THE SOIL STORY CURRICULUM

Rebuilding Healthy Soil for Carbon Cycle Balance

Earth's Systems

Photosynthesis

Healthy Soil

Food & Farming

Taking Action

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THE SOIL STORY CURRICULAR GUIDE

The Soil Story Curricular Guide was created through a collaborative partnership between Kiss the Ground and Life Lab. It serves as a supplemental material for teaching middle schoolers Next Generation Science Standards.

Kiss the Ground (KTG) is a nonprofit with a mission to inspire participation in the regeneration of the planet, beginning with soil. The organization creates educational curriculum, campaigns, and media to raise awareness and empower individuals to purchase food that supports health soils and a balanced climate. KTG also works with farmers, educators, non government organizations, scientists, students, and policymakers to advocate for regenerative agriculture, raise funds to train farmers, and help brands and businesses to invest in healthy soils.

www.kisstheground.com

Life Lab cultivates children's love of learning, healthy food, and nature through garden-based education. Through hands-on workshops and award-winning publications, Life Lab provides educators with the inspiration and information necessary to engage young people in experiential learning in gardens.

www.lifelab.org

THE SOIL STORY & THE COMPOST STORY VIDEO

The Soil Story is an engaging video that examines important connections between soil, farming, compost, and the carbon cycle on Earth. Created by Kiss the Ground, the video introduces a number of topics upon which this curricular guide is based. *The Soil Story* is narrated by Pashon Murray, the founder of the formidable nonprofit, Detroit Dirt. Pashon is known for her urban renewal program that aims to close the waste loop by creating a zero-waste mindset that promotes a low-carbon economy.

https://youtu.be/UvRlIf3ccVA

The Compost Story is video, narrated by celebrity guests Paul Blackthrone, Amy Smarts, Kendrick Sampson, Rosario Dawson, and Adrian Grenier that invites viewers to learn about nature's most astonishing processes, the black gold we call compost. Compost as the regenerating, probiotic, solution for our depleted land, could play a major role in rebalancing the world's carbon cycle. The Compost Story wants to spread the hopeful message that we can turn polluting waste streams into a valuable resource. It's a win-win proposition, an elegant solution to many of our modern day problems.

www.kisstheground.com/thecompoststory/

Forward

Learning about soil has changed my life. We know relatively little about soil yet, it is the foundation for ecosystem biodiversity. Soil provides nutrients for plants to be healthy, serves as a "sponge" to hold water, and helps store atmospheric carbon.

I was first inspired by the importance of healthy soils while studying nutrition and learning the healing properties of foods grown on farms caring for their soil. Then, I learned, along with my good friends who started Kiss the Ground in a living room, that plants working with healthy soils can pull carbon out of the atmosphere. And now I'm additionally inspired by the role that healthy soils can play in resilience. When our soils are healthy, plants have an easier time withstanding extreme weather events such as drought and floods. With less than 60 harvests left worldwide due to soil loss and desertification (according to the UN FAO), we have a lot of work to do in healing our soils. In so many ways there are only a few meals that stand between civilized society and anarchy (some say 7, others say 9). Thus, the health of our soils globally is ultimately tied to our food production and peaceful human societies.

As a child of the 80's, I wore "save the polar bears" shirts, convinced my parents to recycle and thought the best thing I could do for the health of the planet was protest in Washington, D.C. and create a lifestyle where I "treaded lightly". Since then, I've come to understand that the way I was taught about environmentalism created apathy. As young children, when we learned about species going extinct, changing weather patterns, and food insecurity we were taught that wearing caused based t-shirts, making posters, and donating to nonprofits counted as "doing our part." But learning about a massive problem and then making a poster can actually breed apathy. All we have to do is say we care and assume that someone else will actually "do something". Since, I've come to understand that to truly face environmental challenges and participate in things such as global soil restoration—we need to change our narrative from "do less harm" and "tread lightly" to "participate" and "become stewards". As humans, we can actually be the keystone species that works with nature to regenerate the planet.

Let's inspire a generation of humans who participate. "The re-Generation" is possible in our lifetimes with your help and the help of all of our fellow residents of Planet Earth. May we seize this critical moment in time and be able to share with our children's children how we worked together, with love catalyzing us to act, and truth prevailing over profit.

As a mother, I've dedicated my life to regenerate the planet, because I understand that it is the only path forward for my son's generation and his children to thrive. May we all find ourselves on this path in our individual and creative ways.

In love,

Lauren Tucker
Executive Director

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Introduction

The collection of experiences in The Soil Story Curricular Guide is designed to educate young people about the cycling of matter and the flow of energy among living and nonliving parts of an ecosystem. There are many everyday examples of this in the real world, such as animals breaking down and releasing chemical energy in the food they eat. Many of these processes, however, happen on a scale too big or too small to observe firsthand in the classroom. This series of lessons aims to make some of these processes more understandable to middle school students. Specifically, each of the five lessons supports students with understanding how carbon, as a form of matter, moves to and from various reservoirs on Earth.

Building on what the Next Generation Science Standards (Achieve, 2013) suggest students know by the end of fifth grade, this unit engages middle school learners in using a visual model to explain interactions that occur when matter cycles between the geosphere, hydrosphere, biosphere, and atmosphere. In this way, The Soil Story Curricular Guide introduces students to the carbon cycle, a topic they delve deeper into in high school. Unlike many other educational resources that teach about the carbon cycle, this unit highlights a commonly overlooked part of the carbon cycle: the pedosphere (soil).

Increasingly, scientists, farmers, and environmentalists alike are rediscovering the importance of a robust pedosphere, or soil biome. *The Soil Story* video, around which this curricular guide is created, provides an engaging look at the role soil plays in the carbon cycle. More pointedly, it proposes that rebuilding healthy soil on the planet is the key to carbon cycle balance. In addition, the video serves as a jumping off point for students to interpret digital media. Coupled with rich discussion, hands-on investigation, and visual interpretation, *The Soil Story* video invites students to examine the role plants, microorganisms, and humans play in regenerating a rich resource right beneath our feet.

Unit-at-a-Glance

Lesson Title	Guiding Questions	Activities	
Earth's Systems	Where is carbon found on Earth?	Engage	Elicit Ideas about Carbon
		Explore	Model How Carbon Moves
		Explain	Integrate Evidence from *The Soil Story* Video
		Elaborate	Reflect on the Use of a Model
		Evaluate	Summarize Ideas
Photosynthesis	What role do plants play in the carbon cycle?	Engage	Pose the Plant Matter Mystery
		Explore	Conduct Bromothymol Blue Reaction
		Explain	Explain How Plants Use Carbon
		Elaborate	Model Photosynthesis
		Evaluate	Solve the Plant Matter Mystery
Healthy Soil	What role do soil microbes play in the carbon cycle?	Engage	Define Interdependence
		Explore	Compare Soil and Dirt
		Explain	View "The Living Soil Beneath Our Feet" and Explain How Microbes Use Carbon
		Elaborate	Connect Soil Microbes and the Carbon Cycle
		Evaluate	Celebrate Microbes
Food and Farming	What role do farmers play in carbon cycle?	Engage	Meet the Microbes in our Gut
		Explore	Taste Mindfully
		Explain	Evaluate Compost Claims
		Elaborate	Sort Agricultural Practices
		Evaluate	Prepare to Take Action
Taking Action	What role do you play in the carbon cycle?	Engage	Tell the Kiss the Ground Origin Story
		Explore	Complete an Environmental Survey
		Explain	Plan a Project
		Elaborate	Share Learning
		Evaluate	Reflect on Learning

Lesson 1: Earth's Systems

Lesson 1 invites students to examine their existing understanding of carbon. From *The Soil Story* video, students learn that carbon is a natural element found in every living organism on Earth, as well as in many non-living objects such as rocks or coal. The Science and Engineering Practice of "developing and using models" enables learners to visualize where carbon is stored on Earth and how it cycles between the geosphere (rocks, minerals, fossils), hydrosphere (oceans, rivers, lakes), biosphere (plants, animals, microorganisms), atmosphere (air, water vapor, particles like dust, pollen, etc.) and pedosphere (soil, which contains elements from all the other spheres, including rocks, water, air, and life). The video asserts that the carbon cycle is out of balance and names some of the ways human activity has disrupted this naturally occurring cycle.

Lesson 2: Photosynthesis

In Lesson 2, students collect evidence that plants absorb carbon (in the form of CO_2) from the atmosphere during the process of photosynthesis. By observing evidence of the chemical reaction that takes place inside of plants, algae, phytoplankton, and other microorganisms, students begin to develop an understanding of the molecular interactions in the carbon cycle. Namely, they discover that carbon dioxide molecules in the atmosphere are broken down and rearranged to form carbohydrate molecules in plant matter in the biosphere.

Lesson 3: Healthy Soil

By Lesson 3 students are primed to look more closely at the molecular exchange that happens under the ground. Most students have a cursory understanding that plants get essential nutrients from the soil, but they do not necessarily understand how these nutrients are made available to plants. One of the primary mechanisms by which this happens is a "Great Exchange" between plants and soil biota. Students explore the concept of interdependence in which the plants provide carbohydrates to fungus, bacteria, and invertebrates in the soil and those soil dwellers, in turn, provide the plants with decayed nutrient matter. To reinforce this concept, students gather evidence for soil life by observing the presence of biotic matter in rich soil and comparing it to the relatively inert qualities of dirt. As they examine another interaction between the pedosphere and biosphere, students deepen their understanding of how carbon cycles on Earth.

Lesson 4: Food and Farming

After students have been introduced to the role soil microbes play in the carbon cycle, Lesson 4 asks students connect to healthy soil with agriculture, the system by which humans grow the foods and fibers that enable our survival. Students learn that the human gut is similar to the soil, in that both are rich biomes filled with microorganisms working together. In many regards, microbes in the soil and microbes in human gut work in similar ways. New technologies are helping us understand the human microbiome and how healthy soil contributes to healthy people. Students engage all of their senses as they mindfully taste fresh produce, which sets the stage for a critical discussion of different types of agricultural practices. Using "agricultural practice" cards, students engage in argument from evidence about what farmers can do to increase soil biodiversity (i.e., nurture bacteria, fungus, and invertebrates) and decrease carbon release into the atmosphere.

Lesson 5: Taking Action

Finally, in Lesson 5, students take on the role of soil activists. Inspired by the Kiss the Ground origin story, students examine their newfound understanding of the carbon cycle and the importance of the pedosphere to evaluate the environment around their school campus or community. They revisit their carbon cycle model and identify one interaction they can impact with collective action. Then they plan and implement a community project to increase soil biodiversity and share what they've learned with others. Perhaps they build a compost pile in the school garden or plant a tree in their community.

UNIT SUMMARY

This unit of study is designed to educate young people about the cycling of matter and flow of energy among living and nonliving parts of the Earth. More specifically, this series of lessons introduces middle school students to the carbon cycle and the importance of rebuilding healthy soil on the planet. Through rich discussion, hands-on investigation, visual interpretation, and custom-created media, students examine the role plants, microorganisms, and humans play in protecting a resource that is right under our feet and restoring balance to the carbon cycle.

GUIDING QUESTIONS:

- How does carbon cycle between Earth's systems?
- How can we leverage naturally-occurring processes to restore carbon cycle balance?

NEXT GENERATION SCIENCE STANDARDS (NGSS):

Performance Expectation: MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

NGSS Disciplinary Core Ideas:

Earth Science

- Earth’s Materials and Systems (MS-ESS2.A)
- Human Impact on Earth Systems (MS-ESS3.C)

Life Science

- Interdependent Relationships in Ecosystems (MS-LS2.A)
- Cycle of Matter and Energy Transfer in Ecosystems (MS-LS2.B)
- Biodiversity and Humans (MS-LS4.D)

Physical Science

- Energy in Chemical Processes and Everyday Life (MS-PS3.D)

Engineering

- ETS1.B: Developing Possible Solutions

NGSS Science and Engineering Practices:

- Developing and Using Models
- Constructing Explanations
- Obtaining, Evaluating, and Communicating Information
- Engaging in Argument from Evidence

NGSS Crosscutting Concepts:

- Systems and System Models
- Cause and Effect
- Energy and Matter

GUIDING QUESTION

Where is carbon found on Earth?

FOCUS ON SCIENCE PRACTICE: DEVELOPING AND USING MODELS

Many middle school students are familiar with everyday uses of the term "models" (e.g., supermodels, model cars). In science, models help explain and/or predict how or why things happen the way they do. A mental model is a set of ideas about how something works or came to be. Mental models comprise the conceptual understanding about a phenomenon and the way these concepts are cognitively organized for a learner. Models are not "right answers" but can vary from person to person. The relationships between ideas can be enhanced and shared with the use of physical, scientific models such as diagrams, simulations, or replicas or the real thing under investigation. Because mental models develop over time, students should engage in this practice until they develop understanding that is more consistent with a scientific perspective (i.e., what is known to date about a phenomenon). As a representation of a phenomena, any model inherently has limitations. In this lesson, students create a model of how carbon moves through Earth's systems. The tools that help the students develop a scientific model of this process are the labels, arrows, and text that can be moved from place to place on the image. Obviously, this model is much, much smaller than Earth's systems. Another limitation of this paper model is that is it is two-dimensional. Discussing these limitations with students is a fruitful way to think about how a model can be improved and or expanded.

KEY VOCABULARY

- **Atmosphere:** Layer of gases surrounding the Earth.
- **Biosphere:** The biosphere is made up of the parts of Earth where life exists or that is capable of supporting life. It extends from the earths crust to the water and beyond to the atmosphere.
- **Geosphere:** That portion of the Earth system that includes the Earth's interior,

KEY VOCABULARY (CONTINUED)

rocks and minerals, landforms and the processes that shape the Earth's surface.

- **Hydrosphere:** The combined mass of water found on the surface of the planet, underground, and in the air.
- **Pedosphere:** The outermost layer of the Earth that is composed of soil and subject to soil formation processes.
- **Carbon:** An element found in every living thing, and many nonliving things, on Earth.
- **Carbon Cycle:** The movement of carbon between Earth's systems (the atmosphere, biosphere, geosphere, hydrosphere and pedosphere).

MATERIALS

- Computer with internet access
- Projector or document camera
- ***Slides 1.1–1.4***
- Labels: "True" and "False"
- One pair of scissors per group of 4
- One set of cut-out arrows, labels, and interactions for class model from ***Handouts 1.1: Carbon Cycle Model*** and ***1.2: Carbon Cycle Modeling Tool***
- Document camera

SUGGESTED TIME

45 min – 1 hour

PREPARATION

- Set up computer and projector.
- Print copies of Handouts 1.1 and 1.2 for each group of 4 students.
- Print one copy of Handout 1.3 for each student.
- Cue *The Soil Story* video: ***https://youtu.be/UvRlIf3ccVA***
- Handwrite or print out two labels that say "True" and "False".

HANDOUTS

- ***Handout 1.1: Carbon Cycle Model***
- ***Handout 1.2: Carbon Cycle Modeling Tools***
- ***Handout 1.3: Soil Story Assessment***

ENGAGE

1. Introduce the Quick Write routine. Post the prompt, *"What do you know about the connection between soil, farming, and compost?"* and give students 5 minutes to write in a journal, notebook, or index card that you can collect.
2. Tell your students that you want to find out what they already know about the topic they are about to study. Ask if they have ever heard the word "carbon." Elicit some initial ideas students may have. Explain to students that they are not expected to know all the right answers, since they haven't studied carbon yet.
3. Conduct a Vote with Your Feet Activity. Preview the procedure below:
    a. You will read a series of statements, some of which are true and others that are false.
    b. Point out the "True" and "False" labels you posted on the wall before class.
    c. Students they should think about whether they think the statement is true or false and then move to that side of the room. Students should be prepared to tell why they selected their position.
    d. Choose 4 statements to read aloud from the "Vote with Your Feet" activity described on page 14. After each one, give students a minute to move to the side of the room that best represents their position and call on a few students to share their ideas.
    e. After each statement you read, use the comments in the "Vote with Your Feet" in-hand reference sheet on page 14 to define carbon for students.

EXPLORE

1. Use a projector or document camera to display ***Slide 1.1: Earth's Systems.*** Engage the class in a model-building exercise.
2. Explain the purpose of the model. Tell students, *"Without words and arrows, this is just an image. We don't know what it's showing."*
3. Using a document camera or a projector, demonstrate how to use the labels, arrows, and interactions you cut out ahead of time to turn the image into a diagram that shows how carbon cycles between two of Earth's Systems.
    a. Use the definitions on pages 9-10 to briefly define Earth's 5 systems—the atmosphere, biosphere, geosphere, hydrosphere, and pedosphere.

b. Place labels for "atmosphere" and "biosphere" in the appropriate places on the image.

c. Add an arrow between the atmosphere and the biosphere.

d. Add the interaction "Land plants take in carbon dioxide (CO_2) and use the carbon to grow new leaves," and explain how this example connects the two systems.

4. Call attention to the fact that the labels, arrows, and interactions are movable. The diagram is a model for testing out ideas. Invite a few students to come up to the document camera or point on the projected image new ideas to the class carbon cycle model.
5. Distribute ***Handout 1.1: Carbon Cycle Model*** and ***Handout 1.2: Carbon Cycle Modeling Tools***. Have students cut out the labels, arrows, and interactions.
6. In groups of 4, have students place a few labels, arrows, and interactions on their carbon cycle model.
7. Introduce and set purpose for viewing *The Soil Story* video. Explain that the host, Pashon Murry, explores some ideas about soil, farming, and compost. Invite students to listen for how these ideas connect to the carbon cycle. Tell students that after the video, they will have a chance to add new examples to their carbon cycle diagram.
8. Watch the video together.

EXPLAIN

1. Invite students to share ideas they heard in the video that were most compelling. Revisit the question, *What do you know about the connection between soil, farming, and compost? What does this have to do with carbon?*
2. Ask your students to write 1–3 new ideas they heard in the video about how carbon moves between Earth's systems on the blank strips on ***Handout 1.2: Carbon Cycle Modeling Tools***. Then, have the students add these examples to their carbon cycle diagram. (Examples: When humans burn fossil fuels, we move carbon from the fossil reservoir in the geosphere to the atmosphere; when we clearcut, we move carbon from the biosphere to the atmosphere; and when we till, we move carbon from the pedosphere to the atmosphere).
3. Connect ideas, using language of uncertainty. You might phrase ideas in an if-then format, such as, *"If carbon is stored in and moves between living and nonliving things, and scientists believe that the carbon cycle is out of balance, then what can we, as humans, do about it?"*

4. Project ***Slide 1.3: How Carbon Cycles on Earth.*** Explain the following: *For the last several hundred million years on earth, because of the work of plants, animals, and microbes, carbon has cycled naturally, as you can see represented in this slide, allowing everything to stay in relative balance.*
5. Show ***Slide 1.4: The Carbon Cycle Today*** and explain: *Since the mid-1700s, when humans figured out how to extract carbon from the Earth, the levels of carbon in the atmosphere have changed.*

ELABORATE

1. Discuss how using the arrows, labels, and interactions turned an image into a diagram. Highlight that a diagram is a type of model. Then ask students how their background knowledge, information from the video, and the model helped them explain where carbon is found on Earth.
2. Invite students to revisit their Quick Write from the beginning of the lesson and add any new ideas they may have about soil, farming, or compost. If time allows, have them share their ideas with a classmate.

EVALUATE

1. Distribute ***Handout 1.3: Soil Story Assessment*** and give students time to complete an individual model of the carbon cycle. Then, have them complete all of page 1 and question 1 on page 2.
2. Summarize ideas related to the guiding question and preview the guiding question for the next lesson.
3. Collect or have students save ***Handout 1.3: Soil Story Assessment*** for use in all future lessons in this series.

VOTE WITH YOUR FEET STATEMENTS AND CLARIFICATIONS

Use the bold statements below to elicit students’ current understanding of carbon on Earth and the comments to engage the in discussion about each statement.

Carbon is found in every living thing on Earth.

True: Carbon is an element, and it is found in every living thing on Earth. Your cat, your family, your food, and you are all carbon—based organisms. Carbon is also found in many nonliving things, like air and rocks.

Carbon is bad for the environment.

False: Carbon is essential to our environment and is continually cycling through various carbon pools, e.g. the pedosphere, the biosphere or the atmosphere. Carbon is one of the main building blocks of life, and all living and once living things contain carbon. In addition, carbon in the form of organic matter is a critical part of healthy soil.

Most of the carbon on Earth has been here since the Earth was formed.

True: Most of the carbon that’s here on Earth has been here since Earth was formed 4.6 billion years ago -- some carbon is still added every year from meteors! The only thing that is changing is where that carbon is stored.

There is more carbon in the atmosphere now than at any time in the last few hundred thousand years.

True: According to recent scientific research, there is more carbon dioxide in the air now than in the last several hundred thousand years. Historically in that time frame the average was closer to 250 parts per million (PPM). The readings are now over 410 PPM and the level is climbing at 2-3 parts per million annually.

There is more carbon in the atmosphere now than ever before.

False: About 500 million years ago, before plants evolved, it was as high as 7,000 parts per million.

Scientists believe the carbon cycle is out of balance.

True: The amount of carbon in the atmosphere in the form of carbon dioxide is too high, which is causing environmental, economic, and social problems.

GUIDING QUESTION

What role do plants play in the carbon cycle?

FOCUS ON SCIENCE PRACTICE: CONSTRUCTING EXPLANATIONS

When scientists construct explanations, they communicate the answer to a scientific question using the available evidence gathered through other scientific practices (e.g., investigation, data collection and analysis, mathematical computation, reading the work of other scientists). In general, an explanation is described as a claim, along with the evidence that supports it. The explanation is better understood by others if it also includes solid reasoning that links the evidence to the claim. Explanations are the core of what science aims to do: figure things out and accumulate a body of evidence (i.e., knowledge) that can be further investigated. The explanation can only be as good as the question that was asked in the first place. To this end, the goal of student explanations is to gradually build a more complete understanding of a real-world question (or phenomenon). In this lesson, we ask students to orally explain their ideas about where plants get their matter and to revise their explanations as they gather more evidence.

KEY VOCABULARY

- **Bromothymol blue:** An indicator of the presence of carbon.
- **Carbon Dioxide (CO_2):** A colorless, odorless gas produced by burning carbon and organic compounds and by respiration. This is the gas animals, including humans, breathe out.
- **Carbohydrate ($C_6H_{12}O_6$):** Organic compound in food and living tissue, such as sugar and starch.
- **Photosynthesis:** Process by which plants use energy from the sunlight to make food from carbon dioxide and water.
- **Matter:** Any physical substance, including any solid, liquid or gas.

MATERIALS

- 1 branch or log of wood; or outdoor access to a big, log that students can try to lift up
- Chart paper or whiteboard
- Markers
- 1 bottle Bromothymol blue 0.04% aqueous (available at ***Carolina Biological Supply***)
- 1 lab coat, apron or smock
- 1 clear, clean 4 oz bottle
- Water
- 1 funnel
- Dropper
- 1 test tube rack holding 3 clear test tubes with tight fitting stoppers
- 1 straw
- 1 sprig of elodea or hornwort (both available in aquarium stores)
- Colored pencils for students to use (each student will need access to blue, green and yellow pencils)
- Computer with internet access
- Projector
- ***Slide 2.1: Stomata***

HANDOUTS

- ***Handout 2.1: Bromothymol Blue Reaction Observations***
- ***Handout 2.2: Atoms in Photosynthesis***
- ***Handout 1.3: Soil Story Assessment***

SUGGESTED TIME

Part 1: 45 minutes

Part 2: 45 minutes, to be taught 1-7 days after Part 1

PREPARATION

- Watch the instructional video to support the teaching of this lesson. ***https://youtu.be/PWHTaXxVBGI***
- Write the phrase "Possible Explanations About Where Plant Material Comes From" at the top of a chart paper or whiteboard to record students' ideas.
- Print ***Handout 2.1: Bromothymol Blue Reaction Observations*** for each student.
- Print ***Handout 2.2: Atoms in Photosynthesis*** for each group of 4 students.
- Stir 8 milliliters of Bromothymol blue (0.04% aqueous) into 1 liter of water to make a blue solution. Then use a funnel to fill 3 test tubes a little less than half way with the solution. Seal each one with a stopper. The stopper must fit tightly in the bottle. If there are gaps around the stopper or straw, seal them with tape.
  Note: *Bromothymol blue can stain clothing, so wear a lab coat, apron, or smock. Also follow all safety instructions for handling the chemical.*
- Prepare to project ***Slide 2.1: Stomata***

PART 1:

ENGAGE

1. Have students stand in a circle and pass a heavy log around, or head outside and work together to lift a heavy log or dead tree. Let them really feel the weight of it in their hands.
2. In partners, students do the following Think-Pair-Share activity:
   a. **Think:** Ask students to think silently about this question: This wood, like all things, is made of matter. But where do you think that matter came from?
   b. **Pair:** Have students explain their ideas with a partner and see if they had similar or different explanations.
   c. **Share:** Ask for students to share with the whole group. Some students might think the matter came from the soil, from decaying plants, or other similar things. **Do not correct misunderstandings at this time.** Record all of the possible ideas in a place where they'll be able to revisit later.

ENGAGE: PART B

1. Tell students they are now going to observe a chemical reaction that will provide them with some clues, or evidence, as to where all that matter in plants comes from.
2. Define Bromothymol blue and explain its purpose in the reaction, which is to indicate the presence of carbon.
3. Distribute ***Handout 2.1: Bromothymol Blue Reaction Observations*** and colored pencils. Tell student they will draw a diagram (or model) explaining the change they observe.
4. Conduct the Bromothymol blue demonstration as follows:
   a. Place your 3 pre-filled test tubes in a row where your students can see them. Give the students 5 minutes to complete Diagram 1 of Handout 2.1.
   b. Using a straw, breathe in a soft, steady rhythm into two of the three test tubes until the blue color of the Bromothymol blue becomes yellow-green. Leave the third test tube as it was to serve as a comparison with the other two. Then use the stoppers to seal all 3 tubes. ***Note:*** *It's best for the teacher to do this to ensure that no Bromothymol blue is inhaled.*

c. When you have finished breathing into the two tubes, have students complete Diagram 2 of Handout 2.1. Invite students to discuss in small groups what they think caused the change. As they discuss, have them turn their diagrams into models by using arrows and labels to show what they think caused the color to change.

d. Have small groups share out their ideas about what caused the Bromothymol blue to change color. As they share, have them hold up their models to show how they depicted that change visually (generally, with arrows and labels).

e. Review what actually happened: You exhaled carbon dioxide into the test tubes, and in the presence of carbon dioxide, Bromothymol blue turns a yellow-green color. Color change is evidence of the presence of CO_2.

f. Ask students to hypothesize how some of the carbon dioxide could be removed from the Bromothymol blue solution. Have them brainstorm and record their ideas of possible ways to turn the solution back to a blue color on Handout 2.1. Then have them share their ideas.

g. If no one mentions it, suggest putting a plant inside one of the tubes and ask if they think that will change the color and why or why not?

h. Remove the stopper from one of the tubes you breathed into and place a sprig of elodea or hornwort inside. Label the 3 tubes: “C” for Control, “B” for Breathed In, and “B + P” for Breathed In and Then Added a Plant.

i. Place all 3 tubes in bright sunlight and observe changes over several days. Within a day in direct sunlight, the solution with the plant in it should begin to turn back to a bright blue.

j. If students develop other predictions about other ways to change the color, you can set up more test tubes to follow through on their ideas as well.

Part 2: To be conducted 1-7 days following Part 1

EXPLAIN

1. Tell your students the story of Jan Van Helmont.

   About 350 years ago, many people thought that all the matter in plants came from the soil, or basically that the plants “ate” the soil. Then a scientist named Jan Van Helmont decided to find out for sure. He planted a small willow tree in a pot of dry soil weighing

200 pounds. He figured that if the tree ate the soil, then the weight of the soil should decrease over time. For five years he watered and took care of the willow. It grew from 5 pounds to 169 pounds! Then Van Helmont removed the willow and weighed the soil, and it was 199 pounds and 14 ounces. In other words, it had only decreased by 2 ounces! And so he learned that the plant was not getting all of it's matter from the soil. He had revealed a mystery to us: where do plants get their matter?!

2. Invite students to discuss the following question with a partner: What was your initial explanation of where plants get their matter?
3. Provide a quick review explaining that Bromothymol blue is an indicator of the presence of carbon. When you breathed into the tubes, you were adding carbon dioxide, which turns the chemical yellow-green.
4. Ask students to observe the 3 test tubes and look for any changes. *What effect did the plant have on the color of the solution? Why do you think that happened?* Guide students to construct an explanation about the role of the plant in the reaction.

ELABORATE

1. Ask students to share what they already know or have learned about photosynthesis.
2. Summarize how photosynthesis changed the carbon dioxide molecules: *When the plant was added, it pulled in the CO_2, so the chemical turned back to its original blue color.*
3. Project ***Slide 2.1: Stomata.*** Explain: *Leaves have little holes called stomata that are kind of like their "mouths." These stomata can only be seen with a microscope. They bring in CO_2 from and release O_2 into the atmosphere.*
4. Ask your students: *If plants pull in carbon dioxide, then what do they do with it?*
5. Tell students they are now going to explore the process of photosynthesis on an atomic level.
6. Write the following on the board:

$6CO_2$	+	$6H_2O$
carbon dioxide		water

7. Have students cut apart atoms from ***Handout 2.2: Atoms for Photosynthesis.***
8. Give your students the following challenge: *Place all of your atoms face up on a large table or work surface, and then try to arrange them into six carbon dioxide (CO_2) molecules and six water molecules (H_2O), as written up on the board, by clustering*

atoms together into molecules. Demonstrate how this can be done by bringing one carbon and 2 oxygen atoms together. *This is now one carbon dioxide molecule.*

9. Once all of the groups have arranged their atoms into carbon dioxide and water, explain that these are the molecules plants need to photosynthesize. Talk about where you might find each one as you go around, saying things like, *"Oh, this must be the carbon dioxide I just exhaled!"* or *"This must be some water from the rain we had yesterday."*

10. Now explain that *plants have an incredible role in our ecosystem because only plants, algae, phytoplankton and other similar microorganisms, reacting with energy from sunlight, can take this carbon dioxide and water, break the molecules apart, and rearrange the atoms to make carbohydrates.* Add the following to your equation on the board:

$6CO_2$	+	$6H_2O$	$\longrightarrow$	$C_6H_{12}O_6$	+	$6O_2$
carbon dioxide		water		carbohydrates		oxygen

11. Give your students a new challenge: *Now see if you can rearrange all of these atoms from your molecules and make 1 new carbohydrate molecule and 6 oxygen molecules as shown on the equation on the board.* Help students as needed.

12. Once they've rearranged their atoms, review what each of these new molecules represents, as in: *This carbohydrate is part of a new branch growing on a tree. And this oxygen is getting pumped back into the air and we can breathe it in.*

13. Ask: *Now, in this process, was any matter lost? Was any new matter gained? (No, the atoms were just rearranged). This is why people might say, "Trees and plants grow out of thin air!"*

14. Find a plant and turn a leaf upside down, so that you are looking at the underside. Remind students that this is where the stomata, or "plant mouths" are generally found. Take a deep breath and then dramatically exhale some CO_2 on it as you say, *"Thank you, green plant!"*

EVALUATE

1. Go back to the heavy log observation and their original list of possible explanations about where plant matter comes from. Pose the following question to students: "*Based on the evidence you saw here today, what is your best explanation now about where the matter in this log comes from?"*

2. Ask students to think about the plant in the test tube and ask, "*What is it doing*

with that carbon dioxide we breathed into the tube?" (It's combining it with water to make carbohydrates in the form of new plant material).

3. Give students time to discuss their answers, ultimately highlighting that the matter in plants comes from water and carbon dioxide molecules that have been rearranged into carbohydrates and oxygen molecules. The oxygen molecules were released into the atmosphere, and the carbohydrates formed the plant structures we are holding. This is one of the ways in which carbon cycles on Earth.
4. Have students add new ideas to the carbon cycle model and complete the Lesson 2 Section on ***Handout 1.3: Soil Story Assessment.***

PHENOMENA-CENTERED INSTRUCTION

One of the key goals of the Next Generation Science Standards (NGSS) is to engage students with real-world, scientific phenomena. Scientific phenomena are observable events that prompt people to wonder, ask questions, and construct explanations. The best phenomena for guiding science instruction are relevant and compelling to students; too complex for students to explain after a single lesson; and observable. Observable phenomena include those that are made observable via demonstrations, video presentations, data with observable patterns, or technological tools and devices that allow us to see things at very large or small scales (telescopes, microscopes).

There are two key types of phenomena in science instruction: Anchoring and Investigative. An anchoring phenomenon is larger in scale, and can therefore provide focus for a long-term instructional unit that requires significant, in-depth understanding of several related science ideas. The anchoring phenomenon in this unit is the important role that plants and soil play in the carbon cycle. In order to make sense of that large-scale, anchoring phenomenon, the lessons in this unit also include several smaller-scale, investigative phenomena. In investigative phenomena, students gain personal experiences with observable events and are provided opportunities to construct explanations. This lesson includes two investigative phenomena: lifting the log and attempting to explain where the matter came from, and observing the Bromothymol blue demonstration and attempting to explain why our breath and then the plant were both able to change the color of the carbon indicator. These investigative phenomena help students to gain a clearer understanding of photosynthesis. Photosynthesis, in turn, is one of many scientific phenomena that students will need to understand in order to grapple with the larger anchoring phenomenon of this unit, which focuses again on the important role that plants and soil play in the carbon cycle.

Phenomena-centered instruction integrates the three dimensions of the NGSS: students use Science and Engineering Practices in order to explore Disciplinary Core Ideas that are generalizable across all domains of science (e.g., earth, life, physical, engineering) as Crosscutting Concepts. You can learn more about phenomena-centered instruction at: ***http://stemteachingtools.org/assets/landscapes/STT42_Using_Phenomena_in_NGSS.pdf***

GUIDING QUESTION

What role do soil microbes play in the carbon cycle?

FOCUS ON SCIENCE PRACTICE: OBTAINING, EVALUATING, & COMMUNICATING INFORMATION

Now, more than ever, students must be critical consumers of information. The information age has created a greater need for digital literacy. In addition, digital literacy has become extremely important in both postsecondary education and the job sector. The types of sources from which students gather evidence matter a lot in science, as does their ability to interpret these sources and gather evidence from them. Video, text, and oral presentations (e.g., lectures) can all be sources of information. Because scientists engage in the practice of digital literacy for real communicative purposes, students should be asked to do the same. This practice does not intend for students to research in the traditional sense in order to tell about something. Instead, we want students to identify evidence that supports students to make a claim, construct an explanation or develop a model. In addition, good evidence enables students to engage in argumentation and prompts them to ask new questions. In this lesson, students obtain and evaluate information from video and images, as well as from direct observations of soil. Alongside their previous experiences with the carbon cycle model and the photosynthesis investigation, they communicate how soil can sequester carbon.

KEY VOCABULARY

- **Biome:** A large, naturally occurring community of flora and fauna in a major habitat.
- **Decomposers:** Bacteria, fungus, and invertebrates that break down organic material.
- **Excretion:** The process of eliminating waste matter.
- **Microbes:** Microscopic organisms, including those living in the human body and in the soil.

KEY VOCABULARY (CONTINUED)

- **Terrestrial:** On the surface of the Earth.
- **Interdependence:** A relationship in which organisms help one another.

MATERIALS

- 1 old newspaper
- A bucket full of relatively inert dirt: You might find this on a dirt road or on the side of a parking lot. ***Note:*** *If possible, the students could collect this.*
- A bucket full of soil rich with life: You might find this on an organic farm or community garden or the bottom of a compost pile. ***Note:*** *If possible, the students could collect this.*
- A magnifying glass for each student
- Tweezers for each student
- Computer
- Projector
- ***Slides 1.4; 3.1–3.3***

Note: *Captain Planet Foundation offers educators ecoSTEM Resource Kits. Their PolliNation Kit includes Magnifying Bug Viewers, and their EARTH Kit includes soil testing kits both of which could be used to extend this activity.*

Note: *If you have microscopes in your classroom, you can also prepare slides and have your students observe these two substances under microscopes. For more information on how to do that, visit:* ***http://agron-www.agron.iastate.edu/~loynachan/LoynQuickEasy.pdf***

PREPARATION

- Set up computer and projector.
- Cue the video: *The Soil Beneath Our Feet,* 3-minute video from the California Academy of Sciences, found at: ***https://www.calacademy.org/educators/the-living-soil-beneath-our-feet***
- Make 1 copy of ***Handout 3.1: Gathering Information About "The Great Exchange"*** for each student.

SUGGESTED TIME

45 min – 1 hour

HANDOUTS

- ***Handout 1.3: Soil Story Assessment***
- ***Handout 3.1: Gathering Information About "The Great Exchange"***

ENGAGE

1. Ask your students to do a brief Quick Write on the following question: *Describe a personal relationship you have in which you and the other person both help one another. It might be a family member, a friend, or a teammate. How do you help them? How do they help you?*
2. Have students share examples in small groups or to the whole class. Use these examples to define the word "interdependence." *Interdependence is a relationship in which two or more organisms depend upon one another.*
3. Explain that students are going to learn about interdependence between plants and soil organisms. They'll also learn about how this interdependence between soil organisms and plants is important to the carbon cycle.

EXPLORE

1. Place a piece of old newspaper on each table. On top of the newspaper, give each team of 4–6 students a handful of relatively inert dirt and one of rich soil. Using magnifiers and tweezers, have your students observe and compare the two samples.
2. Have a recorder from each team write down everything their team notices that's different between these two samples, and everything they wonder about these two substances.
3. After several minutes of observation, invite students to share their initial observations.
4. Ask students to consider the claim: *Soil is full of life.* What evidence did they gather from their observations that support this claim? Ask if any of them found any life forms moving around in their soil.
5. After students share their evidence, tell them that some soil organisms are too small to see without a microscope. *In fact, in one teaspoon of healthy soil, there are more microbes than there are people on the earth!*
6. Define biome and give some examples (rainforest, coral reefs, or deserts). Explain that there's another massive biome underneath our feet: the pedosphere (soil)!

EXPLAIN

1. Introduce the ***Handout 3.1: Gathering Information About "The Great Exchange"*** and highlight the guiding question, *How are plants and soil microbes interdependent?*
2. Demonstrate how each section on the graphic organizer is for recording information from different sources (e.g., from the video, from the slide, from soil observation and from students' own background knowledge).
3. Set purpose for viewing the video, ***The Living Soil Beneath Our Feet***. As they watch, ask students to focus on ways the different organisms rely on each other. Then watch the video together.
4. Debrief the video. Ask students what evidence they gathered that plants and soil microbes are interdependent. Probe for examples of interdependence (e.g., ways that trees are helping the fungi and bacteria, and ways the fungi and bacteria are helping the trees).
5. Give students time to record ideas on the graphic organizer. Remind them they can use pictures, words, or notes to convey their ideas.
6. Project ***Slide 3.1: The Great Exchange.*** Explain that the biodiversity in the soil biome is critical because inside soil a "Great Exchange" is taking place, wherein the plants and the soil organisms are interdependent: they help one another grow healthy and strong!
7. Project ***Slide 3.2: Plants and Soil Organisms Working Together.*** Ask students what they notice. If they don't mention it, reiterate that *bacteria and fungi are critical for plant growth and for building soil. These organisms break down nutrients in the soil and supply them to the plants through their roots. In exchange, the plants "leak" some of their carbohydrates to feed the bacteria.*
8. Introduce new information: *Fungi and bacteria are made up of carbon that was once in the atmosphere. And when they die, that carbon is held in their bodies in the soil.*
9. Again, provide students with the opportunity to record more ideas in the appropriate sections on the graphic organizer.

ELABORATE

1. Show ***Slide 3.4: Sequestering Carbon in the Soil***. Have your students grab a handful of the healthy soil they were exploring before, and look for places where it has bunched together. Now have them do the same for the relatively inert dirt. What differences do they notice? Explain that all of the sponginess and air pockets they notice in the healthy soil are formed by "glues" made from dead fungi and bacteria. These glues are full of carbon that could be polluting our atmosphere but, instead, are now sequestered in our soil!
2. Show ***Slide 1.4: The Carbon Cycle Today.*** Discuss the carbon cycle and the impact of human activity on the amount of carbon in our atmosphere. Ask, *How do you think this "Great Exchange" happening in the soil might impact this Carbon Cycle? What new arrows or ideas can we add to this model?*
3. If no one mentions it, explain the following: *The living organisms in the soil create the glues that enable the soil to hold and store carbon because they are made from the carbon that the plants pumped in from the atmosphere. This is really exciting because, in order to bring our carbon cycle back into balance, we're going to need to do two things: reduce the amount of carbon we're releasing into the atmosphere, and capture and store some of the excess carbon that we've already pumped into the atmosphere. The soil gives us a place to store that carbon.*
4. Discuss how humans benefit from "The Great Exchange". *The Great Exchange not only helps us with restoring balance to the carbon cycle, it makes our food more nutritious. In exchange for carbohydrates from the plants, fungi and bacteria provide plants with more nutrients and help them access more water. These nutrients go into the plants which, of course, provide food for us and other animals. You could see in that video how the fungi helped extend the reach of the plants' roots. If there are no fungi and bacteria, plants are losing the opportunity to get more root surface area (up to 10,000 times more). With more root surface area, we're able to get more minerals and trace minerals in our food.*

EVALUATE

1. Have students add new ideas to the carbon cycle model and complete the Lesson 3 Section on ***Handout 1.3: Soil Story Assessment.***

EXTENSION

You can use flour and water to create a model of how relatively inert dirt and living soil differ in their absorption of water, and tendencies to erosion. This exercise comes from one of our favorite teaching resources:

Understanding Soil Health and Watershed Function by Didi Pershouse.

The description of this activity is part of a facilitator's manual that can be downloaded for free at ***http://soilcarboncoalition.org/learn***, along with other resources.

EVIDENCE-BASED REASONING

Reasoning is one of the more complex cognitive tools a scientist uses. Reasoning gets at the purpose of evidence-gathering practices and adds credibility to a scientific explanation because it helps connect the dots between the claim and the evidence that supports the claim. Engaging in the practice of constructing explanations requires that students understand the role of reasoning. Using prompts like, “What do you think?” and “How do you know?” can help create a culture of evidence-based reasoning in your science classroom. In this lesson, we ask students to make sense of the role soil microbes play in the carbon cycle. It is not immediately observable how these tiny organisms break down matter, so we use observations to make sense of it. When students squish the soil sample in their hands and notice how it sticks together, they are gathering evidence for the presence of microbes in one soil sample and not the other. They can “reason” that the soil microbes “do” something in the soil. In this way, the experience enables students to develop a more complete model of the carbon cycle. If your students need more practice with evidence-based reasoning, the BEETLES Project offers the following learning session to support educators with engaging students in this practice: ***http://beetlesproject.org/resources/for-program-leaders/evidence-and-explanations/***

GUIDING QUESTION

What role do farmers play in the carbon cycle?

FOCUS ON SCIENCE PRACTICE: ENGAGING IN ARGUMENT FROM EVIDENCE

As a human social enterprise, science is subject to debate. The nature and quality of evidence used, the methods by which evidence is collected, and how evidence is interpreted may vary from scientist to scientist. Therefore, the discipline relies on a community of scientific practice that engages in processes of sense-making and consensus-building. In this lesson, students evaluate the argument that composting is a valuable practice that nurtures soil and reduces the amount of carbon in the atmosphere. They then sort agricultural practices and give reasons for why they think that each practice is a soil-building practice or a soil-depleting practice. The Lawrence Hall of Science offers resources to help teachers understand and teach scientific argumentation at: ***argumentationtoolkit.org***

KEY VOCABULARY

- **Humus:** An organic component of soil created by the decomposition of leaves and plant material by microorganisms.
- **Organic Matter:** Carbon-based compounds, which includes all matter that comes from the remains of plants and animals and their waste.
- **Upcycling:** Reusing a material for a purpose that has a higher value than the original material.

MATERIALS

- Computer
- Projector
- ***Slides 4.1–4.6***
- Paper
- 2 or more pieces of different local, fresh fruits or vegetables for each student. Depending on your location and season, some great options include:
  - Vegetables that can be enjoyed raw, like sugar snap peas, sliced carrots, or cherry tomatoes
  - Unique fruits like sliced kiwi, persimmon, or figs

SUGGESTED TIME

30 – 45 min

PREPARATION

- Set up computer and projector to show slides.
- Print handouts.
- Wash and prepare food for the tasting (see Tasting Ideas on page 37 for more information).
- Cut out ***Handout 4.2: Agriculture Practice Cards***
- Set up computer and projector.
- Cue the video: *The Compost Story* ***www.thecompoststory.com***

HANDOUTS

- ***Handout 4.1: Why Compost?***
- ***Handout 4.2: Agricultural Practice Cards***
- ***Handout 1.3: Soil Story Assessment***

ENGAGE

1. Project ***Slide 4.1: Microbes in Our Gut*** and explain that, *Just like soil, we have microbes living inside our bodies!*
2. Project ***Slide 4.2: Microbes in Our Gut*** and ask students to interpret the image. After discussing a few students' responses, mention the following: *The number of microbes appears to be increasing as you move down. By the bottom of the slide, we*

are into the billions. Ask students what each circle might represent.

3. Project ***Slide 4.3: Microbes in Our Gut*** and discuss what each circle represents: the number of microbes in each part of our gut. Highlight the following: *Our stomachs and other parts of our bodies are, in fact, small "habitats" for billions of microbes. In fact, when taken all together, these microbes weigh about 3 pounds, which is about the same weight as our brains!*
4. Ask students: *How do you think these microbes might be similar to those found in the soil? How might they be different?*
5. Explain the following: *These microbes are different than those found in the soil, but interestingly they promote human health just like soil microbes promote soil health. Scientists are learning more all the time about how microbes help keep the human body healthy.* Ask, *Have you heard of eating yogurt or other foods that are high in probiotics as a way to promote health, especially after taking a round of antibiotics? The idea behind that is that yogurt is full of probiotics, which are microbes that are helpful to our bodies, and these can replace some of the microbes we may have damaged or killed with antibiotics. With newfound information on how these microbes help us stay healthy, many people believe that the pharmaceutical drugs of the future will be microbes we can ingest and the foods* ***they*** *eat, with the understanding that promoting* ***their*** *health will, in turn, promote our own health.*
6. Set purpose for the upcoming Mindful Tasting activity: *Feeding ourselves and our microbes fresh, nutritious food is a good way to stay healthy.*
7. Remind students of the following: *Some microbes make us healthy but others can make us sick. In particular, some microbes found in soil can make us sick, which is why we wash our produce and hands before eating.* Then have students was their hands thoroughly before conducting the Mindful Tasting.

EXPLORE

Introduce norms for the Mindful Tasting.

a. Introduce the produce you have and share anything you know about where it was grown, by whom, etc. Ask students: *How did the soil microbes help this produce grow?*
b. Explain that you're going to taste some fresh foods in a way that highlights the flavors and textures of the food they're trying.
c. When they get their piece of produce, they can use all of their senses except

for taste to explore it: *What does it look like? Feel like? Smell like? Does it make a sound when you rub the skin or knock on it?*

d. Model with how to pay attention to taste. Explain that now you will focus all of your attention on how the food tastes and feels. Close your eyes and practice with one piece of produce. Open your eyes and share your reaction to the taste. Use as much descriptive language as possible.

e. Tell students that you hope they'll try everything, but they do not need to finish anything they don't like.

f. Discuss with them polite ways to react if they don't like something that's been given to them. For example, they might spit it out into a napkin and throw it in the compost or trash subtly. Or they might say, "Thanks for that, but it turns out that those aren't my favorite."

g. Handout produce, one at a time, and guide students to taste.

EXPLAIN

1. Debrief the tasting. Ask students what foods they liked best and why. If students like some foods because they taste "sweet," you might explain how some plant parts (e.g., strawberry) are sweeter than others (kale). Notice a relationship between plant part, and the amount of sugar in the piece of produce.
2. Ask if students could taste the nutrients in the foods they tried. Explain that, although they can't taste nutrients, taste can be evidence of freshness and fresh food is often more nutritious.
3. After finishing, pose the following question for students to discuss in groups of 3 or 4: *How do farmers grow nutritious food for us to eat?* Take possible answers. If it doesn't come up, remind students about soil microbes and how they provide nutrients to plants.
4. Introduce ***The Compost Story*** Video and invite students to share their experiences with composting. Prepare students to watch the video, asking them to take notes about the central message of the video.

   www.thecompoststory.com
5. Watch the video, pausing at strategic points and asking students to discuss the ideas they obtained so far.
6. After finishing, pose the following question for students to discuss in groups of 3 or 4: *"Why do the actors in the video argue that we are crazy not to compost? Do*

you agree or disagree? Support your answer with evidence."

7. Introduce ***Handout 4.1: Why Compost?*** Show students to distinguish an idea that is a claim from one that is evidence.
8. Give students time to work in groups to complete the Why Compost? graphic organizer.
9. After several minutes, ask groups to share their ideas. Prompt them to provide evidence for their choices.
10. Conclude by asking if students thought the message or argument in *The Compost Story* was convincing.

ELABORATE

1. Show ***Slides 4.4 through 4.6: Are We Building or Depleting Soil?*** Explain that there are different types agricultural practices farmers use. Some practices degrade soil and others build it back up.
2. Explain the next activity: *Students will get cards with images of agricultural practices. Their job is to use their understanding of soil, farming and carbon to determine if they think the practice degrades or builds the soil.*
3. Ask, *what kind of practice is composting and why?* Put the card for "composting" in the "Soil Building" category.
4. Give each team of 3–4 students a set of ***Handout 4.2: Agricultural Practice Cards.*** Have teams of students work together to categorize their cards two groups based on their initial ideas: Soil-Building Practices and Soil-Depleting Practices.

EVALUATE

1. Ask students to reflect on the various agricultural practices and discuss barriers that prevent farmers from using soil-building practices. (Possible answers include increased costs involved in transitioning to a new way of growing; limited knowledge of alternatives; information and advertising done by chemical companies; and the like.)
2. Make sure students understand that farmers aren't trying to do damage to the Earth. Until recently, scientists didn't know as much about the critical role soil

plays and the impacts of conventional agricultural practices.

3. Let students know: *Composting isn't just for farmers. Anyone can do it!* In the final lesson of the unit, they will choose their own way to take action.
4. Have students add new ideas to the carbon cycle model and complete the Lesson 4 Section on ***Handout 1.3: Soil Story Assessment.***

TASTING IDEAS

For your Mindful Tasting activity, we recommend using seasonal, local, fresh, organic produce both because it will taste great and also because it reflects a consumer choice to support farmers who use soil-building practices. If you have a school garden or a local garden or farm to visit, this would be an ideal time to go and harvest something together with your students. If not, you can bring in fresh produce or take a field trip to a local farmer's' market to purchase these together. Farmers will often sell larger quantities of produce at reduced rates or donate at the end of a market day. Remember that each student doesn't need his/her whole own fruit or vegetable for this activity. You can slice 1 apple, for example, to provide a tasting for 10 students.

Here are a few fun options to take your Mindful Tasting to the next level:

Host a Blind Taste Test.
Invite two volunteers to come up. Have them close their eyes or wear blindfolds. Give each one a type of produce and challenge them to guess what it is. The first person to get it right wins.

Conduct a Vote for the Best Produce.
Have each student vote for the one they liked the best. You could do this between two different foods (i.e. apples and oranges); between different varieties of the same food (e.g., Fuji and Pink Lady apples); between two foods that were grown in different ways (e.g., conventional and organic apples) or between 2 foods prepared in different ways (e.g., fresh and dehydrated apples).

Cook or prepare a meal together including fresh produce.
For some youth-friendly, garden-fresh recipe ideas, visit: ***http://www.lifelab.org/2012/08/garden-recipes/***

GUIDING QUESTION

What role do you play in the carbon cycle?

FOCUS ON SCIENCE PRACTICE: ASKING QUESTIONS AND SOLVING PROBLEMS

Humans are innately curious. Very young children often pose questions when they can't yet make sense of something they experience. In science, questions serve to further the pursuit of new knowledge about how the world works. The primary purpose of these questions is to solve a real-world problem. Some questions, such as: "How can we reduce the amount of carbon in the atmosphere?" are too complex to be answered in one investigation, by one scientist, or in a set amount of time. Nonetheless, all questions move investigation forward. In the final lesson, students are prompted to consider their own questions and develop ideas for solutions based on observations of environmental problems they see on their school campus or in their community.

MATERIALS

- Chart Paper
- Colored pencils
- Labels: "Agree" and "Disagree"

HANDOUTS

- ***Handout 1.3: Soil Story Assessment***
- ***Handout 5.1: Environmental Impact Survey***
- ***Handout 5.2: Farmer Gabe Brown's Five Fundamentals of Soil Health***

SUGGESTED TIME

45-60 min., plus additional sessions to complete a project

PREPARATION

- Post "Agree" and "Disagree" labels on opposites sides of the room.
- Print one copy of ***Handout 5.2: Farmer Gabe Brown's Five Fundamentals of Soil Health*** for each student.

ENGAGE

1. Pose the following imaginary scenario: *You're in a park and you overhear someone talking about the amount of carbon in the atmosphere. Then their friend says, "There's a solution! The solution is in the soil, building healthy soil."*
2. Conduct a "Vote with Your Feet" activity, like you did in Lesson 1.
   a. Have students stand and walk to the end of the room that represents how strongly they agree or disagree with the statement. In this case, they might also stand anywhere in between to represent that they agree or disagree somewhat.
   b. Have them share with other people standing near them their reasoning for answering the way they did.
   c. Ask for some volunteers from each spot on the spectrum share out why they chose to stand where they did. As students share, invite other students to move spots if they feel persuaded by a particular argument.
3. Tell the Kiss the Ground Origin Story:

   In the Spring of 2013, Ryland Engelhart, Co-Owner of Cafe Gratitude (CA based organic, vegan restaurant), heard about soil as a solution to carbon cycle *imbalance from Graeme Sait, a farming educator, at a conference in New Zealand. Ryland learned that building healthy soil has the miraculous ability to sequester carbon from the atmosphere, and knew in his heart it was a story that had to be shared with the world. Ryland told Finian Makepeace, childhood friend and professional musician, and together they began telling others about the power of healthy soil. They gathered an inspired group of friends every week in Ryland's living room: filmmakers, marketing experts, restaurant owners, musicians, gardeners, designers, soil advocates, and activists. Kiss the Ground was born from weekly meetings of dedicated and inspired friends. Since, the organization has participated in national and international coalitions to accelerate carbon farming and regenerative agriculture. They've affected California state policy to support healthy soils. They've released educational videos and in 2018 will release a full length documentary. They've inspired brands to take on carbon farming and regenerative agriculture in their supply chains. Their work is growing, all from an inspired moment and a desire to protect our planet for future generations, and they've invited us to join them!*

EXPLORE

1. Use the Kiss the Ground Origin Story to inspire students to take steps to improve their community or campus.
2. Pass out ***Handout 5.1: Environmental Impact Survey***. Using the colored pencils and paper, have students work in small groups to draw a map of their school campus. Instruct them to include any outdoor landscape (garden, bare land, grassy areas, etc.).
3. Take a walk around campus with your students. As students walk around campus, instruct them to document on their map where they notice an area where something could be done to regenerate the soil or otherwise change the campus for the better. ***Note:*** *this activity might require additional research and interviewing. For example if students want to identify if pesticides or fertilizer are being used on the landscape, they may need to speak with administration and/or maintenance staff.*
4. Have students read ***Handout 5.2: Farmer Gabe Brown's Five Fundamentals of Soil Health***. Then have them work in pairs to add to their maps 2 or more new ideas, inspired by the reading, for regenerating soil on their campus.

EXPLAIN

1. Explain the culminating activity for this unit to students: *In order to demonstrate what you have learned about the role plants, microbes, farmers, and all people play in the carbon cycle, your final task is to create a project that is designed to address one or more of these areas.*
2. Brainstorm ideas with students. Record all ideas on a chart. See Project-Based Learning on page 38 for details.
3. Support students as they design and carry out their projects. See Project-Based Learning on page 38 for further information.

ELABORATE

Following their projects, students can produce and submit a video or photos of their work to Kiss the Ground to be shared broadly on social media. If you would like to submit videos and/or photos, please send them to ***Jessica@kisstheground.com*** along with your school name and a description of the project.

EVALUATE

1. Have students revisit their carbon models and complete the final question on ***Handout 1.3: Soil Story Assessment.***
2. Conduct a final reflection discussion, inviting students to share what they learned, what they enjoyed most, and what they hope to continue doing to regenerate the soil and improve our role in the carbon cycle.

PROJECT-BASED LEARNING

Project-based learning (PBL) is an approach guided by the principles of experiential learning in which students apply what they learn to a engage in an extended real-world, hands-on project. Successful projects begin with robust driving questions and allow students to actively investigate solutions to complex problems. Project-based learning is best implemented collaboratively and technology is often a primary tool for completing projects. For these reasons, PBL is very compatible with other 21st century skills. Sharing projects with an outside audience is an effective way to showcase what students have learned as well as for inspiring and promoting change in people's behavior. We've outlined a few composting projects to spark ideas for your students, but any project related to carbon on Earth would work well with this unit. The best projects are those chosen and designed by the students themselves. The Buck Institute for Education provides planning guides, grading rubrics, how-to videos and more to support teachers in designing and facilitating quality Project Based Learning at ***www.bie.org.***

Example Projects

- Students may choose to use the **Compost Cake lesson** found in the Teaching Resources to build a compost pile at school or begin composting at home.
- Students may choose to use the **Cal Recycle Worm Guide** to start a worm compost bin at school, found at: ***http://www.calrecycle.ca.gov/Education/Curriculum/Worms/***
- Students may use the **School Composting Resource** to start a school-wide composting program, found at: ***http://www.lifelab.org/composting/***
- Students may choose to **support composting at home.** They could request a green waste bin from their city; and/or find a neighbor or community garden that will accept their compostable material.
- Students may choose to share the Environmental Protection Agency's **Guide to Composting at Home** with other interested students and families, found at: ***https://www.epa.gov/recycle/composting-home***
- Students may choose to **arrange a field trip to a local landfill or a waste hauling facility** to gain perspective on just how much waste humans produce and then design a project to reduce that waste, such as reusing materials, or composting at school or at home.
- Students may choose to participate in a **citizen science project** (***http://crowdandcloud.org***) related to any of the issues discussed in this unit.

PROJECT-BASED LEARNING (CONTINUED)

- Students may choose to participate in the **Alive and Awake: Earth Challenge** (***https://iamaliveandawake.com***) to sequester carbon through tree planting.
- Students may choose to use the **What are Perennial Plants** (***http://www.lifelab.org/for-educators/schoolgardens/perennials/***) as a guide to start a perennial garden on campus or at home.
- Students may choose to take on an activity in the **Understanding Food and Climate Change Guide** (***https://foodandclimate.ecoliteracy.org/interactive-guide/cover.xhtml***) the address climate and the food system.

LESSON 1: EARTH'S SYSTEMS

ESS2.A: Earth's Materials and Systems

All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS-ESS2-1) The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

ESS3.C: Human Impacts on Earth Systems

Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3) Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3),(MS-ESS3-4)

LESSON 2: PHOTOSYNTHESIS

LS1.C: Organization for Matter and Energy Flow in Organisms

Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6) Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7)

PS3.D: Energy in Chemical Processes and Everyday Life

The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6) Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7)

LESSON 3: HEALTHY SOIL

LS2.A: Interdependent Relationships in Ecosystems

Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1) In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2- 1) Growth of organisms and population increases are limited by access to resources. (MS-LS2-1) Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)

MS-LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health. (MS-LS2-5)

LESSON 4: FOOD AND FARMING

LS4.D: Biodiversity and Humans

Change in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

LESSON 5: TAKING ACTION

ETS1.B: Developing Possible Solutions

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS-LS2-5)

The scientific community generally agrees that the rise in global temperature and its related impacts (i.e., climate change) is due to increased levels of carbon in the atmosphere and, extremely likely, a result of human activity on Earth. However, not all student understanding will be consistent with this scientific perspective, which presents a tremendous challenge for educators teaching about this topic. Because climate change is such a contentious issue, we treat the role of human activity lightly. Rather than confront students' existing beliefs head-on, we introduce students to the ways in which scientists engage in their work. Using the focal science and engineering practices, such as using and developing models, constructing explanations, obtaining, evaluating, and communicating information, engaging in argument from evidence, and asking questions and defining problems, students are allowed to reach their own conclusions about human impact. These evidence-based ways of thinking invite students to engage like scientists by collecting and evaluating available evidence and using a model to represent an explanation of what happens when carbon moves between living and nonliving things.

Recognizing the public controversy over the existence and causes of climate change, we have designed a curricular guide that we believe meets the needs of any educator looking to incorporate soil study into their middle school instructional sequence. However, we at Kiss the Ground take a forward-thinking approach on this topic. We take a hopeful stance that 21st century students are open to the ideas presented in *The Soil Story* video. To that end, we would like to elaborate on some of the ideas presented therein and offer additional resources for delving deeper into the topic of climate change. In addition, we have listed below additional resources specifically designed to teach about the evidence behind the scientific consensus around climate change in more depth.

Where is carbon found on Earth?

Carbon has been on Earth for billions of years. When humans extract fossil fuels, we release carbon that was previously locked in the rocks and minerals of the geosphere. Excess carbon in the atmosphere traps heat, which causes global temperatures to rise. According to scientific evidence, temperatures are increasing more quickly than they have in the past, leading to arctic ice melt, sea level rise, and shifts in regional weather patterns.

Natural phenomena and human activity can both change the nature of where and how carbon is stored as matter. Scientists think current levels of carbon in the atmosphere are potentially dangerous to biodiversity and the health of the planet. In order to rebalance the carbon cycle, we need to reduce the amount of carbon in the atmosphere. One way to do this is to leverage naturally-occurring processes in the pedosphere. Soil has the incredible ability to capture and store (i.e., sequester) some of the carbon already in the atmosphere and put it back to work in the biosphere.

What role do plants play in the carbon cycle?

Plants, during the process of photosynthesis, use energy from the sun to convert carbon dioxide and water molecules into chemical energy, which they store as carbohydrates.

When plants are eaten by animals or when they die and decompose, carbon is returned to the atmosphere through respiration and decomposition. While plants live, however, they continue to pull carbon from the atmosphere, store it in plant material and pump it into the soil.

What role do soil microbes in the carbon cycle?

Nature's ability to build soil and feed plants is responsible for making the soil a larger pool of carbon than the atmosphere and biosphere combined! This process not only helps us sequester carbon from the atmosphere; healthy, biodiverse soil also provides us with nutrient-rich foods that support our health.

What role do farmers play in carbon cycle?

Conventional agricultural practices—including overgrazing, clearcutting, monocropping, tilling, use of synthetic pesticides, herbicides, fungicides, and fertilizers, and leaving soil bare—are all degenerative because they decrease soil biodiversity and increase carbon emissions into the atmosphere. In this sense, conventional agriculture is a big contributor to climate change.

Humans can't just give up farming altogether, but farmers can restore soil health with soil-building agricultural practices. Planned grazing, selective cutting, polycultures, no- or low-till farming, organic fertilizers, composting, and planting cover crops all allow farmers to increase soil biodiversity and sequester carbon in the soil while growing food and fiber. In this way, agriculture has the potential to become part of the solution to climate change.

What role do you play in the carbon cycle?

Just as farmers can shift from soil-depleting to soil-building practices, we can also be part of the climate change solution! Many concepts of regenerative agriculture can be translated to organizations and individuals who are not necessarily in the business of agriculture. For example, schools can choose to compost food waste instead of sending it to the landfill. We all make many small choices everyday that add up to our individual "carbon footprint." Although we cannot measure each individual's impact on a daily basis, we can see the collective impact humans have on the planet and use scientific practices to address the unintended negative effects our choice may have.

NGSS DISCIPLINARY CORE IDEAS ABOUT HUMAN IMPACT

ESS3.D: Global Climate Change

Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

CURRICULAR RESOURCES DESIGNED TO TEACH ABOUT HUMAN IMPACT

Center for Ecoliteracy: "Understanding Food and Climate Change": ***www.ecoliteracy.org***

Climate Generation Curricula for Grades 3–12: ***https://www.climategen.org/5***

MARE Ocean Science Curriculum Sequence: ***http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence***

Mitigating Climate Change through Composting and Planting Trees: ***http://bit.ly/cotwo***

Soil Carbon Coalition: ***https://soilcarboncoalition.org/learning/Flour-and-Water-INVESTIGATION.pdf***

Soil Science Society of America: ***http://www.soils4teachers.org/home***

National Aeronautic and Space Administration (NASA) Global Climate Change:
https://climate.nasa.gov/causes/
https://climate.nasa.gov/interactives/climate-time-machine

National Center for Science Teaching (NCSE): ***https://ncse.com/library-resource/teaching-climate-change-best-practices***

Soil and Regeneration

Videos

1. ***The Soil Story***
2. *Edward Norton is The Soil*
3. *Why Soil Matters*
4. *Soil Solutions to Climate Problems*, narrated by Michael Pollan by the Center for Food Safety
5. *Earth As An Apple*

Books

Cows Save the Planet

Dirt: The Erosion of Civilizations

Farmacology: Total Health from the Ground Up

Gaia's Garden: A Guide to Home-Scale Permaculture

Grass, Soil, Hope

Holistic Management Handbook

Kiss the Ground: How the Food You Eat Can Reverse Climate Change, Heal Your Body and Ultimately Save Our World

Permaculture, Designer's Handbook

Restoration Agriculture

Rodale's Basic Organic Gardening: A Beginner's Guide to Starting a Healthy Garden

See more from the *Soil Not Oil Coalition*

Tending the Wild

The Carbon Farming Solution

The Rodale Book of Composting: Easy Methods for Every Gardener

The Soil Will Save Us

Water in Plain Sight

Grant Resources:

http://www.noaa.gov/office-education/elp/grants

https://kidsgardening.org/garden-grants/

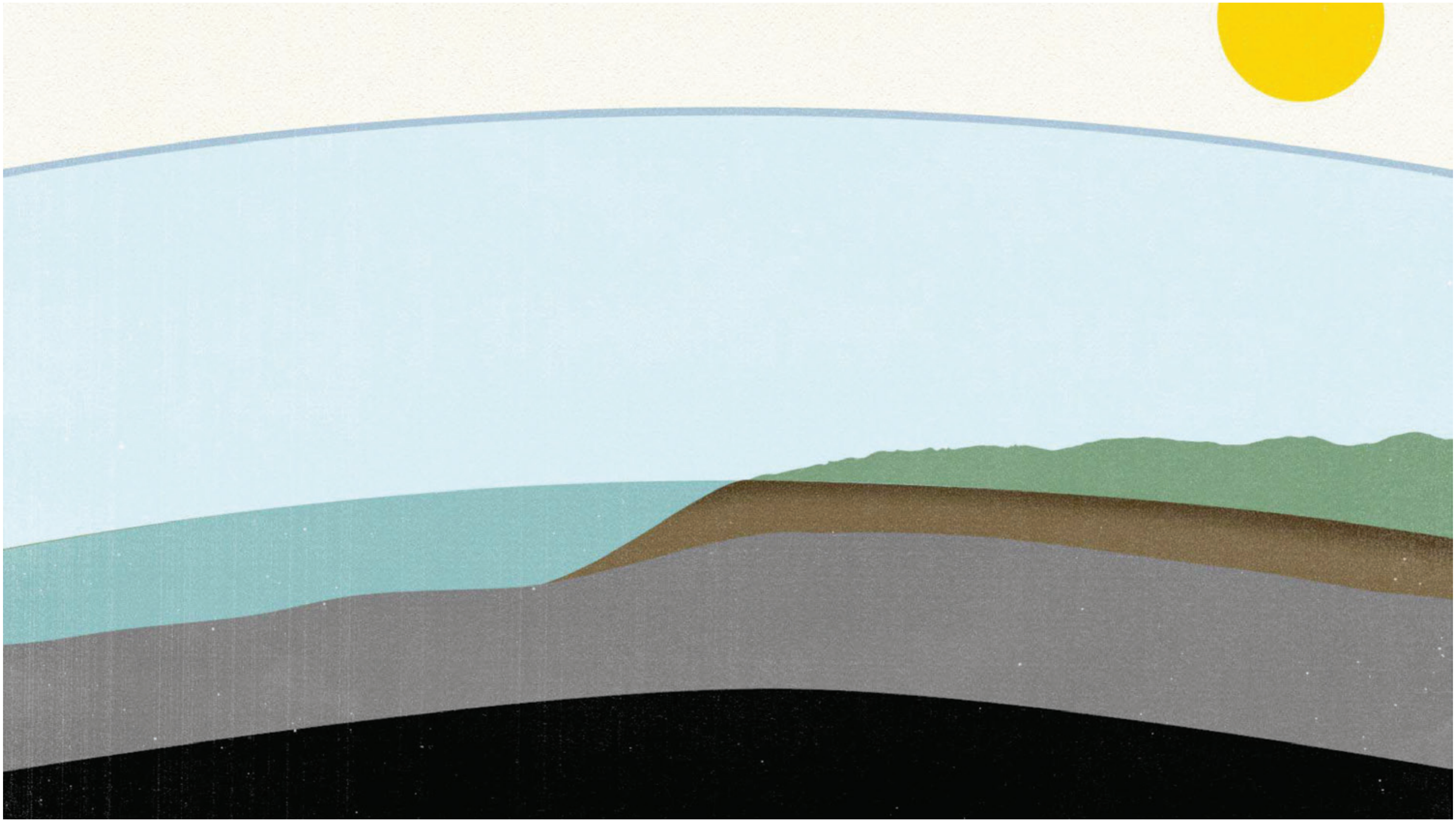
https://www.exploravision.org/what-exploravision

Captain Planet Foundation *https://captainplanetfoundation.org/grants/*

HANDOUT 1.1:
Carbon Cycle Model

NAME: ____________________

DATE: ____________



HANDOUT 1.2:
Carbon Cycle Modeling Tools

Ocean animals exhale carbon dioxide (CO_2).

Land animals exhale carbon dioxide (CO_2).

Ocean plants and animals decompose.

Land plants and animals decompose.

Ocean plants take in carbon dioxide (CO_2) and use the carbon to grow more leaves.

Land plants take in carbon dioxide (CO_2) and use the carbon to grow new leaves.

Ocean plants and animals die, get buried, and eventually become fossilized.

Land plants and animals die, get buried, and eventually become fossilized.

Carbon dioxide (CO_2) from the air mixes into the surface of the ocean.

ATMOSPHERE

BIOSPHERE

GEOSPHERE

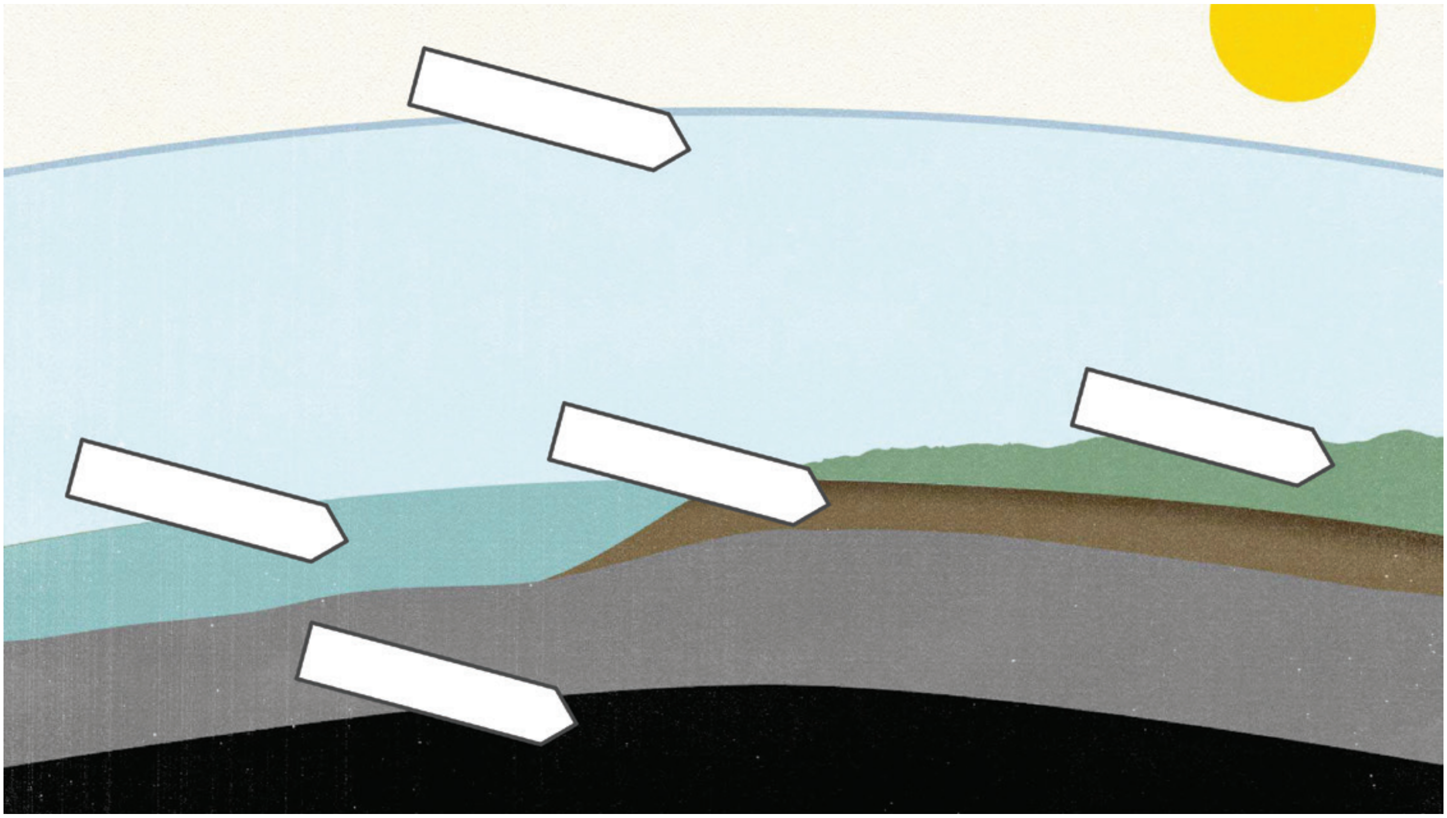
PEDOSPHERE

HYDROSPHERE

HANDOUT 1.3:
Soil Story Assessment

NAME: ______________________________

DATE: ______________



1. Place the labels in the locations where you think they exist on Earth.

Geosphere   Pedosphere   Hydrosphere   Biosphere   Atmosphere

2. Then, write on the diagram the types of matter found in each sphere

Rocks	Plants	Soil	Life
Oceans	Minerals	Rivers	Water Vapor
Air	Fossils	Dust	Animals
Water	Pollen	Microorganisms	Lakes

3. Circle the systems on Earth where you think carbon can be found.

LESSON 1 Where is carbon found on Earth?

LESSON 2 What role do plants play in the carbon cycle?

LESSON 3 What role do soil microbes in the carbon cycle?

LESSON 4 What role do farmers play in carbon cycle?

LESSON 5 What role do you play in the carbon cycle?

HANDOUT 2.1:
Bromothymol Blue Reaction Observations

NAME: ____________________

DATE: __________

**1. Observe the 3 test tubes filled with Bromothymol blue.
Depict the change you observe in Diagrams 1 and 2.**

DIAGRAM 1
Before

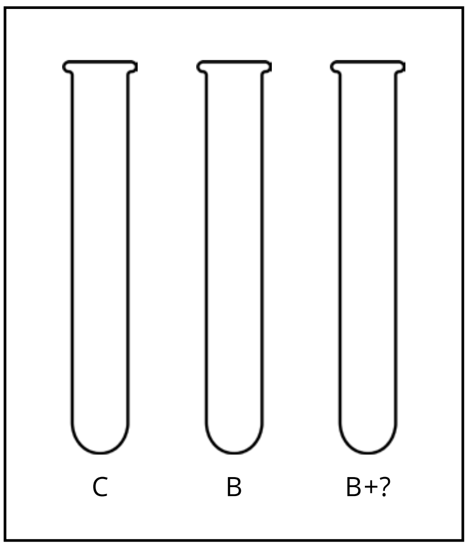


DIAGRAM 2
After

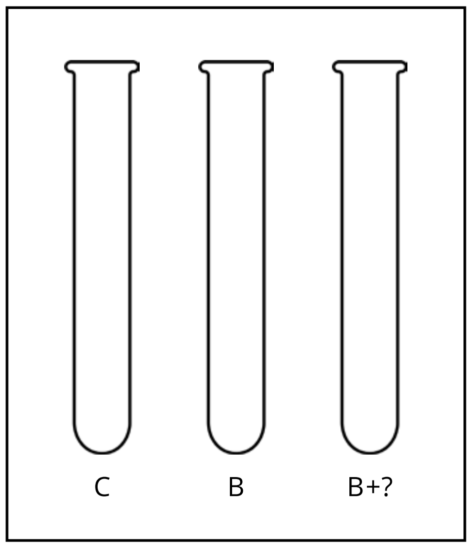
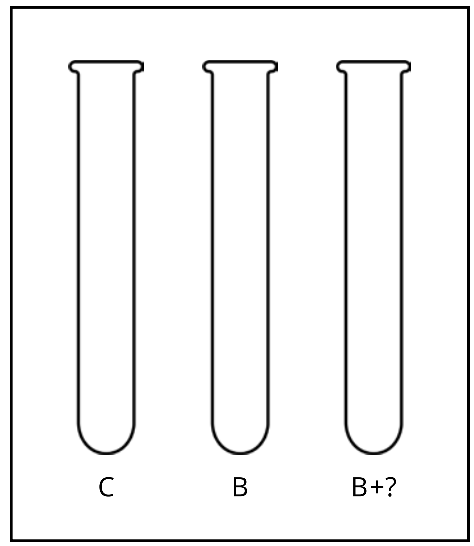


DIAGRAM 3
1-7 Days after we did something to change the color back to blue

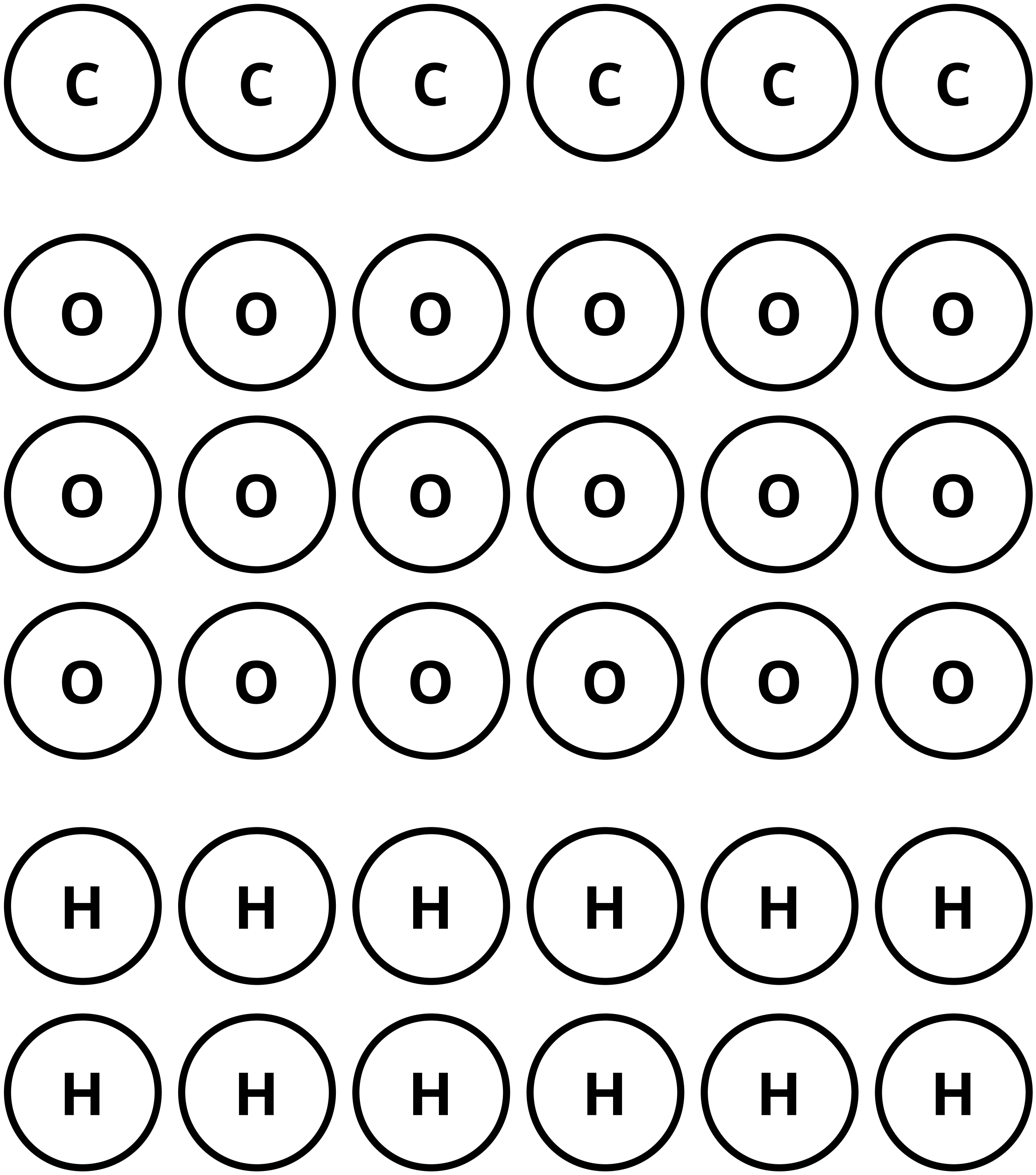


C=Control B=Breath Added ? = Something done to try to change the color back to blue

2. Add arrows and labels to Diagram #2 to show what you think caused the change you observed.

**3. How might you change the color in those tubes back to blue?
List your ideas here:**

HANDOUT 2.2:
Atoms for Photosynthesis



HANDOUT 3.1:
Gathering Information about "The Great Exchange"

NAME: ____________________

DATE: __________

IMAGES + TEXT

VIDEO

SOIL OBSERVATION

HOW ARE PLANTS AND SOIL MICROBES INTERDEPENDENT?

BACKGROUND KNOWLEDGE

OTHER

DISCUSSION

HANDOUT 4.1:
Why Compost?

NAME: ____________________

DATE: ____________

Directions: After watching The Compost Story video, choose one claim made in the video to draft an argument for the benefits of composting, by selecting 3 or more pieces of evidence from previous lessons that support that claim.

Guiding Question: What role do farmers play in the carbon cycle?

Compost Claims from The Compost Story video:

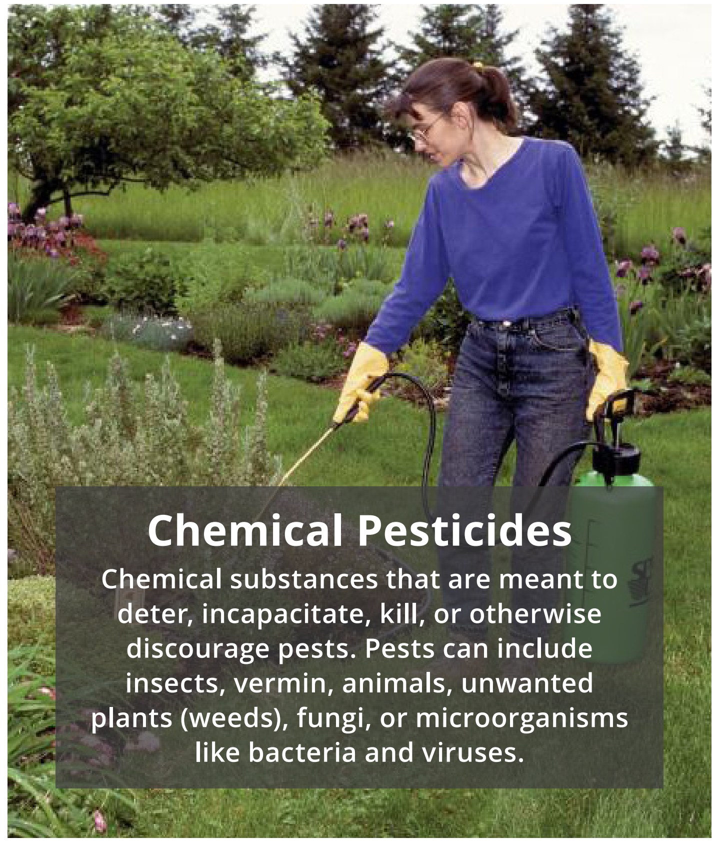
- Compost can enhance food nutrients, increase crop yield, and strengthen plants' immune systems, all while increasing the soil's water holding capacity.
- Compost can help restore our underground water supplies, fertilize farms, and produce tastier, more nutritious foods.
- Compost stimulates plant growth, retains water, and adds humus to depleted soil.

CLAIM:
EVIDENCE FROM LESSON 1: CARBON ON EARTH
EVIDENCE FROM LESSON 2: PHOTOSYNTHESIS
EVIDENCE FROM LESSON 3: SOIL MICROBES
EVIDENCE FROM LESSON 4: COMPOST

HANDOUT 4.2:
Agricultural Practice Cards

Integrated Pest Management

An ecosystem-based strategy that focuses on low-input, long-term prevention of pests and disease through a combination of techniques, such as diversification, biological control, habitat manipulation, modifying cultural practices and use of resistant varieties that challenge conventional systems.

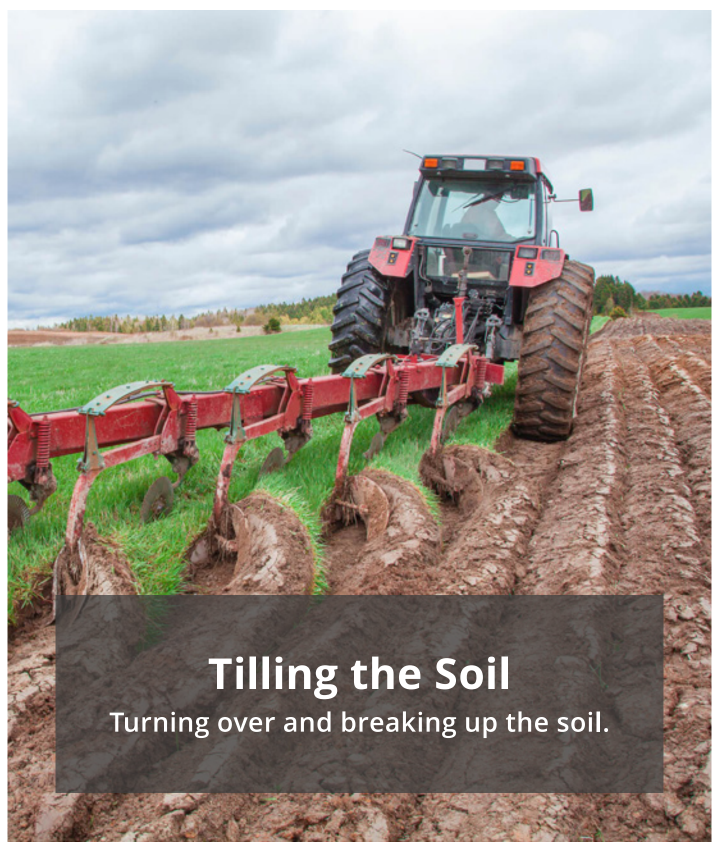


Chemical Pesticides

Chemical substances that are meant to deter, incapacitate, kill, or otherwise discourage pests. Pests can include insects, vermin, animals, unwanted plants (weeds), fungi, or microorganisms like bacteria and viruses.

No-Till Farming

A way of growing crops or pasture from year to year without disturbing the soil through tillage.

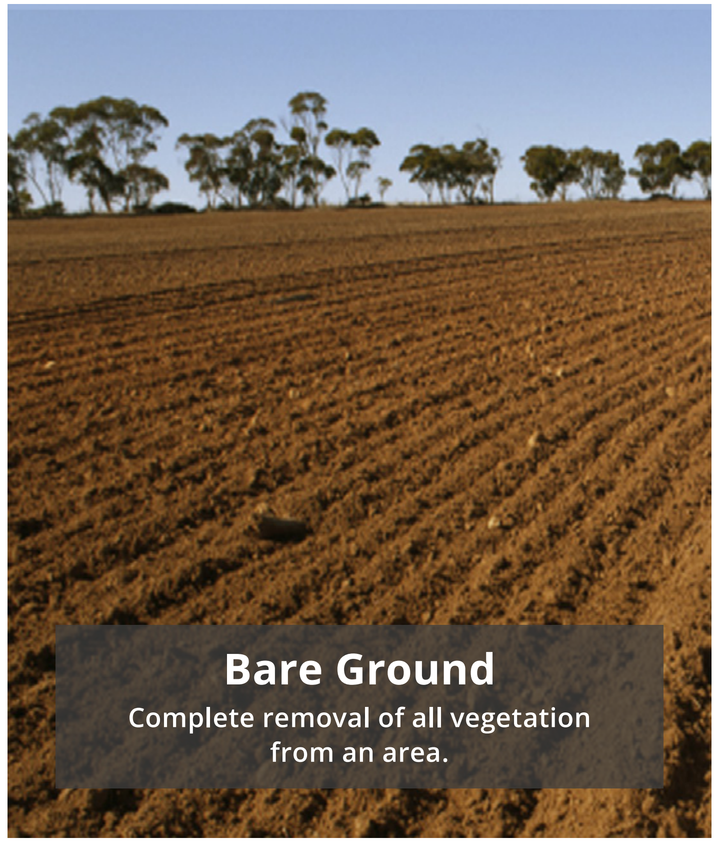


Tilling the Soil

Turning over and breaking up the soil.

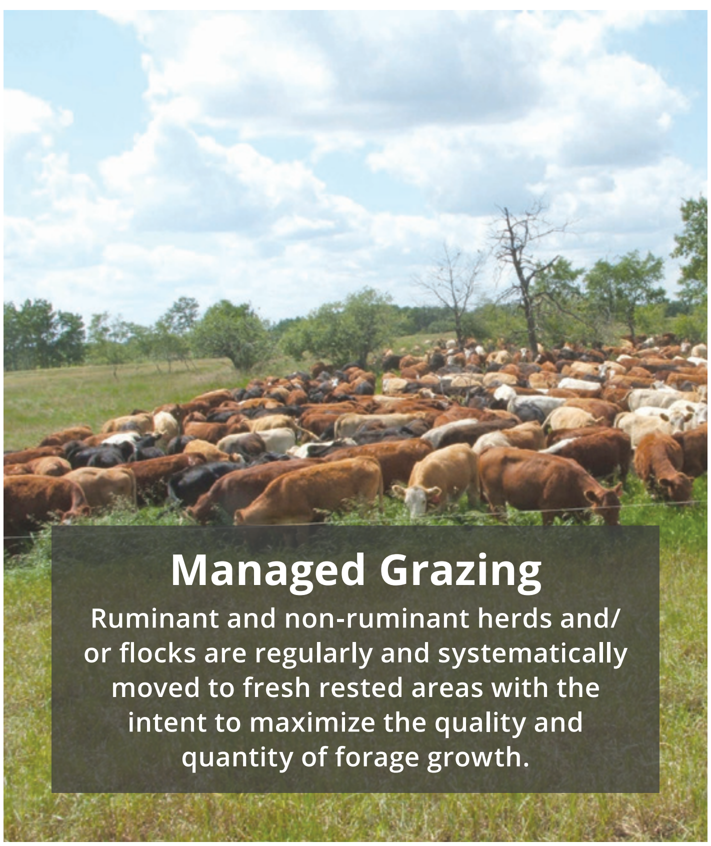
Cover Crop

A grass, legume other green plant that is typically grown between growing seasons for the benefit of the soil rather than the crop yield. Cover crops are commonly used to suppress weeds, manage soil erosion, help build and improve soil fertility and quality, and control diseases and pests.



Bare Ground

Complete removal of all vegetation from an area.



Managed Grazing

Ruminant and non-ruminant herds and/or flocks are regularly and systematically moved to fresh rested areas with the intent to maximize the quality and quantity of forage growth.

Concentrated Animal Feeding Operation (CAFO)

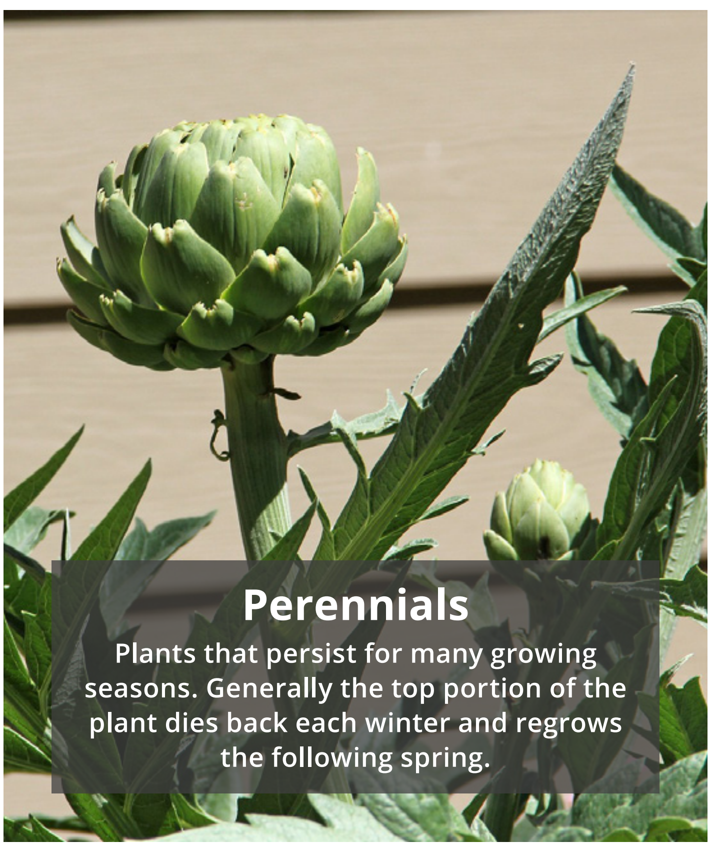
Agricultural enterprises where animals are kept and raised in confined situations. CAFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland.

Compost

A mixture of organic matter, as from leaves, grass clippings, food scraps, and manure, that has decayed or has been digested by organisms, used to improve soil structure and provide nutrients.

Chemical Fertilizer

Raw chemicals that have been manufactured at a factory into liquid or solid forms that specifically target plants' nutritional needs, designed to mimic naturally occurring nutrients.



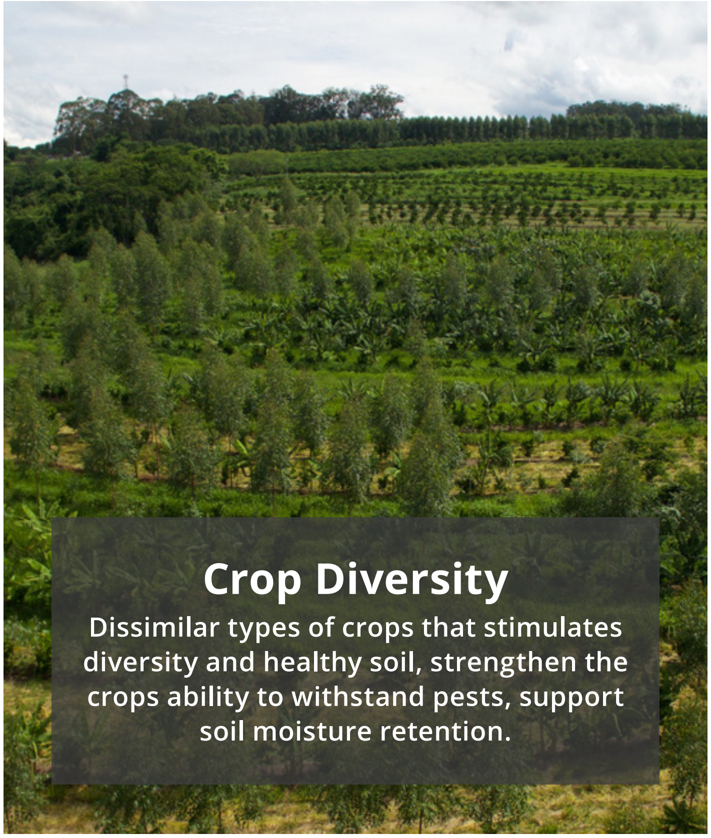
Perennials

Plants that persist for many growing seasons. Generally the top portion of the plant dies back each winter and regrows the following spring.

Annuals

Annuals are species that go through their entire life cycle, from germination through to maturity and crop production within a single year. Having produced its crop, the plant then dies.


Monocrop
The agricultural practice of growing a single crop year after year on the same land, in the absence of rotation through other crops or growing multiple crops on the same land (polyculture).


Crop Diversity
Dissimilar types of crops that stimulates diversity and healthy soil, strengthen the crops ability to withstand pests, support soil moisture retention.

HANDOUT 5.1:
Environmental Impact Survey

Use colored pencils to draw a map of your school campus here, including any outdoor landscape (garden, bare land, grassy areas, etc).

On your map, note the following:

- Where could something be done to rejuvenate the soil? How can you tell?

- Where could more plants be grown? What makes this a good place?

- Where could something else be done to change the campus for the better? What ideas do you have?

Note: *this activity might require additional research and interviewing. For example if you want to identify if pesticides or fertilizer are being used on the landscape, you may need to speak with administration and/or maintenance staff.*

HANDOUT 5.2:

Farmer Gabe Brown's Five Fundamentals of Soil Health

1. DO NOT DISTURB

Avoid plowing the soil, and abstain from harmful chemical amendments. These practices are like demolishing a house, making it difficult for the complex soil ecosystem to thrive.

2. KEEP ARMOR ON THE SOIL

Covered soil (living plants or trampled/dead plant material covering the soil surface) reduces soil erosion from wind and rain and helps keep soil temperatures down.

3. DIVERSIFY

Growing a diversity of plants ensures nutrient-dense soil, increases soil carbon, and reduces the risk of pests and diseases.

4. LIVING ROOTS

Keeping living roots in the ground year-round (or as long as possible) provides a steady source of food for organisms in the soil. In turn, the soil microorganisms help prevent soil erosion, increase water infiltration rates, and provide the plants with key nutrients.

5. ADD ANIMALS

Including animals in the farming system closes the nutrient loop and reduces the need for imported fertilizers. Of course, the correct farm animals to use will depend on the ecosystem.

OUTDOORS ❀ GRADES 2-6 ❀ FALL, SPRING ❀ ACTIVITY

Let's Make a Compost Cake

DESCRIPTION

Students build a compost pile.

OBJECTIVE

To experience the process of decomposition and the nutrient cycle.

TEACHER BACKGROUND

See detailed description of composting, page 477. Be sure students wash hands well when done with this activity.

MATERIALS

- compost materials
- shovels and spading forks
- wheelbarrow
- water access and hose with fan spray nozzle
- meter stick
- compost thermometer
- science journals

PREPARATION

1. Select a permanent compost area for the garden. The ideal location is close to the garden for easy hauling as well as easy access. The area should be a minimum of 3 square feet ($1m^2$).

2. Collect composting materials.

CLASS DISCUSSION

What types of materials decompose? *(materials that have been alive)* Why is it important for these materials to decompose? *(they become nutrients for other plants)* Is this a cycle? What are the parts of this cycle? *(living plant or animal grows, dies, decomposes, provides nutrients for another living plant or animal to grow)* What is the cycle called? *(nutrient cycle)* Do you think we can create a nutrient cycle in our garden? *(Record predictions.)*

ACTION

1. Demonstrate building a miniature compost cake with samples of browns *(carbon-rich materials such as dead plants, leaves, or straw)*, greens *(nitrogen-rich materials such as grass clippings, fresh plant matter, or food scraps)*, and soil *(or old compost)* prior to building the actual pile. Discuss the different ingredients that can be used in the pile. Stress the importance of the size, ingredients, and moisture level.

2. Go to the garden and equip students with shovels, spading forks, and a wheelbarrow. Have students use their spading forks to loosen the ground where the pile will be.

3. Divide groups of up to 10 students at a time into teams of Browns, Greens, and Soil. Assign one student to be the waterer. Begin with a browns layer of stalky material to allow drainage. Rotate groups, layering browns, greens, and soil repeatedly until the pile is at least 3 feet (1 m) tall. Browns layers and greens layers should be 4 to 6 inches (10 to 15 cm) thick; soil or old compost layers should be 1 to 2 inches (2.5 to 5 cm) thick. The waterer should water each layer as it is added to the pile. Be sure students maintain the rectangular shape of the pile and keep the corners square. Like the foundation of a house, each layer becomes the base for new layers, and if they're not square, the pile will collapse and the heat needed for decomposition will be lost.

4. Have students measure and record the dimensions of the compost pile.

5. Have students use a compost thermometer to take the pile's temperature.

6. Have students draw the compost cake in their journals, recording layers, measurements, and temperature.

7. Check your pile monthly and make sure it is moist enough. In dry periods you may need to water the pile.

WRAP UP

What are the ingredients of a compost cake? What will happen to the organic matter? What will the pile look like in a few months? How will the compost be useful after it is decomposed? What materials could you use at home to make compost?

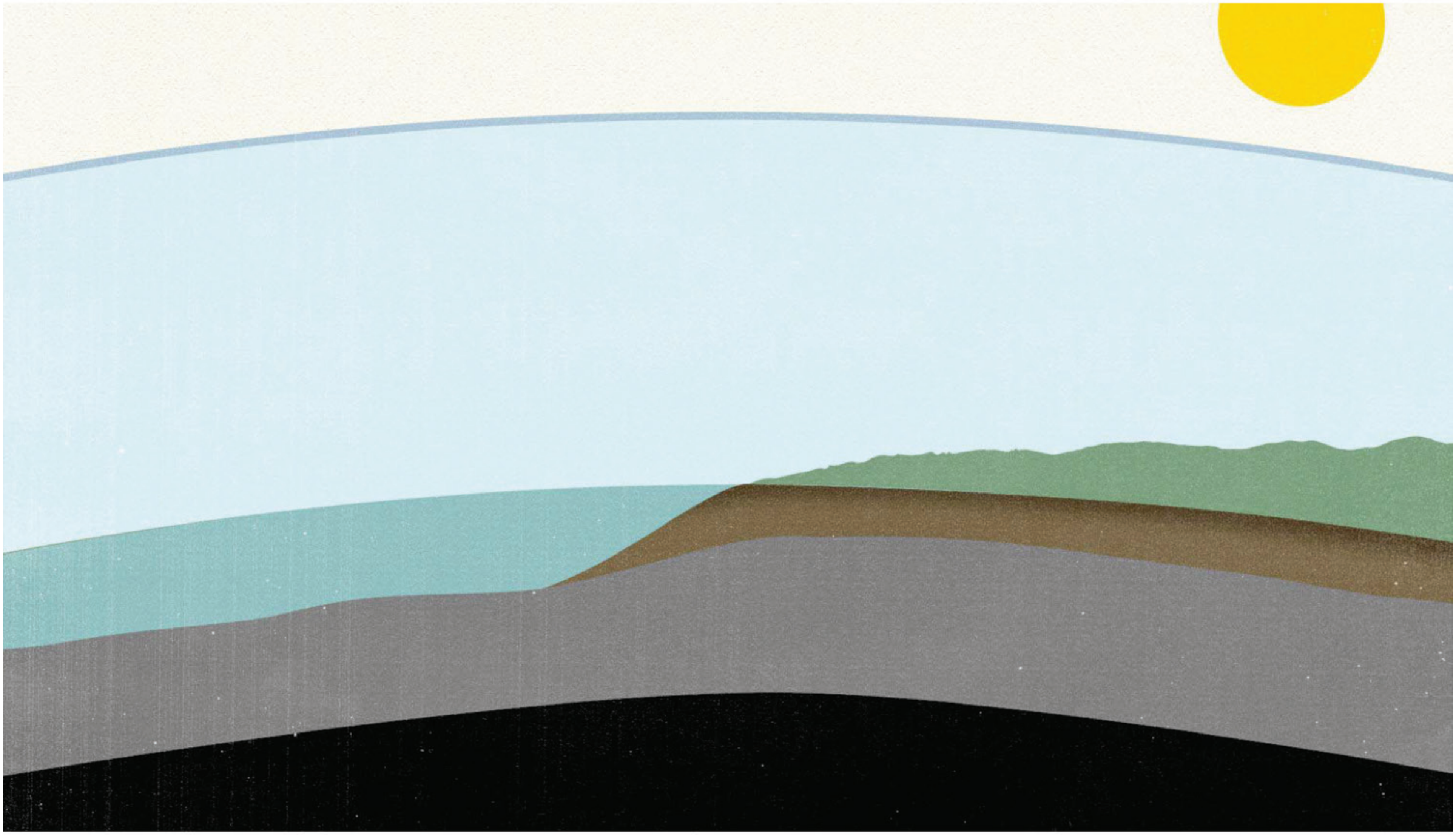
DIGGING DEEPER

1. Record the temperature of the compost cake each day for the next week and put the readings on a class graph. The pile will heat up to approximately 160°F (71.1°C) and then start to cool down. Let the students feel the heat from the pile. Discuss how the heat is being produced through the biological activity of the microorganisms.

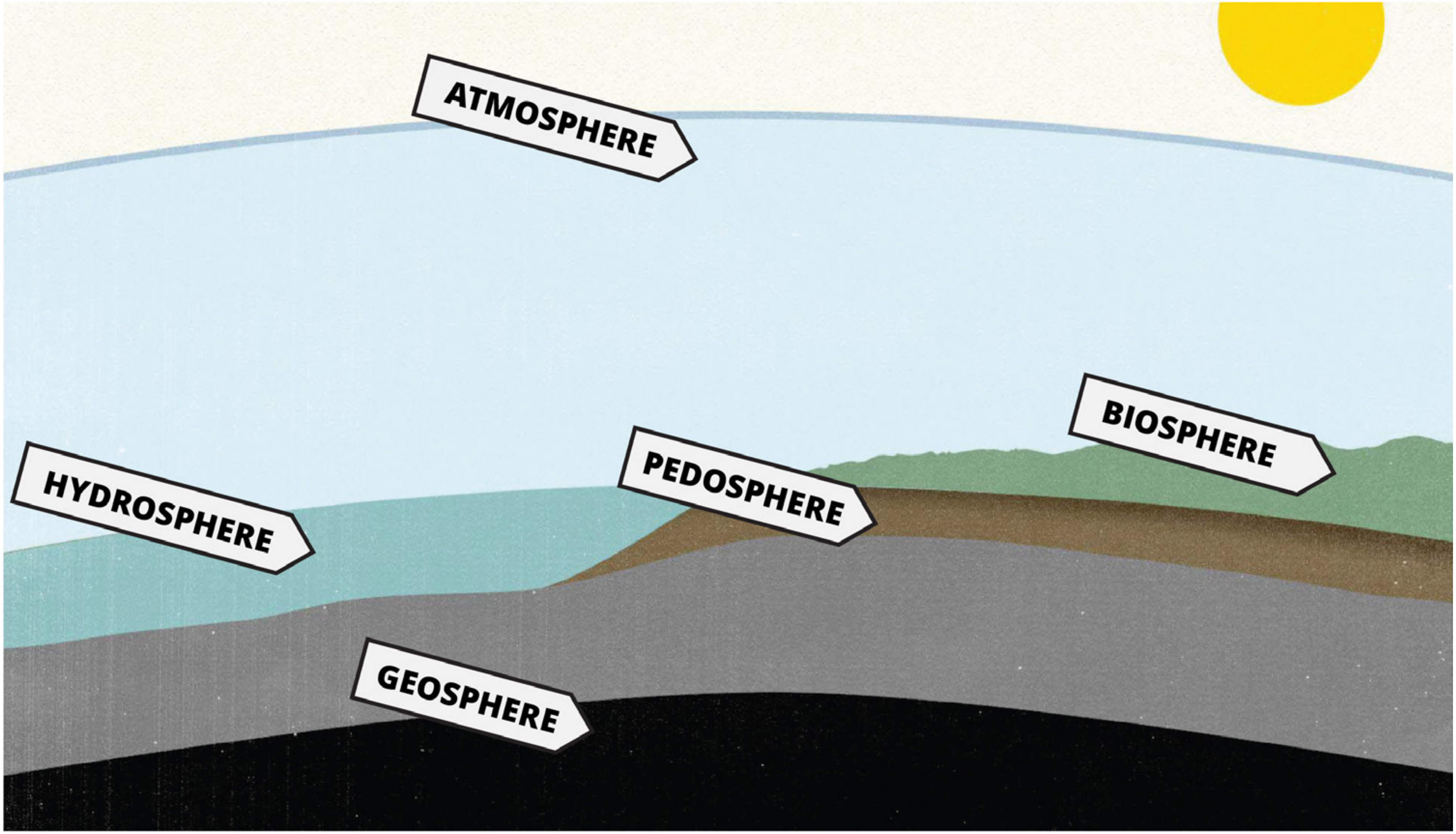
2. In a month, measure the dimensions of the pile again. How has it changed? What layers can you identify? Help students turn the pile to increase the speed of decomposition.

3. Have students observe chunks of compost through a microscope and record what is seen.

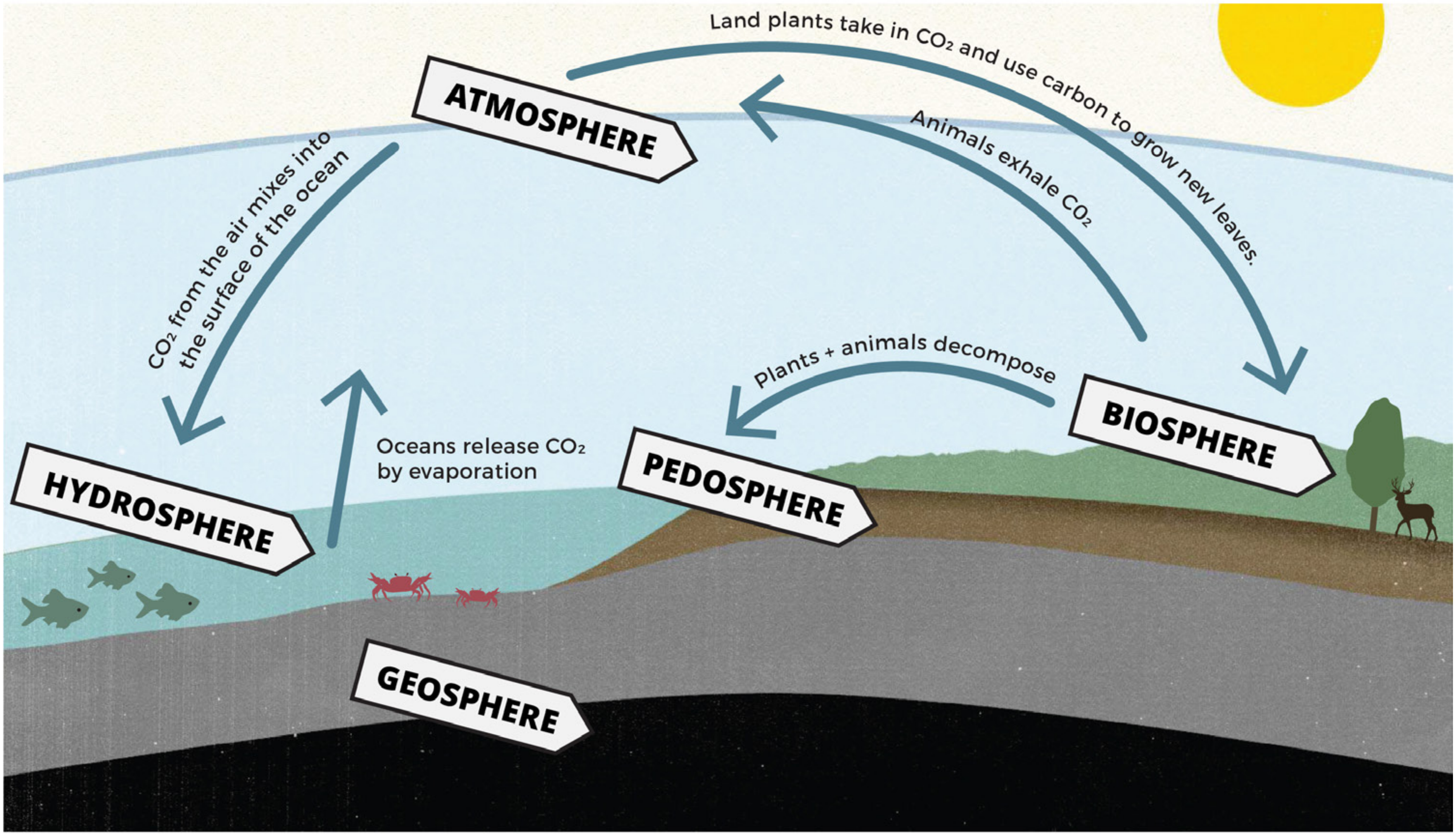
SLIDE 1.1:
Earth's Systems



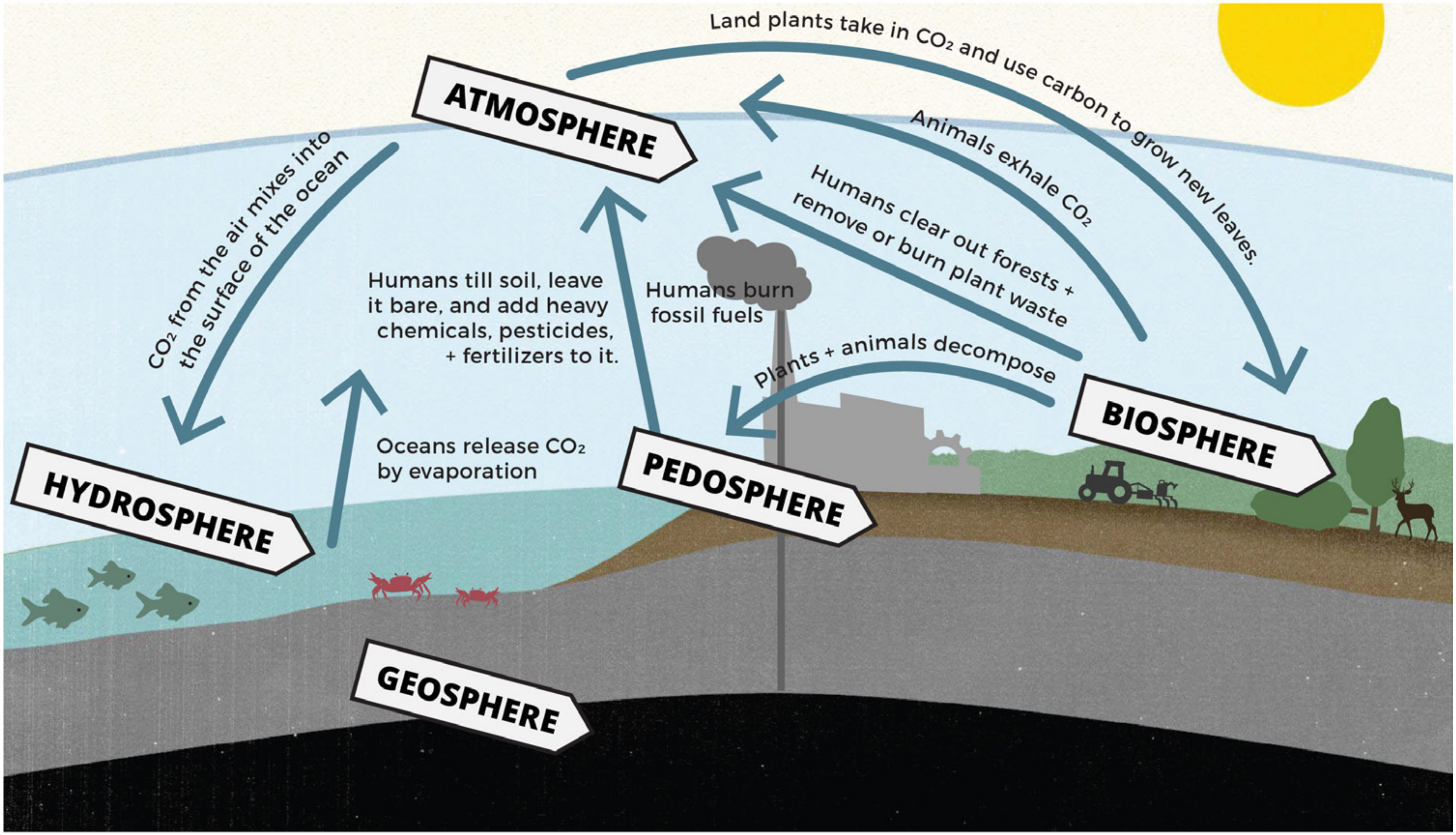
SLIDE 1.2:
Earth's Systems



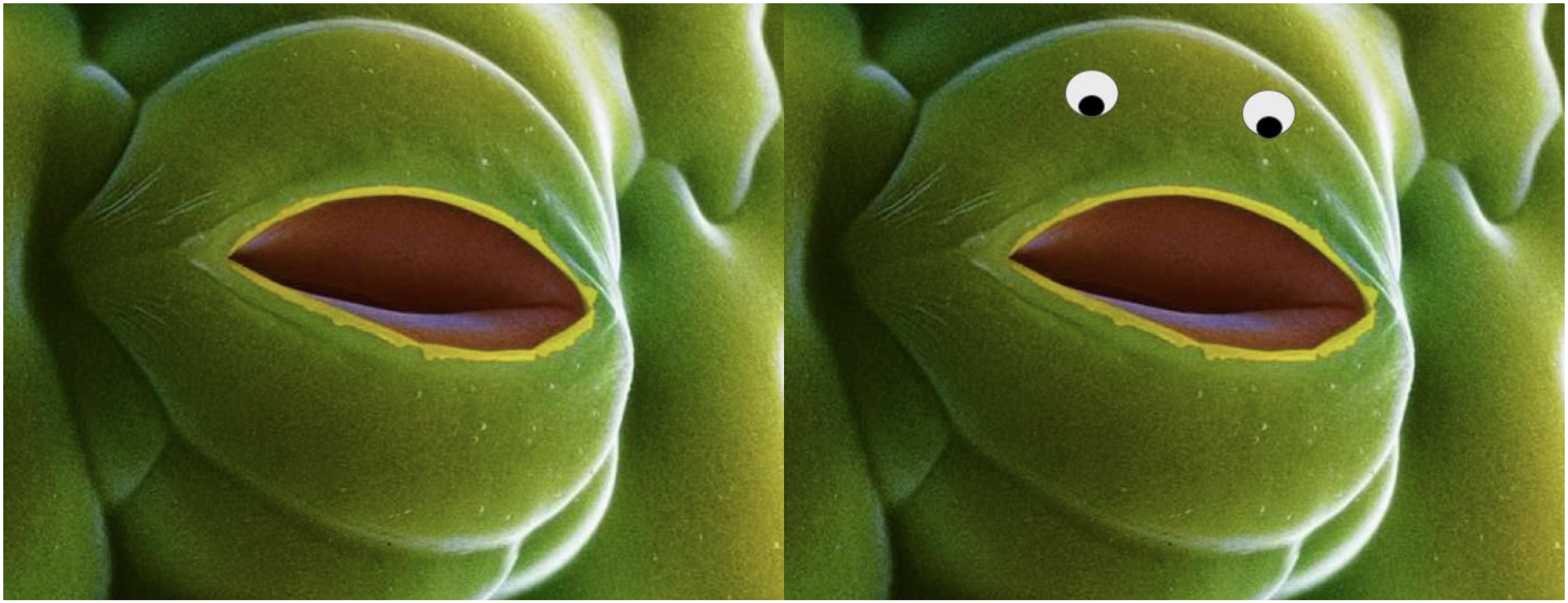
SLIDE 1.3:
How Carbon Cycles on Earth



SLIDE 1.4:
The Carbon Cycle Today

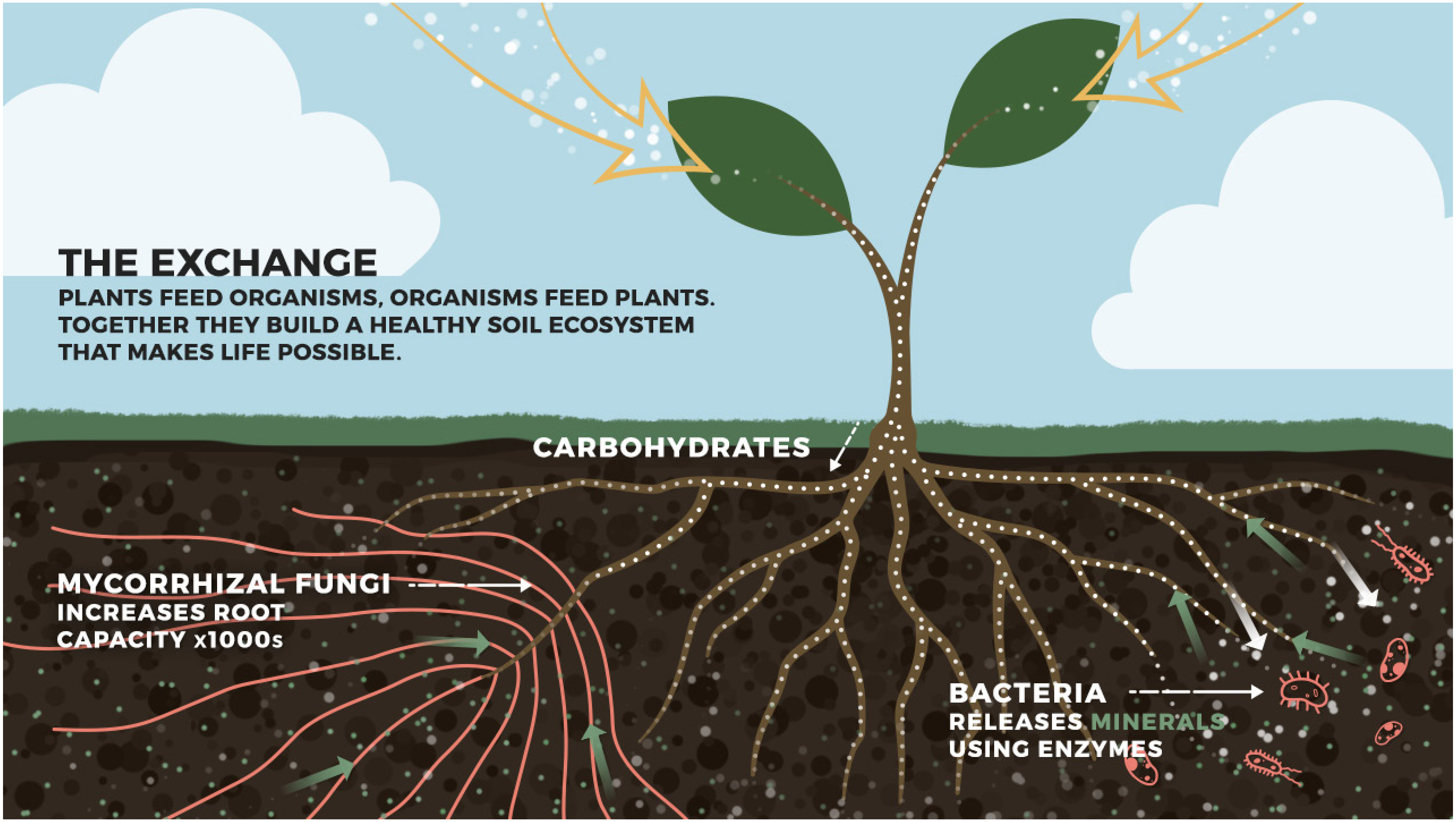


SLIDE 2.1:
Stomata

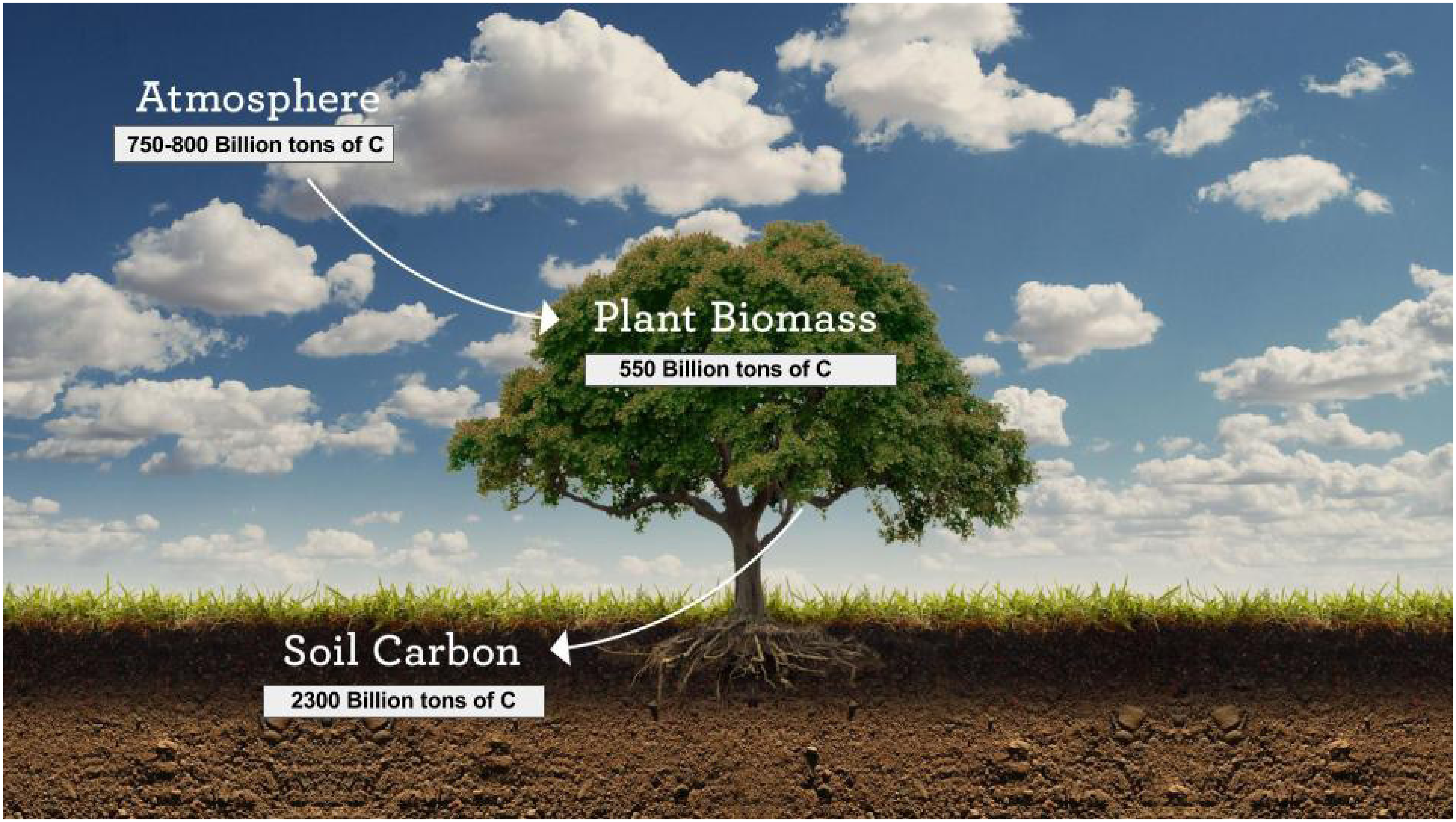


Stomata are tiny holes, often found on the underside of leaves, that open and close to allow the plant to respire. In this way, they are like the "mouths" of plants.

SLIDE 3.1:
The Great Exchange

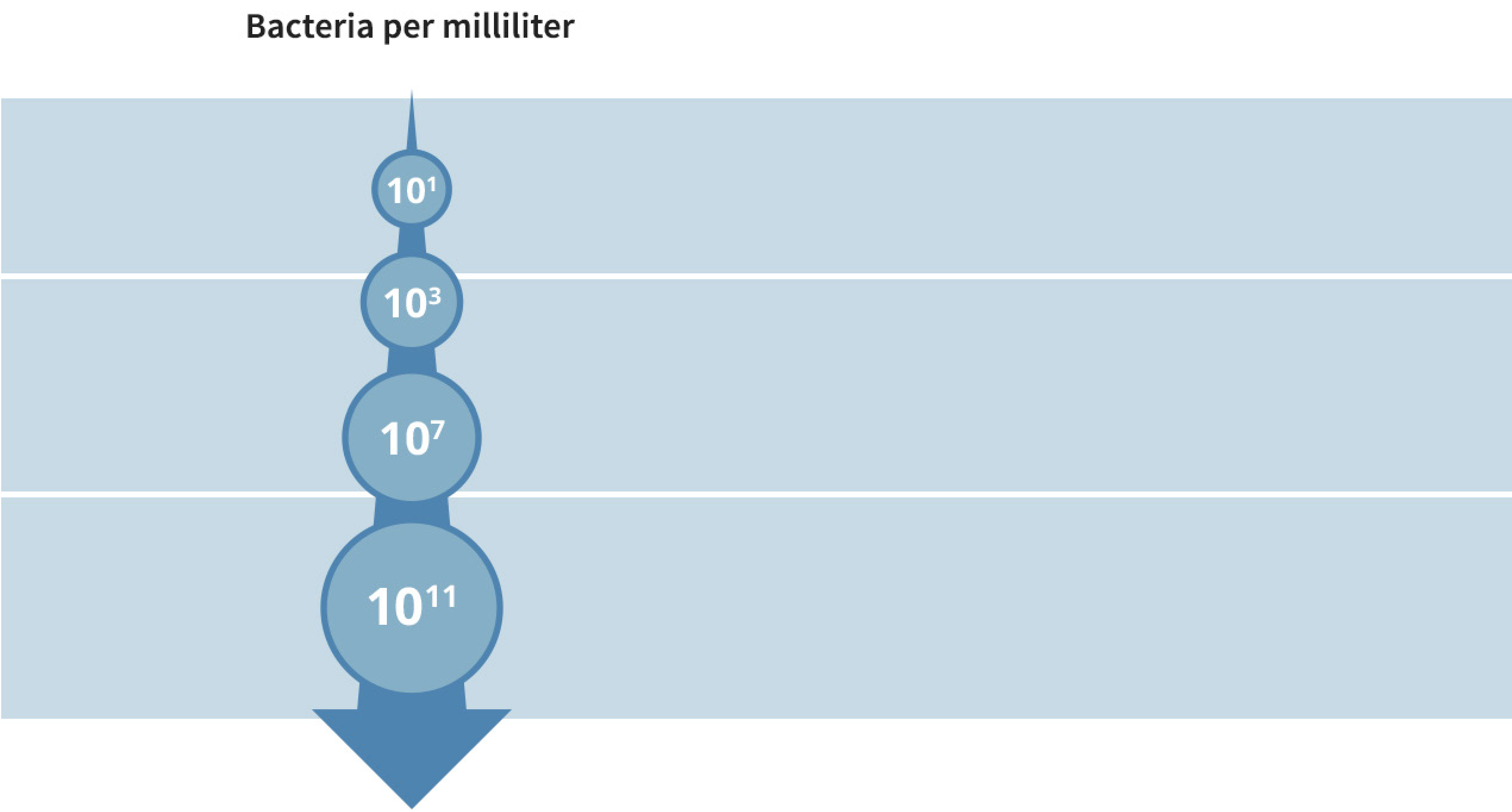


SLIDE 3.4:
Sequestering Carbon in Soil

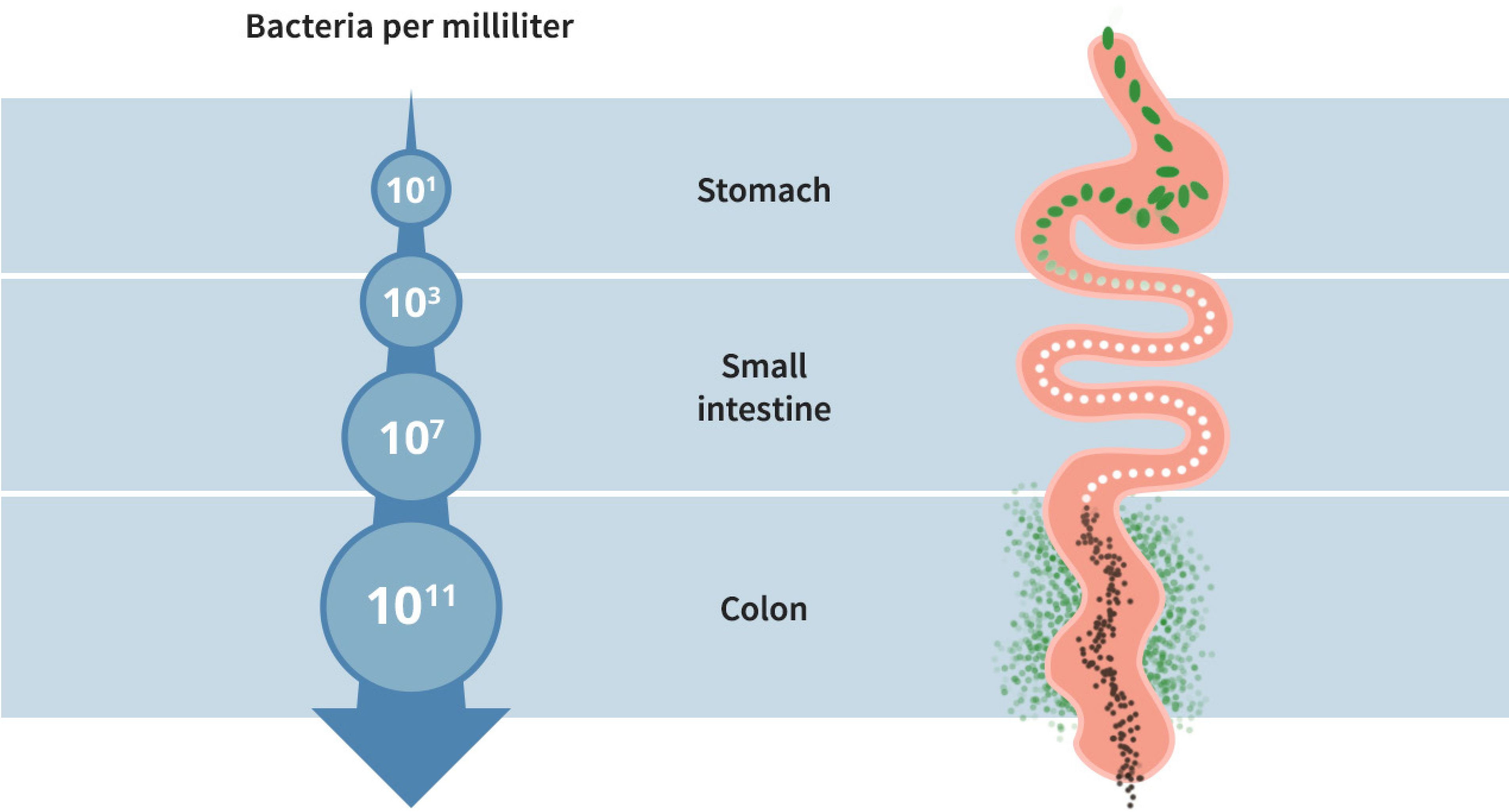


MICROBES IN OUR GUT

SLIDE 4.2:
Microbes in Our Gut



SLIDE 4.3:
Microbes in Our Gut



SLIDE 4.4:
Are We Building or Depleting Soil?

SLIDE 4.5:
Are We Building or Depleting Soil?

SLIDE 4.6:
Are We Building or Depleting Soil?