wasn't very old, and she didn't seem sick. I'm sad to have lost one of the herd. Otherwise, we're all doing pretty well and are trying to stay warm until spring.

Spring:

I love spring! The warm weather is much more comfortable, and it's good for the goats to have some fresh grass to eat. Two of my goats had kids this year. They're so cute, and I'm glad we have kids, since we lost a couple of older goats in the last year. It's my turn to bury dead matter again. It's a dirty job, but I think I'm getting used to it.

Summer:

I can't figure out why, but it seems like we've harvested less alfalfa this summer than we did in the past. That means there's less for the goats to eat now, and they'll have less hay for the winter. Nobody's sure why, since we're getting plenty of sunlight in the biodome. I guess I'll have to start feeding the goats a bit less, so we don't run out.

Fall:

Time for the goats' yearly checkup. The vet said the goats don't have any diseases, but they're looking a bit thin. I guess we're seeing the effects of this summer's alfalfa shortage. I'm not sure what to do: I don't want to use up too much hay, but I want to make sure the goats have enough to eat. Anyway, it's breeding season again. Hoping for some kids in the spring!



The goats love the alfalfa we harvested last summer!

Year 4

Winter:

I'm starting to get worried. Two of my goats died this winter, and I'm not sure why. The rest of the goats look a little thin, but they eat everything in sight, and they don't have any diseases. I think we have enough hay to get us through the winter. Maybe everything will get better once the goats can eat some fresh spring grass.

Spring:

None of the goats had kids this spring. I'm so disappointed. Kid goats are so much fun, and I like to think the herd is doing well. It's my turn to gather and bury dead matter again; I raked up a lot of leaves and droppings, but at least there weren't any dead animals to bury. Looking forward to a good summer harvest for the goats.

Summer:

This year's alfalfa harvest is even smaller than last year's. I'm worried about how we're going to feed the goats enough this summer and still have enough alfalfa to make hay for the winter.

Fall:

It's breeding season again, and time for our yearly visit from the vet. She said the goats don't show any signs of disease, but that they are looking very thin. This seems to be a problem with many of the animals in the biodome: they are all getting thinner. I don't know what to do; the alfalfa crop is still producing less than in the first few years of the biodome project.

Year 5

Winter:

Three more goats died this winter. I was sad to lose them, and I'm confused about what's happening to the goats. I know they're not sick, but why aren't they really healthy? Should I be doing something different? Something has to change soon.

Spring:

Another spring with no kids born. We now have fewer goats than we started with, even though six kids were born in the early years of the biodome. I don't like to see the herd getting smaller. It's my turn to gather and bury dead matter again.

Summer:

This summer's alfalfa harvest was the smallest yet. I'm not sure what the goats are going to eat this winter. They're already too thin.

Fall:

We've all been removed from the biodome. It turns out all of the populations had started to decrease, and it wasn't safe for us to stay. The vet couldn't find any signs of disease, though. I wonder what happened. I'm so sad that we won't be able to complete our mission.



I don't know why our goats are looking so thin—it's scary.



All of these things contain carbon.

What Is Carbon?

What's in diamonds, steel, plastic, plants, and animals—including you? It's carbon! Carbon is a type of atom, and it's all around you.

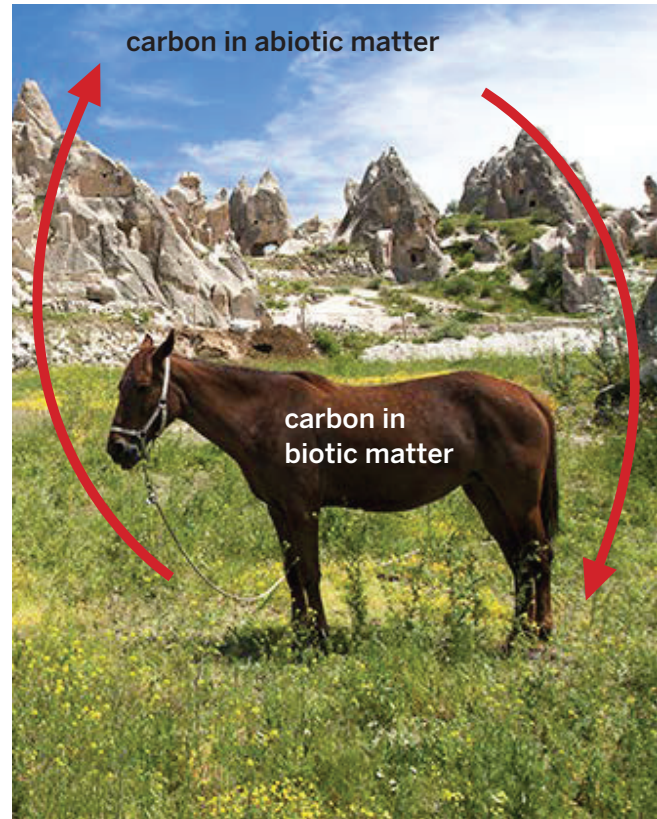
Carbon is essential to life on Earth. All biotic matter—the matter that makes up living things—has carbon in it. Along with nitrogen and oxygen, carbon is one of the most important atoms that make up biotic matter. There are carbon atoms in energy storage molecules like glucose, starch, and fats, as well as in proteins, DNA, and most of the other types of molecules that living things need to survive. Whenever you eat, part of what you're eating is made up of carbon. Carbon helps make up the bodies of animals, plants, bacteria, and all other living things. Carbon is even found in the dead remains of living things, which are another type of biotic matter.

Carbon isn't only found in biotic matter, though. If you've ever used a pencil, you've seen and touched pure carbon—it's the black stuff that makes up the tip that you use to write. People often call this part of a pencil the "lead," but it is actually a substance called graphite, which is made up entirely of carbon atoms. Although the tip of a pencil may break when you use it, pure carbon can also form one of the hardest substances found on Earth: diamond. In addition to graphite and diamonds, carbon is found in many other kinds of abiotic matter, like steel and plastic.

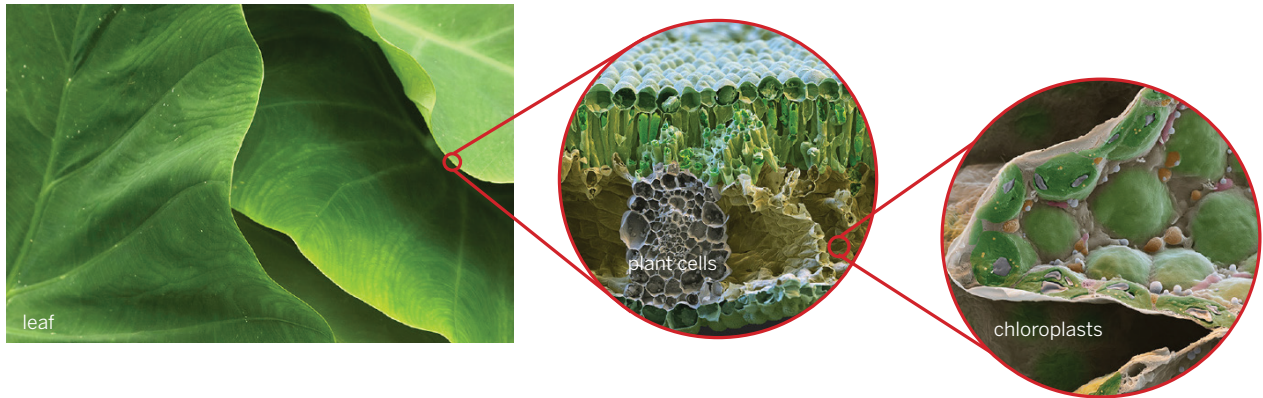
You can see carbon in the form of a pencil or a diamond, but in other forms, carbon is actually invisible. The air all around you contains an invisible gas called carbon dioxide, which—you

guessed it—is partly made up of carbon. You add carbon dioxide gas to the air with every breath you take. Whenever you breathe out, you give off carbon in the form of carbon dioxide. This carbon dioxide becomes part of the abiotic matter of Earth's atmosphere.

Why is carbon found in so many different kinds of matter, both biotic and abiotic? It's because carbon atoms are good at joining with each other and with other types of atoms to form molecules. That ability to join with other atoms allows carbon to make up many different types of things, from diamonds to invisible gases to living things like you.



Carbon can be found in many different kinds of matter, both biotic (living) and abiotic (nonliving).



Photosynthesis happens in cell parts called chloroplasts.

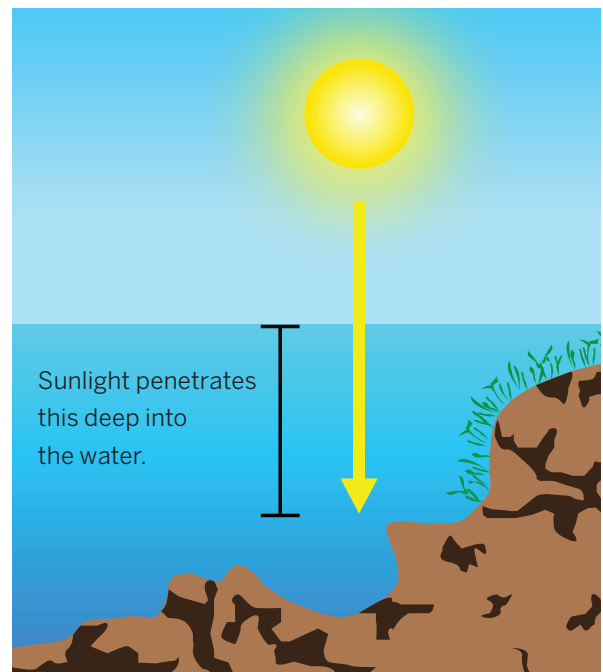
Sunlight and Life

Chapter 1: Introduction

The edge of a big lake is full of life. Fish dart through the bright green reeds, ducks dive for algae growing in the shallow mud, and insects buzz everywhere. However, if you go out to the middle of the lake and dive to the bottom, you'll find a dead zone—a dark and barren area with hardly any organisms: no fish, no plants, not much of anything.

Why do some areas support so much life, while others are relatively lifeless? To survive, organisms need energy—and this energy comes from energy storage molecules. These molecules store energy that can be released in an organism's body. Energy storage molecules include glucose, starch, and fat. Ecosystems with lots of organisms need to have lots of energy storage molecules to keep all those organisms alive. Some ecosystems contain lots of energy storage molecules, while others don't contain as many.

Only producers (such as plants) can make the energy storage molecules that fuel life in an ecosystem. Energy storage molecules are made mostly of carbon, and carbon is all around us in the form of carbon dioxide gas.



In deep lakes, there are many more organisms living in the shallow water where light can penetrate. In the deepest, darkest waters of a lake, not much life exists.

Producers take in carbon dioxide molecules from the air and water. Using energy from sunlight, producers combine the carbon dioxide molecules with water molecules, changing them into glucose molecules and oxygen molecules. This process is called photosynthesis. Through photosynthesis, producers take carbon from abiotic matter and move it into biotic matter in the form of glucose. Then the organisms in an ecosystem can use that glucose to make other energy storage molecules, like starch and fat.

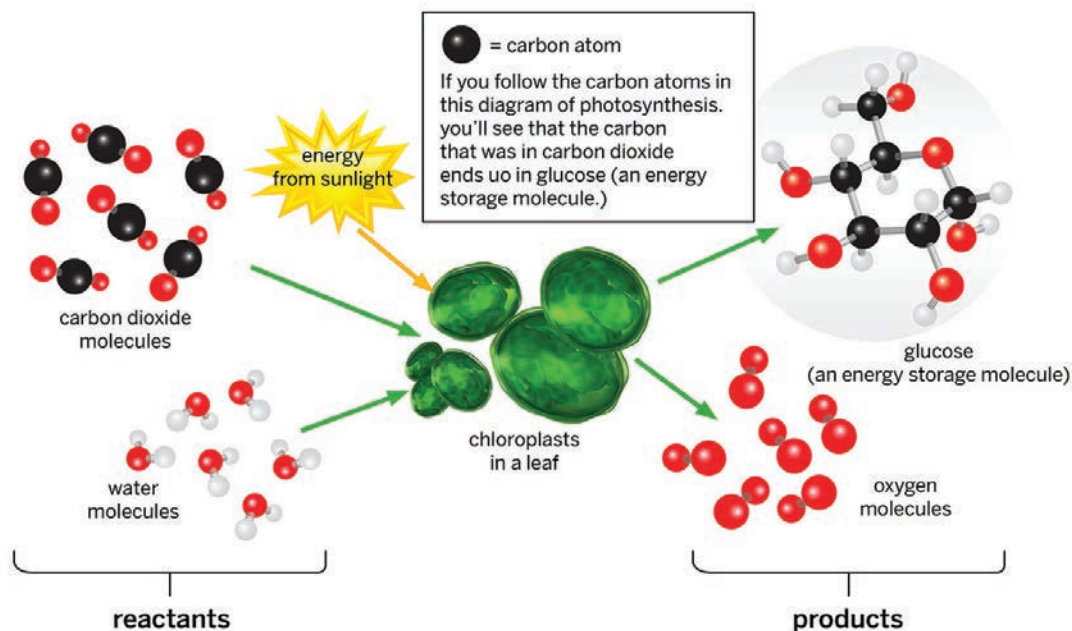
The process of photosynthesis takes place in tiny cell parts called chloroplasts. Only producers have them, so only producers can do photosynthesis. In order to get the energy to do photosynthesis, producers need sunlight.

Sunlight is one reason some ecosystems have so many more energy storage molecules—and so much more life—than others. With more sunlight, producers like plants and algae can do

more photosynthesis. They take more carbon out of the atmosphere and turn it into more energy storage molecules to meet their energy needs. As producers make more energy storage molecules, consumers—the animals that eat the producers—get more energy storage molecules from eating the producers. Those consumers use energy from the energy storage molecules to survive and reproduce, increasing in number. Then secondary consumers—the ones that eat animals—are able to get more energy storage molecules from eating the primary consumers that ate the plants. An ecosystem that gets lots of sunlight can support lots of organisms, while an ecosystem that gets less sunlight can support fewer organisms.

To find out about other ecosystems where the amount of sunlight has a big effect on the amount of living things, read one of the chapters that follow.

Photosynthesis



Using energy from sunlight, carbon dioxide and water react to form glucose (an energy storage molecule) and oxygen. During this reaction, atoms are rearranged.



During winter, the Arctic is dark almost 24 hours a day.

Chapter 2: Arctic Seasons

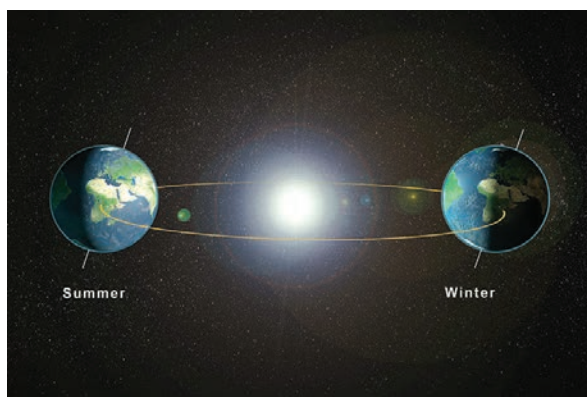
The Arctic is the area near Earth's North Pole. If you visit the Arctic in winter, you'll see a dark, wind-swept landscape, with no plants visible and a few hardy animals searching for food in the snow. If you visit the same spot in summer, it's completely transformed. Low plants bloom everywhere. Big herds of grazing animals feast on the plants, and wolves lurk around the edges of the herds, hoping to feast themselves. The air is alive with insects and birds.

What causes this transformation? Because of the way Earth tilts in its orbit around the sun, the North Pole points toward the sun in summer and away from the sun in winter. This means that the North Pole is in darkness 24 hours a day during the winter: for months, the sun is never seen. However, during the summer, the North Pole is in sunlight 24 hours a day: for months, the sun never sets.

All that sunlight fuels a boom in photosynthesis. Plants and other producers take in water from melted snow and carbon dioxide from the air. Using energy from sunlight, they transform the water and carbon dioxide into oxygen and



During summer, the sun shines on the Arctic almost 24 hours a day.



Because of the way Earth tilts, the Arctic is pointed toward the sun in the summer and away from the sun in the winter.

glucose, a type of energy storage molecule. This transformation happens through the process of photosynthesis. Because the sun never sets in the summer, Arctic plants can photosynthesize 24 hours a day, constantly producing energy storage molecules that are stored in their bodies, available for animals to eat.

The plant-eating animals that live in the Arctic time their reproduction so their offspring are born at just the right time to take advantage of this bounty of plants (and energy storage molecules). As the animals digest the plants, they use the carbon in glucose to make other energy storage molecules, like fat, which can be stored for times when there is less food. Arctic predators also time their reproduction to the season, having offspring just when lots of food is available for them in the form of other young animals. Reproduction leads to a population boom for the year-round residents of the Arctic. However, that's not the only reason there are more animals in the Arctic in summer: birds and many other animals migrate to the Arctic in summer to feast and reproduce. When summer ends, they go away again to sunnier areas.

As summer ends and the sunlight dies away, the plants stop photosynthesizing and lie dormant. Many plants survive the winter as seeds. Only a few animals remain. Some hide themselves away and hibernate through the long winter—not eating at all and using as little energy as possible. Darkness descends, and the Arctic once more becomes a relatively lifeless winter landscape.



Plenty of sunlight allows mosses and other plants to grow in the Arctic summer.



In the summer, caribou eat the grasses and mosses found in the Arctic.



Arctic foxes have to scrounge for food during winter.



Coral reefs thrive in places where sunlight can shine through shallow, clear water.

Chapter 3: Coral Reefs and Clear Water

Coral reefs form in clear, shallow water with lots of sunlight. Reefs may look like they are made of rock, but they're not—reefs are living structures made up of millions of tiny animals called coral polyps. Their hard skeletons stick together to form reefs that may be up to 2,300 kilometers (1,429 miles) long! What's even more amazing about coral reefs is the huge number of different organisms that make their homes in them: fish, sea stars, urchins, shrimp, sponges, crabs, sharks, and more.

Coral reefs depend on sunlight. Why? Coral polyps are animals, not plants—they can't do photosynthesis. However, inside each tiny polyp are even tinier algae made of just one cell each. These algae are producers, and it's their ability to do photosynthesis that gives life to the reef ecosystem.

As sunlight filters through the clear, shallow water, the algae perform photosynthesis. There is carbon dioxide dissolved in ocean water, and the algae take in carbon dioxide along with water. Using energy from sunlight, the algae change the



In this close-up photo of coral polyps, you can see the tiny green algae living inside them!



Parrotfish eat coral polyps. If you dive near a reef, you can hear parrotfish munching on the coral.

water and carbon dioxide molecules into oxygen molecules and glucose, a type of energy storage molecule. The energy storage molecules are stored in the bodies of the algae. Because the algae live inside the coral polyps, the polyps are able to use some of the energy storage molecules produced by the algae for their own energy needs.

With a constant supply of energy storage molecules, the coral polyps grow and reproduce, forming huge reefs. Many types of fish eat coral polyps, getting the energy storage molecules they need. Sharks and other large fish prey on the smaller fish that eat coral. With plenty of sunlight, one coral reef can support a huge community of organisms.

Since reefs depend on sunlight, they also depend on clear water that the sunlight can penetrate. If the water above a coral reef becomes too muddy or polluted, the whole reef ecosystem is threatened. Muddy water blocks sunlight, preventing it from reaching the coral reef. Without sunlight, the algae inside the coral polyps can't photosynthesize. The algae run out of energy storage molecules, and they quickly die. Without access to the energy storage molecules from the algae, the coral polyps soon die as well. The fish and other animals that depended on the coral die off or swim away to find other food. A coral reef without access to sunlight becomes a skeletal reef—it can't support the life it did before. Sunlight truly is life to a coral reef.



With sunlight and clear water, healthy coral reefs provide homes for many different species of organisms.



Muddy water blocked the sunlight and killed this coral reef. Most of the animals that lived there either died off or left in search of food.



This scientist is collecting insects from the rain forest canopy. The canopy gets plenty of sunlight, which helps it support many different species.

Chapter 4: Light Shafts on the Rain Forest Floor

We usually think of rain forests as being full of life, and the treetops definitely are. The leafy branches of tall rain forest trees are known as the canopy, and this is where most organisms in the rain forest are found. Colorful birds fly back and forth, eating fruit or insects, mating, and nesting. Rain forest plants take root up in the treetops, growing on high tree branches. Each branch of a rain forest tree is like a garden, with dozens of different kinds of plants growing on it and insects and other small organisms everywhere.

The vibrant life of the rain forest canopy is powered by sunlight. Rain forest trees and the smaller plants growing on their branches use the energy from sunlight to perform photosynthesis: they take in carbon dioxide from the atmosphere and water from all the rain that falls. Through the process of photosynthesis, the trees and plants change the carbon dioxide and water into oxygen and a type of energy storage molecule called glucose. These energy storage molecules are stored in the bodies of the trees and plants and become



A toucan eats fruit in the sunny rain forest canopy.

available for insects, birds, and other animals to eat. Because so many energy storage molecules are available, huge numbers of organisms can meet their energy needs in the rain forest canopy.

The rain forest floor, on the other hand, is dark and shady—a very different place from the canopy. Leaves block most of the sunlight on its way down. In fact, only about 2% of the sunlight that hits the rain forest penetrates down all the way to the ground. Because there is so little sunlight on the rain forest floor, plants at that level can't photosynthesize very well. There are relatively few plants growing on the rain forest floor, which means that there is not a lot of photosynthesis going on and few energy storage molecules available for animals to eat. The lack of sunlight means that the rain forest floor cannot support as much life as the rain forest canopy.

However, when a huge tree falls, all that changes. A falling tree rips a big hole in the rain forest canopy, letting a shaft of sunlight hit the forest floor. As sunlight warms the ground, seeds that may have been lying there for years begin to sprout. In the shaft of sunlight, plants and young trees start growing. With access to sunlight, these plants can photosynthesize, changing carbon dioxide and water into oxygen and energy storage molecules. The plants store the energy storage molecules in their bodies, where they become available for animals to eat. The shaft of sunlight brings life to the rain forest floor, at least for a while. Eventually, the young trees will grow tall and block the sunlight once more.



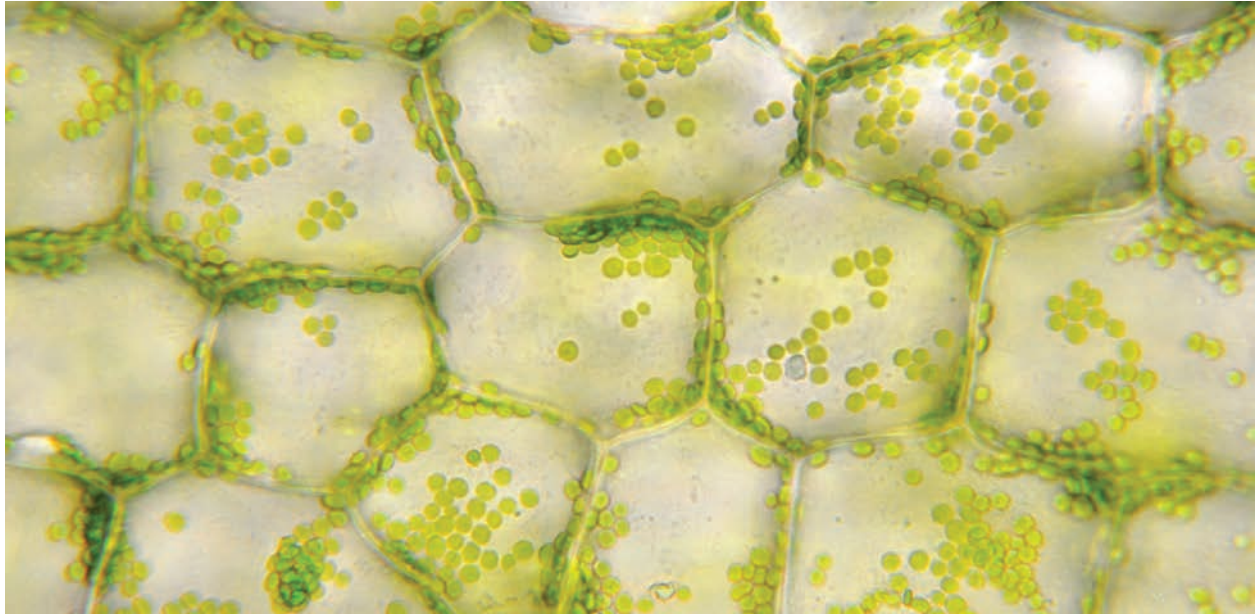
Green basilisk lizards live in rain forest trees near lakes and ponds. When in danger, they can jump down and run over the surface of the water to escape!



The rain forest floor gets little sunlight, preventing many plants from growing there.



When a big tree falls in the rain forest, it makes a hole in the canopy. Light streams down, and lots of plants grow in the shaft of sunlight.

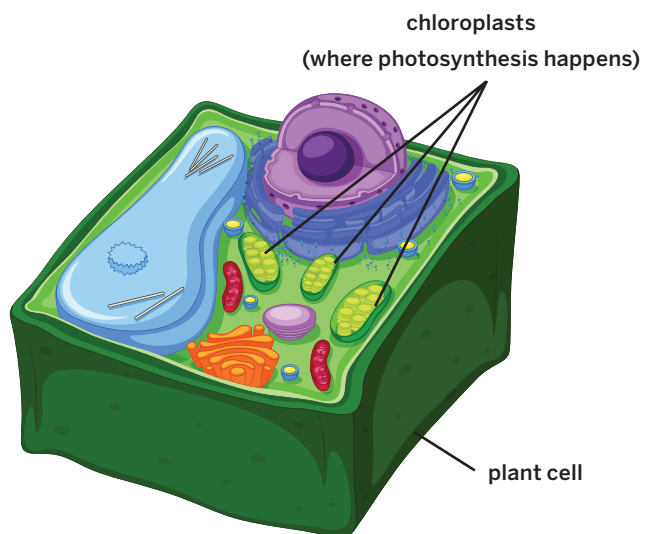


This photo shows plant cells under a microscope. The little green spots inside the cells are chloroplasts.

Where Did Chloroplasts Come From?

Why can a plant make its own food through photosynthesis, and you can't? It's because a plant's cells have something your cells don't have. The things you're missing are chloroplasts. If you look at plant or algae cells under a microscope, you can see lots of tiny round, green spots inside each cell. Those spots are the chloroplasts. When you look at a green leaf, you are really seeing the color of the chloroplasts inside the cells that make up the leaf.

Chloroplasts are a kind of organelle—that's the term for special cell parts that perform important functions for a cell. Chloroplasts are extremely important organelles for plants and algae, because the chloroplasts are where photosynthesis takes place. Inside each chloroplast, water and carbon dioxide molecules are changed in a chemical reaction, forming



This diagram shows organelles in a plant cell. Like your cells, a plant cell has a nucleus, mitochondria, and a cell membrane. However, unlike your cells, the plant cell has chloroplasts.

oxygen and glucose molecules, which the plant cell can use as food. The photosynthesis reaction is powered by energy from sunlight, and it's the basis of nearly every ecosystem on Earth.

Where did chloroplasts come from? Here's the amazing thing: more than a billion years ago, these cell parts were independent bacteria. These ancient bacteria were similar in many ways to cyanobacteria (sigh-AN-oh-bac-teer-ee-ah), which are a type of bacteria still alive today. If you've ever seen pond scum (the green goop that often grows at the surface of small ponds), you've seen cyanobacteria. Cyanobacteria are bacteria that can perform photosynthesis, and so were the ancient bacteria that gave rise to chloroplasts.

At the time, all life on Earth was in the form of bacteria and other single-celled organisms (known as microorganisms). Some ancient bacteria were able to perform photosynthesis,

while many other microorganisms around them could not. Somehow (there are a few different theories about how this happened), some ancient photosynthetic bacteria were absorbed by other, larger microorganisms. The bacteria became parts of the larger microorganisms—they became the organelles we call chloroplasts. Once the larger microorganisms contained chloroplasts, they gained the ability to perform photosynthesis.

Today, chloroplasts are organelles in plant cells, but they still have their own DNA, which is different from the DNA in the nucleus of the cell. If a plant cell somehow loses its chloroplasts, the cell can't make more: only a chloroplast can make another chloroplast. Based on this, scientists have figured out that chloroplasts were independent microorganisms before they became part of plant cells. It's amazing but true!



This microscope photo shows groups of cyanobacteria. These bacteria can perform photosynthesis, and they are probably similar to the ancient microorganisms that gave rise to chloroplasts.



Decomposers break down dead animals and plants.

A Feast for Decomposers

Chapter 1: Introduction

Imagine you're invited to a feast. When you get there, your host serves you droppings, dry brown leaves, bare bones, feathers, and a fallen tree. But you can't eat that! This is a feast for decomposers, not for humans. Decomposers are fungi, bacteria, worms, and other small organisms that specialize in breaking down dead matter.

Decomposers can break down things that nothing else can. Bones, droppings, and other dead matter may not seem like food, but they contain materials that decomposers can use for energy and growth. For example, dead matter contains energy storage molecules that many decomposers use for cellular

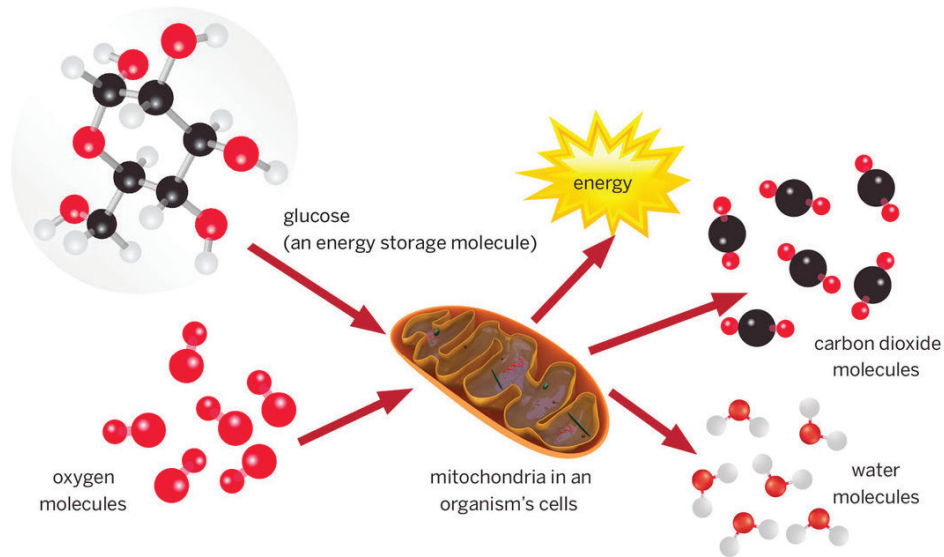


Droppings may not seem like food, but to decomposers, they make a good meal.



Decomposers can break down something as large as a fallen tree.

Cellular Respiration



In cell parts called the mitochondria, glucose (an energy storage molecule) plus oxygen combine to make carbon dioxide plus water, releasing energy. This process is called cellular respiration.

respiration. Cellular respiration is a process that many organisms, including humans, use to release energy in order to survive. During cellular respiration, oxygen and energy storage molecules combine, releasing energy and giving off carbon dioxide. Energy storage molecules contain carbon, an important component of living things. Through cellular respiration, decomposers are able to release carbon found in dead matter, making it available to the ecosystem. Without decomposers, this carbon would stay trapped in the dead matter. Decomposers don't just release carbon from dead matter, they also make other materials available to an ecosystem, such as nitrogen. Nitrogen is a critical nutrient for plant growth. Decomposers may be small, but they play an important role in any ecosystem. To learn more about decomposers, read one or more of the chapters that follow.

Chapter 2: Wonderful Worms

Earthworms are an essential part of soil ecosystems, and one of the major decomposers on Earth. If you looked out at a field of cows, the worms living in the soil under the field might weigh more than all the cows combined! Without worms (and their poop, called “casts”), we would not have the rich, fertile soil needed to grow the food we eat.

Worms take large pieces of things like dead leaves, manure, and even cardboard, pull them below the surface of the soil, shred them, and digest them until they are small enough for bacteria to consume. Worms use the energy storage molecules in dead matter and oxygen they take in through their skin to perform cellular respiration, releasing energy and giving off carbon dioxide. The worms’ shredded and partially digested food mixes with the soil, and all the nutrients contained in the dead matter become available for new plants to use. Worms also digest soil and turn it into nutrient-rich casts, which help plants grow. One earthworm can produce about 10 pounds of casts in one year. That’s a lot of poop!



Worms are decomposers that live in the soil.



This cutaway view shows worms beneath the surface of the soil. One worm is dragging a dead leaf underground. The worm will partially digest the leaf, leaving pieces small enough for bacteria to consume.



Termites are one kind of insect that can break down dead matter. Termites break wood down into small pieces. Then smaller decomposers, like bacteria, can break it down even more.

Chapter 3: Insects Break the Big Stuff Down

When an organism dies, many different types of decomposers feed on it. However, not all of the decomposers show up at the same time. Different decomposers have different jobs and eat different types of dead matter. The first decomposers on the scene are usually insects.

Insects are responsible for the first round of decomposition because they make matter more accessible to other decomposers. Decomposing insects eat all kinds of dead matter: dead plants, animal carcasses, and animal droppings. They use the energy storage molecules in the dead matter to release energy during cellular respiration. As they eat, they shred dead matter into smaller pieces, allowing tiny decomposers like bacteria to break the dead matter down even more. In some cases, bugs also give other decomposers access to places they couldn't have gotten to otherwise. For example, insects that eat dead plants leave tunnels behind them, giving other decomposers

a way of getting to parts of the plant matter—like the insides of fallen tree trunks—that would have been closed off otherwise.

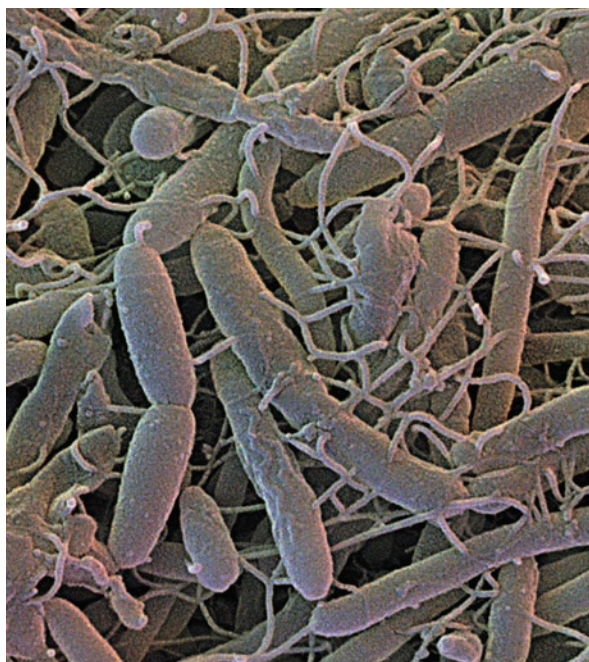
Different insects have different roles to play in breaking down dead matter, and different insects arrive on dead organisms at different times. In fact, the timing of each insect appearing after the death of an organism is so predictable that scientists use the presence of certain insects to tell them how long an organism has been dead.

Chapter 4: Soil Bacteria by the Billions

In addition to the decomposers we can see, there are even more that are too small to see. Many billions of tiny bacteria live in the soil. These microscopic decomposers work all the time to break down dead matter.

After worms and other bigger decomposers have broken dead matter down into smaller pieces, soil bacteria break down the dead matter even further. These bacteria are able to get at the energy storage molecules remaining in the dead matter, using those molecules to release energy. Many kinds of bacteria perform cellular respiration, taking the carbon trapped in dead matter and putting it back into the ecosystem as carbon dioxide.

There are many thousands of species of soil bacteria. Some are very sensitive to changes in temperature and chemical composition of soil, while others are very hardy and can handle severe heat and cold. Some can even lie dormant for many years, waiting for just the right conditions. No matter what, you can be sure that healthy soil will contain many bacteria—as many as a billion per teaspoon!



Soil bacteria can't be seen by the naked eye, but they can be seen under a microscope. This image of soil bacteria has been magnified 17,000 times larger than their actual size.



This image has been magnified 9,700 times. It shows a tiny root hair from a plant, covered with even smaller bacteria.

Chapter 5: Surprising Soil Fungus

You may think you've never seen soil fungus, but you have. Fungus is hidden everywhere in the soil, and sometimes it grows upward to form mushrooms in all colors and shapes.

Mushrooms and other soil fungi are not plants—they are decomposers. Soil fungus is good at decomposing tough dead matter, like dead leaves and pieces of wood, and getting the energy storage molecules that were trapped inside. Through the process of cellular respiration, the fungus uses these energy storage molecules for energy, releasing carbon dioxide into the air.

Soil fungi are not plants, but they are often helpful to plants. Some fungi in the soil help protect the roots of plants. They grow around roots, helping the plant get nutrients from a larger area of the soil and hiding the roots from pests.



We can see soil fungus when it forms mushrooms that pop up from the ground.



Underground, soil fungus spreads out in all directions. It's everywhere!



Different types of soil fungus form mushrooms in many different sizes, shapes, and colors.



Some fungi break down wood. You may find them growing on dead trees and fallen logs.

Chapter 6: Fungi That Feast on Wood

Take a walk in the forest, and you will notice all sorts of wonderful shapes growing on dead tree trunks, fallen logs, and piles of decomposing leaves. Some look a lot like the mushrooms you eat, and some look like orange fans or black bubbles. These are wood-decay fungi, which help decompose things like fallen branches and even whole trees. Like other kinds of fungi, they take the energy storage molecules trapped in dead matter and use them to get energy through cellular respiration. In the process, they give off carbon dioxide.

Wood-decay fungi are the only organisms that have evolved to decompose lignin, a substance found in wood. Also, fungi can get deep into the wood to help break it down (unlike bacteria, which just decompose on the surface). For these two reasons, fungi are the main decomposers in forest ecosystems, where there are lots of large pieces of wood to break down. Next time you are walking past some trees, check to see if there's any fungus nearby!

Chapter 7: Mold Makes Fuzzy Fruit

You know what happens when you leave a peach in the fruit bowl too long—it grows blue and white fuzz and eventually you throw it out. But what about when a peach falls off a tree and there's no one around to eat it (or forget to eat it)? It still grows that blue and white fuzz, called “mold.” Mold is a kind of fungus that helps decompose things like fruit and bread, using the energy storage molecules trapped inside to get energy through the process of cellular respiration.

When a peach falls to the ground, mold grows quickly, breaking the fruit down. This allows the fruit to provide nutrients for other organisms in the soil, which break it down further into nutrients for new plants to use. The peach pit might even sprout into a little tree, which will grow in the nutrient-rich soil provided by the decomposers—and use the carbon dioxide they give off during cellular respiration.



Fruit decomposes when it falls on the ground.



This strawberry has fuzzy white mold growing on it. Mold is a kind of decomposer.



Seen through a microscope, mold looks very different.



These are the bones of a dead whale on the ocean floor. Aquatic bacteria and other decomposers break down the bones over many years.

Chapter 8: Aquatic Bacteria Bonanza

Imagine the magnificent blue whale, largest animal on Earth. Blue whales live a long time, but eventually they die. What happens to those 181,000 kilograms (400,000 pounds) of whale flesh? The ocean doesn't just get filled with rotting whales and fish. That's because decomposers step in and help break down their bodies.

Aquatic bacteria are one of the many kinds of decomposers that help break down the body of a whale that dies in the ocean. After sharks and other fish eat the large chunks of flesh, and smaller animals like marine worms eat the bits of meat that are left over, bacteria begin to feed off the fat left in the whale's bones. These bacteria use the energy storage molecules in the whale's body to release energy. The bacteria also provide nourishment for clams, sea snails, and other animals. This can go on for decades, with the carcass of one whale providing decomposers with food for 80 years!



Silkworms get energy storage molecules by eating leaves from mulberry trees.

The Mulberry Tree and the Silkworm

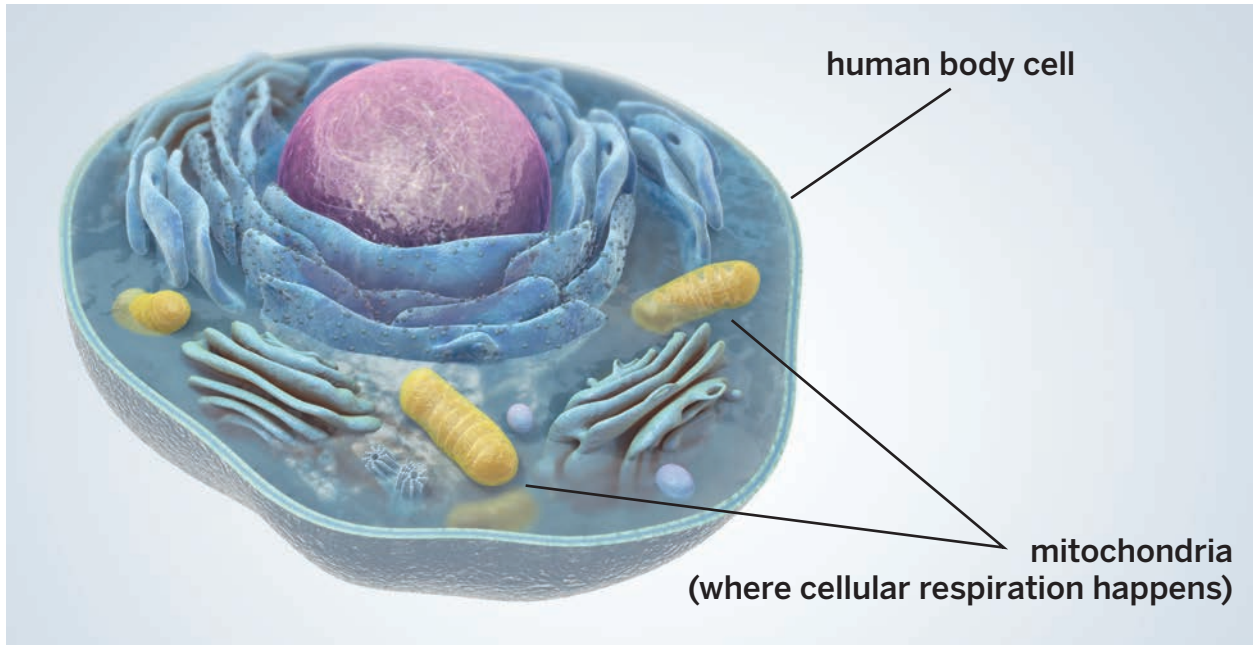
Producers are the only organisms that can perform photosynthesis, so it can be easy to forget that they also perform cellular respiration. Producers make energy storage molecules through photosynthesis, but the story doesn't stop there—they need to use those energy storage molecules to release energy through cellular respiration so they can do things like grow and reproduce.

However, producers make more energy storage molecules than they need for energy. They don't use all of the energy storage molecules they produce for cellular respiration. Producers use those extra energy storage molecules as building blocks to make their stems, leaves, roots, and other parts. And that's a good thing,

because otherwise there wouldn't be any energy storage molecules available to the rest of the ecosystem. Let's look at an example.

Mulberry trees that grow in China are an important food source for silkworms. Mulberry trees perform photosynthesis to produce energy storage molecules that they can use for cellular respiration. Mulberry trees also use energy storage molecules as building blocks to make their stems, leaves and roots. Silkworms eat some of the leaves of the plants and get the energy storage molecules that built those leaves for their own cellular respiration. Mulberry trees make enough energy storage molecules to do cellular respiration and enough to build their leaves and stems, and therefore, enough for silkworms to use as food.

For this to work, mulberry trees must make more energy storage molecules than they use for cellular respiration. Another way to think about this is in terms of carbon: mulberry trees must take in more carbon from carbon dioxide during photosynthesis than they release through cellular respiration.



The mitochondria are the cell parts where cellular respiration happens, releasing energy from food.

How Did We Get Mitochondria?

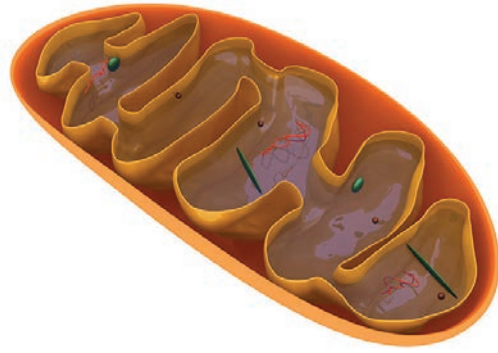
You've probably heard all about how important cellular respiration is to your body—it's the way your cells release lots of energy from your food. You may also know that cellular respiration happens in the organelles (cell parts) called mitochondria. Inside the mitochondria, oxygen and glucose react to form carbon dioxide and water, releasing lots of energy. That's cellular respiration! Because they provide cells with so much energy, mitochondria are often likened to power plants. Your cells aren't the only ones that have mitochondria—so do the cells of all animals, plants, and many other organisms. What are mitochondria, exactly? Where did mitochondria come from?

One clue to where mitochondria came from is their size and shape. Mitochondria are shaped sort of like sausages, long and rounded on the

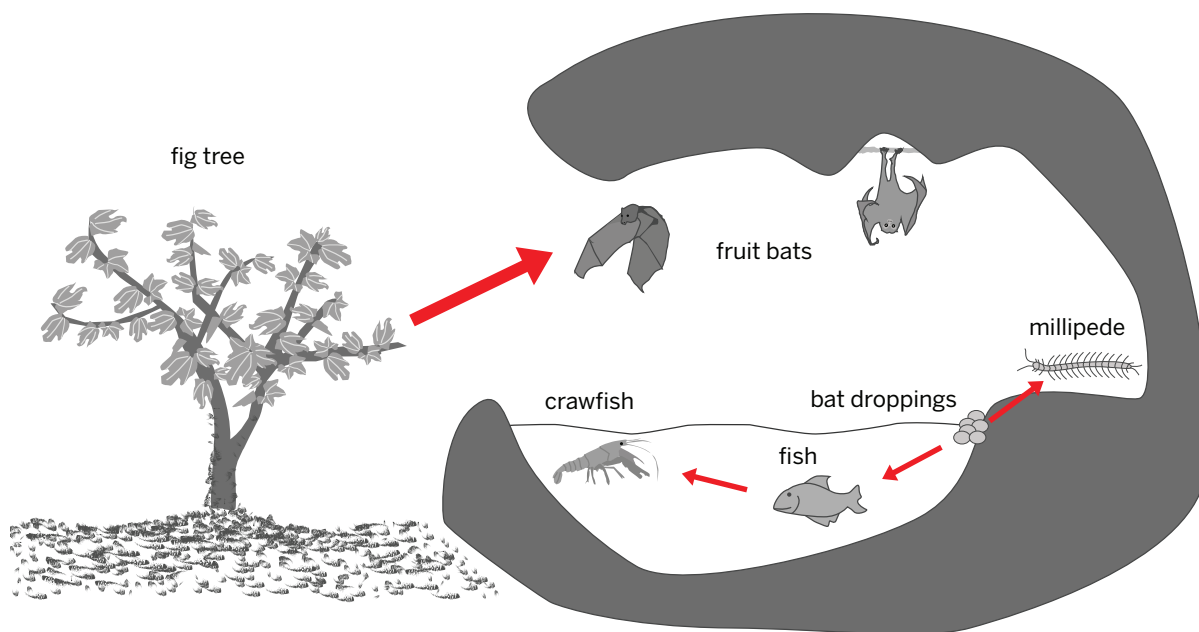
ends. They are typically about 2 micrometers in length, but can be anywhere from 0.5 to 10 micrometers. In size and shape, mitochondria are similar to many types of bacteria. Mitochondria also multiply in the same way bacteria do: one mitochondrion becomes two new mitochondria by splitting in half. Those similarities may be intriguing, but the most important clue to the origin of mitochondria is their DNA. You have probably heard that the nucleus at the center of the cell is the part of the cell that contains DNA, making up the genes that determine your traits. That's true, but the nucleus isn't the only cell part with DNA. The mitochondria have DNA, too—and it's very different from the DNA in the cell nucleus. In fact, mitochondrial DNA is more like the DNA of bacteria than it is like the DNA in the cell nucleus.

Mitochondria have bacteria-like DNA, multiply the same way bacteria do, and are similar in size and shape to bacteria for a simple reason: mitochondria started out as bacteria. More than a billion years ago, the bacteria that gave rise to mitochondria were independent organisms, similar to some types of bacteria that are still around today. At the time, all life on Earth was in the form of bacteria and other single-celled microorganisms. Some ancient bacteria were able to perform cellular respiration, while many other microorganisms around them could not. These other microorganisms had to release energy from their food in other, much less efficient ways.

There are different theories about how this happened, but somehow larger microorganisms in the environment were able to absorb the ancient bacteria that could perform cellular respiration. The bacteria became parts of the larger microorganisms—they became the organelles we call mitochondria. Once the larger microorganisms contained mitochondria, they gained the ability to release energy through cellular respiration. This ancient event is the reason why you are able to get so much energy out of your food. Thank your mitochondria!



Mitochondria are similar to bacteria in size and shape.



The food web above shows where organisms in one kind of cave ecosystem get their energy storage molecules. The arrows show how the energy storage molecules move in this cave ecosystem. They point from the food to the consumer.

Getting Energy in a Cave Ecosystem

Most ecosystems are full of energy storage molecules that were produced using energy from the sun. Producers make storage molecules using energy from the sun, and those energy storage molecules can be passed through the ecosystems as organisms eat one another. However, not all ecosystems get direct sunlight. For example, there is very little light inside caves, yet caves can be full of life. Where do organisms in caves get their energy storage molecules? There are many different kinds of cave ecosystems, and this article shows one example.



The bats that live in this cave are fruit bats. These bats are consumers that live in the cave, but they eat fruit from trees outside the cave.



The fig tree is not in the cave, but it is still part of the cave ecosystem. Fruit bats that live in the cave leave to get fruit like the figs from the fig tree. Fig trees are producers that use energy from the sun to make energy storage molecules. The fruit bats get energy storage molecules when they eat the figs from the tree.



This cave fish is a consumer that feeds on bat droppings (poop). Even bat droppings have energy storage molecules in them. Many cave animals, like this fish, are born without eyes—it's too dark to see, so eyes are useless where they live. Blind cave fish navigate, feed, and reproduce with enhanced senses of smell, taste, and touch.



This crawfish is a consumer. It has no eyes, but it can still catch fish to eat!



This tiny millipede is a consumer that lives in the cave and eats bat droppings.



The coastal prairie ecosystem has many types of producers, but the most common are grasses.

Getting Energy in a Coastal Prairie Ecosystem

Coastal prairie ecosystems are prairies—large areas covered with grass and low plants—that are located on the coast, near the ocean. Coastal prairies may look like just a lot of grass and plants, but they are full of other organisms. You just need to know where to look!



Gophers are consumers that live in underground tunnels. They only eat producers, like grass.



Grasshoppers are consumers that eat the grass they hop on.



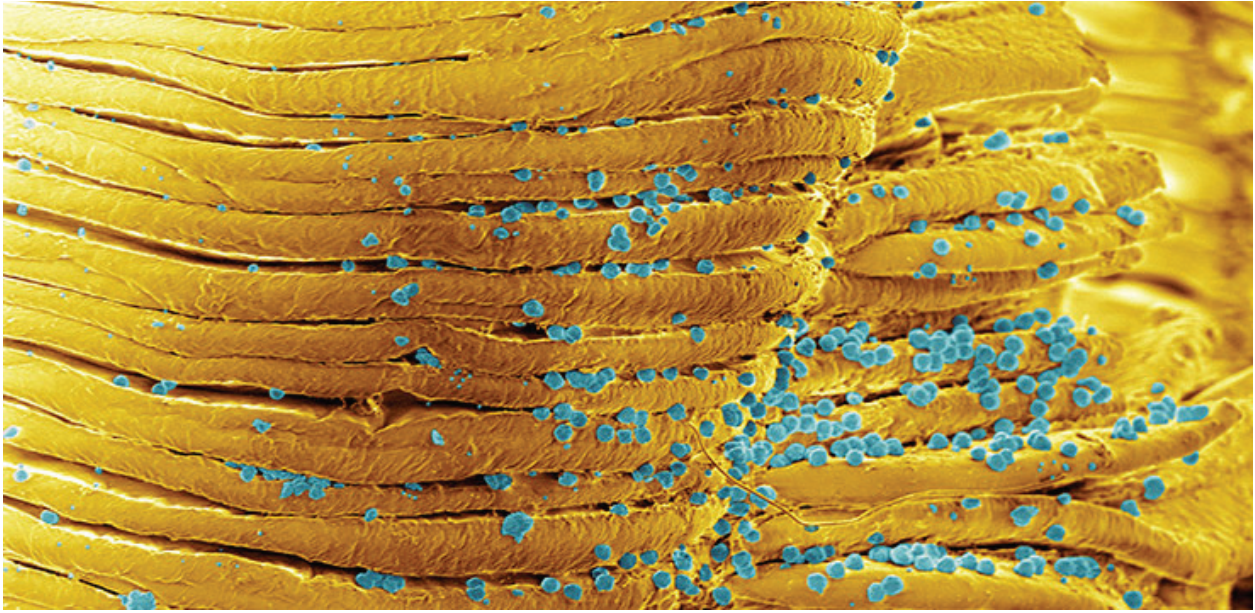
Badgers are consumers that live in the coastal prairie. They eat gophers and other small animals.



Grizzly bears are consumers that eat a variety of foods. They eat different parts of producers like roots and berries, as well as grasses. Grizzly bears also eat animals like gophers.



Worms and other decomposers in the soil break down dead matter like dead grasses and other dead organisms.



The tiny blue dots in this image are bacteria living near a deep-sea vent. Some bacteria are decomposers, but these bacteria are producers! They make energy storage molecules using the carbon from carbon dioxide that is found in the water. Instead of using sunlight for this process, these bacteria use the energy from hydrogen sulfide coming out of the vents to make energy storage molecules. This process is called chemosynthesis.

Getting Energy Near a Deep-Sea Vent

Most of Earth's ecosystems get all their energy from the sun. Producers that perform photosynthesis can use the sun's energy to make energy storage molecules, which can then be transferred through ecosystems and used by organisms to release energy. Sunlight cannot reach the deep ocean, so you might think nothing lives in the darkest parts of the ocean. Yet there are some areas underwater, near deep-sea vents, that are full of life. These ecosystems don't get sunlight, so they must get energy in another way.



These tube worms live near deep-sea vents. They are consumers and get energy storage molecules from eating bacteria that live near the vents. These worms can grow to be over 2 meters (6.6 feet) long.

Deep-sea vents are underwater cracks in Earth's surface. Hot water spews from these vents, heated by the rock below. The water contains substances that some organisms can use as a source of energy to make energy storage molecules. These organisms are producers, but they are not the green, leafy organisms we are used to—they are tiny bacteria.



These vent shrimp are consumers that eat bacteria found near deep-sea vents. Scientists have found evidence that vent shrimp have specialized eyes that can detect heat given off from the vents.



Some species of octopuses can live near deep sea vents. They are consumers that eat shrimp and other organisms, like fish and clams.



Glacier mice are complete ecosystems that are small enough to fit in the palm of your hand.

Glacier Mice

Living Arctic Tumbleweeds

On the windy slopes of glaciers all over the world, glacier mice skitter along in the wind. Glacier mice aren't actual mice—in fact, they aren't even animals! Glacier mice are fist-sized balls of dust and moss that blow around on glaciers in both the northern and southern hemisphere. They're similar in some ways to the dust bunnies that may form under your bed from time to time. A glacier mouse is not an organism, but there are many organisms living inside it! Glacier mice are complete ecosystems that can fit in the palm of your hand.

Glacier mice don't start out as much: usually, a little clump of dust or a pebble gets wet and moss (a kind of tiny plant) begins to grow on the surface. Then the wind comes along and flips the mossy pebble over, and moss starts growing on the other side. That little ball of moss is a glacier mouse. The glacier mouse keeps blowing around in the wind, picking up whatever might be hanging around the glacier. The inside of the mouse is damp and slightly warmer than the icy environment outside—2 to 10°C (36 to 50°F) instead of 0°C (32°F), which

makes it a good place for tiny organisms to live. One glacier mouse can be home to hundreds of microscopic organisms. After a while, each glacier mouse becomes a complete ecosystem.

How can something so small be a complete ecosystem? Ecosystems come in all shapes and sizes—some are hundreds of kilometers across and others are too small to see with the human eye. When scientists study ecosystems, they must define the boundaries of what they're studying: they have to say where one ecosystem stops and another begins. Sometimes the boundaries of an ecosystem are obvious, like where an ocean meets land. Sometimes the boundaries are less obvious,

like where one ocean ecosystem meets another. The boundary of a glacier mouse ecosystem is the outside of the glacier mouse.

Ecosystems are complete systems of living and nonliving things, but energy can flow into ecosystems from outside or out of ecosystems from inside. For example, energy enters the ecosystem of a glacier mouse when sunlight shines on the moss. Glacier mouse ecosystems also exist as part of the larger ecosystems of the glaciers where they're located: when an animal ventures out onto the glacier, or when the glacier mouse is blown to a new location, the change can have an effect on the glacier ecosystem as well.



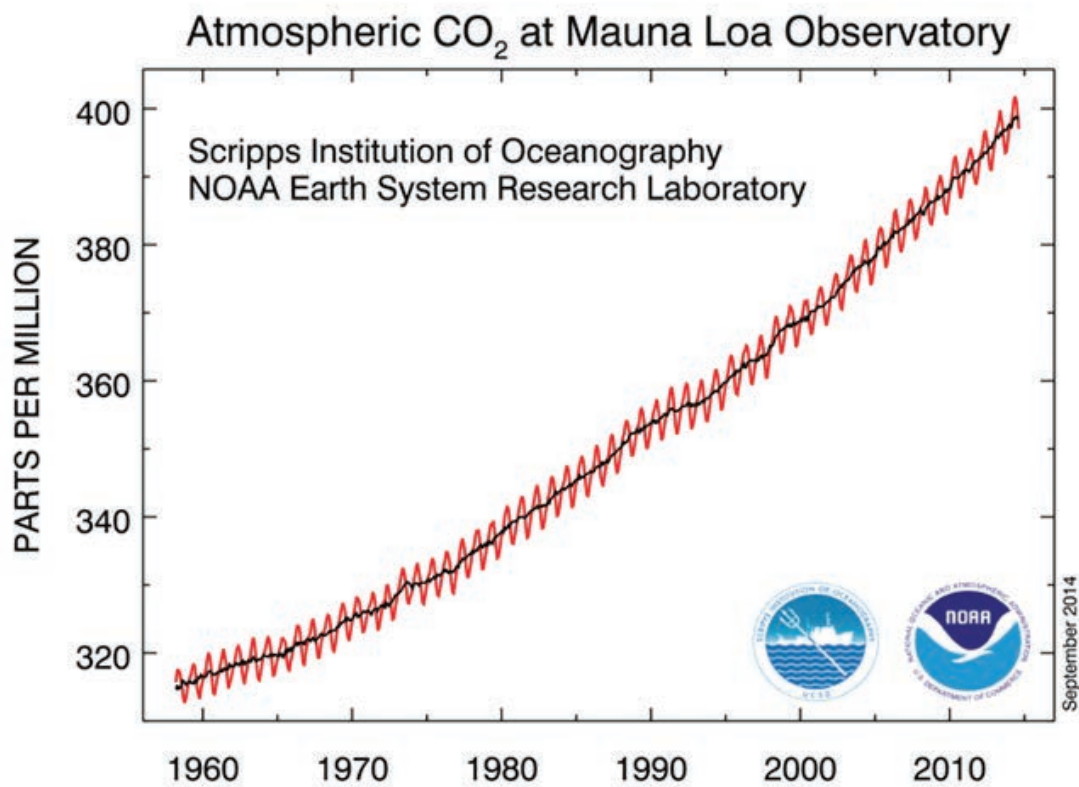
The water bear is one kind of microscopic organism that can live in a glacier mouse ecosystem.

Carbon in the Global Ecosystem

Scientists around the world who study Earth's atmosphere have discovered something dramatic and alarming: an increase in the amount of carbon dioxide in our atmosphere. They are finding that the increase in carbon dioxide in our atmosphere may have worldwide effects on our climate and our oceans, which can threaten life all over the planet.



Many factories burn fossil fuels, releasing carbon into the atmosphere.



This graph shows how quickly carbon dioxide increased in Earth's atmosphere during a 50-year period.

Where is the carbon that makes up all that carbon dioxide coming from? Carbon is an element that makes up a lot of the matter on Earth. New carbon can't be created, so the extra carbon in our atmosphere had to come from somewhere—it must have decreased in some other part of the Earth system. But where? Humans put carbon into the atmosphere when we burn fuels like coal, oil, and gas that are found deep underground. These are called fossil fuels.

These fossil fuels make the modern human lifestyle possible. Most of the time, when we use a cell phone, drive a car, heat our homes, or turn on the lights, we are using energy that comes from burning fossil fuels. We currently depend on these fuels to power our lives, but burning them releases large amounts of carbon dioxide into the air—and that increase in carbon dioxide might jeopardize life as we know it.

Fossil Fuels

Coal, oil, and gas are called “fossil fuels” for a reason: they are the carbon-rich matter left behind by plants and animals that died millions of years ago. These plants and animals were buried deep underground before they could decompose, so decomposers never broke down the dead matter. Over millions of years, the remains of the plants and animals turned into carbon-rich fossil fuels—coal, oil, and gas. The carbon that was in the plants and animals when they died is still there; it's just part of the fossil fuels. When we burn fossil fuels in cars, factories, or power plants, carbon that has been stored in the ground for millions of years is released into the air as carbon dioxide.



Coal is one type of fossil fuel.



Fossil fuels are the remains of animals and plants that died millions of years ago and were buried before they could decompose.

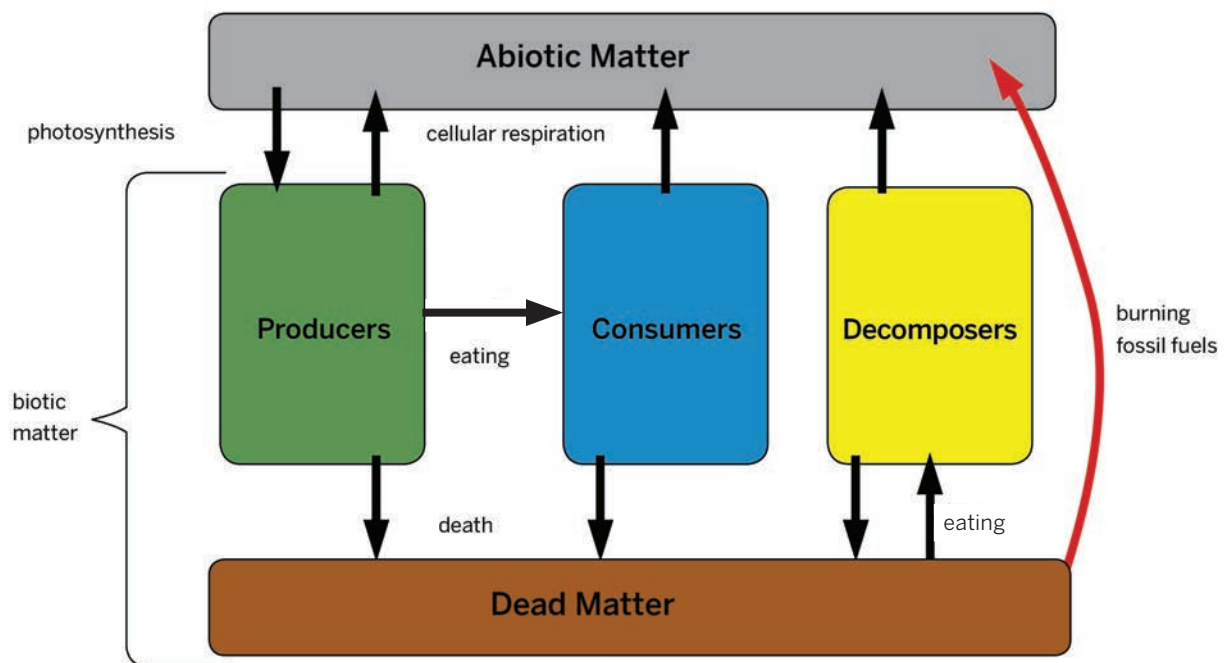
The Carbon Cycle

Earth is a closed ecosystem. There are many different regional ecosystems on Earth, but they all share one atmosphere and one ocean. Very little matter escapes from Earth into space, and almost none enters. Since almost no carbon enters or leaves Earth's system, and carbon isn't being produced or used up, the amount of carbon in the system does not change. If carbon is increasing in one part of Earth's system, it must be decreasing somewhere else.

Although carbon rarely leaves Earth's system, carbon moves in a cycle within Earth's ecosystem. This cycle is powered by energy. Carbon cycles from biotic matter to abiotic matter and back again. This means that carbon spends time in the air, in the ocean, in the soil, and in organisms as it moves continuously through the ecosystem. Powered by energy from sunlight, photosynthesis moves carbon from the air and

water into living things. At the same time, cellular respiration moves carbon from living things to the air and water. This continuous, consistent pattern of movement is called the carbon cycle, and it is essential to the survival of life on Earth. However, human activities are altering the way carbon moves through the global ecosystem.

As people around the world burn more and more fossil fuels, a great deal of carbon from deep underground is moving into the atmosphere. Carbon in one part of the system (abiotic matter) is increasing, and as a result, carbon in another part of the system is decreasing—in this case, biotic matter, which includes dead matter. Since the entire Earth shares the same atmosphere, changes in levels of carbon dioxide affect ecosystems all over the planet.



The Carbon Cycle: The arrows in this diagram show the pathways that carbon follows as it moves around the ecosystem. The black arrows show the pathways that exist naturally in the ecosystem. The large red arrow shows how humans can increase the amount of carbon in the atmosphere by burning dead matter like fossil fuels.

Impacting Planet Earth

All the extra carbon dioxide in the atmosphere is having many negative effects on the global ecosystem, and especially on the climate of our planet. Adding carbon dioxide to the atmosphere changes climate and weather patterns around the globe in ways that make it harder for many organisms to survive. Increased carbon dioxide causes global temperatures to rise, makes ocean water more acidic, and changes weather patterns. These changes may increase the chances of extreme weather events like hurricanes and droughts, which affect humans directly as well as the ecosystems and farms we depend on. By increasing the amount of carbon dioxide in the atmosphere, we are gambling with our very way of life.



Adding carbon dioxide to the atmosphere can cause droughts and other changes in weather patterns.



Earth is a closed ecosystem.

Matter and Energy in Ecosystems: Biodome Collapse



THE LAWRENCE
HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Amplify.

Published and Distributed by Amplify.
www.amplify.com

AMP.NA18

ISBN 978-1-947002-97-5



9 781947 002975 >