7

Tree Mass

NGSS EARLY IMPLEMENTERS

WestEd

A Collaboration of the K-12 Alliance @ WestEd,
Aspire Public Schools, Galt JUSD, High Tech High,
Kings Canyon USD, Lakeside USD, Oakland USD, Palm Springs USD,
San Diego USD, Tracy USD, Vista USD,
Achieve, and the California Department of Education

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Acknowledgments

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Grade 7 Tree Mass

Anchoring Phenomenon: Tiny seedlings grow and transform into trees with a great quantity of matter.

Introduction

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Introduction

The California K–8 NGSS Early Implementation Initiative, developed by the K–12 Alliance at WestEd with close collaborative input on its design and objectives from the State Board of Education, the California Department of Education, and Achieve is a fast-start demonstration project to build local education agency (LEA) capacity to fully implement the Next Generation Science Standards (NGSS) as a core subject in the elementary grades (K–5) and as the SBE's preferred integrated model in grades 6–8.

The four-year Initiative provides teachers and administrators with in-depth, content-rich professional development to build leadership capacity and teacher acumen to deliver high-quality 3-dimensional learning for K–8 students. In addition, through collaborations among the K–12 Alliance, Achieve, and others, the LEAs in the Collaborative have opportunities to pilot test new NGSS-aligned tools, processes, assessment item prototypes, and digital and other instructional materials. The LEAs serve as resources for NGSS implementation across California, and in other NGSS-adopting states as well.

This resource presents the conceptual storyline for a unit of instruction at a specific grade level, then focuses on a portion of the storyline called a learning sequence. The learning sequence uses the three dimensions of the NGSS (disciplinary core ideas—DCI; science and engineering practices—SEP; and crosscutting concepts—CCC) to build and deepen student understanding of natural phenomena and design challenges.

Participants in the CA NGSS K–8 Early Implementation Initiative developed and field-tested the lessons in the learning sequence. The sequences were vetted by the Science Peer Review Panel using Achieve's EQuiP rubric and found to be aligned with the intent of the NGSS.

Overview

This unit builds around the idea that energy flows and matter cycles through living systems. The anchoring phenomenon for the unit is a time-lapse animated video of a seedling growing into a tree. This phenomenon leads students to ask, "Where does it come from?" Students investigate the energy flow and matter cycling in a seedling as it gathers matter through chemical reactions to grow into a large oak tree.

Prior to this unit, students would already have had some middle-school-level instruction in physical science. Specifically, students would enter this lesson after completing units related to DCI PS1.A (Matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter) and PS1.B (Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy).

Students will have had middle-school-level instruction on some portions of PS3.B (The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter) in grade 6. Other aspects of PS3.B (Kinetic energy can be distinguished from the various forms of potential energy and is proportional to the mass of the moving object and grows with the square of the speed) will be explored in grade 8 This unit focuses on a small component of PS3.B (Energy changes to and from each type can be tracked through physical or chemical interactions).

Students would have had instruction in LS1.A (All living things are made up of cells. In organisms, cells work together to form tissues and organs that are specialized for particular body functions.) Students will extend their learning about energy and matter flow within a single tree to the cycling of atoms between living and nonliving parts of an ecosystem and how matter and energy are transferred between organisms within an ecosystem (LS2.B) in later units in grade 7.

The Performance Expectation that is addressed in this unit is:

MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

Learning Sequence Narrative

The Learning Sequence Narrative briefly describes what students do in each lesson and links the learning between the lessons as a conceptual storyline. At the end of each learning sequence, students make connections to their understanding of the investigative phenomenon (and to the anchoring phenomenon if appropriate).

The anchoring phenomenon of a seedling growing into a larger tree is used throughout the learning sequence.

Anchoring Phenomenon: Tiny seedlings grow and transform into trees with a great quantity of matter.

Students figure out this phenomenon by:

Science and Engineering Practices (SEPs)

Planning and Carrying Out Investigations

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurement will be recorded, and how many data are needed to support a claim.

- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- Conduct an investigation ~~and/or evaluate and/or revise the experimental design~~ to produce data to serve as the basis for evidence that meet the goals of the investigation.

Developing and Using Models

- Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.
- Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.

Constructing Explanations and Designing Solutions

- Construct an explanation using models or representations.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

Engaging in Argument from Evidence

- Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.

Disciplinary Core Ideas (DCIs)

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.

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.

Crosscutting Concepts (CCCs)

Cause and Effect

- Cause and effect relationships can be used to predict phenomena in natural or designed systems.

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
- The transfer of energy can be tracked as energy flows through a designed or natural system.

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study.
- Systems may interact with other systems; they may have sub-systems and be part of larger complex systems.

Lesson 1: Tree Matter

In this lesson, students will observe a time-lapse video of a seedling growing into a large tree to develop an initial model to explain how plants transform matter from the surrounding environment to create new plant material.

Lesson 2: Planning Plant Investigations

This lesson follows Lesson 1: Tree Matter where students modeled their thinking of where the matter that makes up a tree comes from. The students build on their thinking by planning an investigation to test where the matter of a tree comes from. The students will not carry out the investigation but will connect their own plan to historical scientific investigations.

Lesson 3: Historical Investigations

In this lesson, students will obtain information about historical investigations that lead to an understanding that plants change the composition of air. In the next lesson, students will carry out an investigation to gain evidence that a gas exchange is involved when plants gain matter (live and grow).

Lesson 4: Investigating Gases

In this lesson, students will build on the learnings from the previous lesson that plants need sunlight to add mass, but soil and water are not part of the additional mass. In this lesson, students investigate the gases that are exchanged within the plant.

Lesson 5: Matter Models

In this lesson, students will think about what is accumulated in the plant due to photosynthesis. Students use candy and toothpicks to model the creation of glucose and cellulose through chemical processes.

Lesson 6: Return to Seedling Growth Models

This is the final lesson of the sequence. Students will revise their initial models from the Lesson 1: Tree Matter and apply the learning they gained from the previous lessons.

Learning Sequence 3-Dimensional Progressions

SEP Progression

Only SEPs that have a strong progression are detailed here. While other SEPs are included in the sequence and important to the lesson in which they are used, if they do not appear in multiple lessons, they are not outlined here.

SEP PROGRESSION	
Developing and Using Models	
Lesson 1	Students use their prior knowledge about the practice Developing and Using Models. Students are asked to develop an initial model to explain the additional mass in a grown tree compared to when it was a seedling. This initial model provides an opportunity for teachers to assess students' ability to use aspects of this SEP, *Develop and/or use a model to predict and/or describe phenomena*, that were introduced in grades 3–5 and continue in grades 6–8.
Lesson 4	Students return to the models they developed in Lesson 1 and the SEP of Developing and Using Models. In Lesson 4, students add to their previous models based on the new information obtained from reading about historical investigations and data from their own. Students' new use of the practice includes *evaluating the limitations of their models and modifying their models based on evidence to match what happens if a variable or component of the systems is changed*.
Lesson 5	Students again revise their model with information gained through their investigations of photosynthesis and respiration. Using physical models to represent the creation of glucose and cellulose molecules, they can now *develop and revise a model to describe unobservable mechanisms*.
Lesson 6	Students return to their models one last time to revise their models individually and then collaboratively. In this last lesson, students *develop and revise a model to show the relationships among variables, including those that are not observable but can be used to predict observable phenomenon.*

Learning Sequence 3-Dimensional Progressions (continued)

SEP PROGRESSION (continued)	
Planning and Carrying Out Investigations	
Lesson 2	This practice is first seen in Lesson 2 when students plan an investigation to test where the matter of a growing tree comes from. This is a chance for students' prior knowledge and skills of this practice to be assessed including their ability to *identify independent and dependent variables and controls, what tools are needed to gather data, how measurements will be recorded, and how many data are needed to support the claim, all while collaboratively planning an investigation.*
Lesson 4	Through group planning and teacher facilitation, students continue their skill with this practice when they again plan an investigation about the gases that are exchanged within a plant. Previous foci of the practice are again emphasized (*collaboratively design and in the design, identify independent and dependent variables and controls, tools needed to do the gathering, and how measurements will be recorded*). This time their use of the practice is expanded to include an additional emphasis on *collecting data* as they conduct the investigation they planned for the *collection of data to serve as the basis for evidence to answer scientific questions*.
Obtaining, Evaluating and Communicating Information	
Lesson 3	Students read a series of short texts about historical investigation that lead to an understanding that plants change the composition of air. During this lesson, students will engage in the practice to *evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts* as they compare the historical investigations to those that they planned in Lesson 2. Students will *critically read these scientific texts adapted for classroom use to obtain scientific information to describe patterns in and/or evidence about the natural world* to come to conclusions about what they will investigate in Lesson 4.
Lesson 5	Students engage in this practice again after they have developed their own physical models to describe what materials are inputted, accumulated, and released (outputs) in a plant during photosynthesis and cellular respiration. Students will *critically read a scientific text adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s)* to revise their own models about how trees acquire mass as they grow.

DCI PROGRESSION	
Lesson 1	Plants transform matter from the surrounding environment to create new plant material (from Grades 3–5).
Lesson 2	A tree requires energy from the sun as a source of energy, and other materials are rearranged so the tree can grow. (LS1.C)
Lesson 3	Historical investigations can provide evidence that trees require light and water and exchange gases as they grow. (LS1.C)

Learning Sequence 3-Dimensional Progressions (continued)

DCI PROGRESSION (continued)	
Lesson 4	Trees rearrange carbon dioxide and water into complex molecules to support growth. (LS1.C)
Lesson 5	Plants take in energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. (PS3.D)
Lesson 6	Trees take in and rearrange carbon dioxide and water into complex food molecules, which are used for energy and growth. (LS1.C)

CCC PROGRESSION	
Matter and Energy Systems and System Models	
Lesson 1	Students use prior knowledge about the processes trees use to get energy AND how matter flows into living systems (trees). In particular, in grades 3–5 *students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances do not change.*
Lesson 2	Students consider how they would investigate where the matter in a growing tree comes from by adding new components in their use of the CCC: *Matter flows and cycles* to their investigation of tree growth including *matter can be tracked in terms of the weight of the substances before and after a process occurs, the total weight of the substances does not change, and matter is transported into, out of, and within systems.* Students consider how to collect evidence about matter that enters, accumulates and exits the tree system. Matter and Energy and Systems and System Models are used as students collaboratively plan their investigations.
Lesson 3	Students continue to use Matter and Energy and Systems and System Models as they consider tree growth (*matter is transported into, out of, and within systems*) as they analyze texts about historical investigations and how each set of findings relates to how *matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs*. This includes considering how *the total weight of the substances does not change as matter is transported into, out of, and within the system. Students consider evidence collected from each investigation to develop and understanding of the inputs, processes and outputs of matter flowing within the plant system*.
Lesson 4	Students combine the crosscutting concept Energy and Matter with Systems and System Models to plan and conduct their own investigations about what gases are exchanged within the tree and the processes that drive that exchange. Students consider aspects of the CCCs such as *within a natural system, the transfer of energy drives the motion and/or cycling of matter* as they think about what matter is cycling through the tree during growth and how these changes occur at different scales within the system over time. (They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems).

Learning Sequence 3-Dimensional Progressions (continued)

CCC PROGRESSION	
Lesson 5	Students use physical models to investigate how molecules enter into a plant and are rearranged and accumulated or released back into the environment. In this task, they deepen their understanding and use of the crosscutting concept, Energy and Matter, to include elements such as *matter is conserved because atoms are conserved in physical and chemical processes and within a natural system, the transfer of energy drives the motion and/or cycling of matter*. Students also discuss how processes within the cell affect the plant's system overall, using the crosscutting concept of System and System Models (*that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems*).
Lesson 6	Students develop their final model, both individually and collaboratively, as they use their full understanding of Energy and Matter to explain the phenomenon of tree growth.

References

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. DOI: https://doi.org/10.17226/13165. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K–12 Science Education Standards. National Academies Press, Washington, DC.

Grade 7 Tree Mass Conceptual Flow

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Energy flows and matter cycles through living and nonliving systems.

Investigative Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Data from historical investigations show that plants don't add mass from water or soil but they do purify the air when in sunlight.

The amount of carbon dioxide in the water surrounding aquatic plants increases and decreases depending on the amount of light.

When matter exits a plant, the molecules are in a different arrangement than when the matter entered.

Tiny seedlings grow and transform into trees with a great quantity of matter.

LS1.C, PS3.D
Plants transform matter from the surrounding environment to create new plant material.

LS1.C
A tree requires energy from the Sun as its source of energy. Other materials are rearranged as the tree grows.

LS1.C, PS3.D
Historical investigations can provide evidence that trees require light and water and exchange gases as they grow.

LS1.C, PS3.D
Trees exchange carbon dioxide and water into complex molecules to support growth.

LS1.C, PS3.D
Plants take in energy from light to make sugars (food) from carbon dioxide and water through the process of photosynthesis which releases oxygen.

LS1.C, PS3.D
Trees take in and rearrange carbon dioxide and water into complex molecules which are used for energy and growth.

Developing and using models

Planning and carrying out investigations

Obtaining, evaluating, and communicating information

Developing and using models
Planning and carrying out investigations

Developing and using models
Obtaining, evaluating, and communicating information

Developing and using models

Energy and Matter

Systems and System Models

Cause and Effect

Tree Matter

7.1

Image via iStock.com/Andrei Stanescu

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Develop a model to explain where all the matter in a tree comes from when it begins as a small seedling. Develop a model to describe the observable and unobservable variables that explain how trees rearrange matter to support growth.

Investigative Phenomenon

Introduce anchoring phenomenon: Tiny seedlings grow and transform into trees with a great quantity of matter.

Standards

Refer to Appendix 7.1 for NGSS, CCSS (ELA), and California ELD Standards.

Storyline Link

In this lesson, students will observe a time-lapse video of a seed growing into a large tree to develop an initial model to explain how plants transform matter from the surrounding environment to create new plant material. Students will make observations from the video, ask questions, and develop an initial model. Student questions and models will be revised in later lessons as they gather additional evidence regarding the transfer of matter and energy within the system.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

60 minutes

One 60-minute session

Materials

Whole Class

- ❑ The growing tree video https://www.youtube.com/watch?v=RjnKAWxCK3k
- ❑ 7.1.R1: Display Idea for Giant Sequoia Tree Probe (optional)
- ❑ A small seedling (optional)
- ❑ A large piece of wood (optional)

Group

(Groups of 4)

- ❑ Chart paper, markers
- ❑ Sticky notes

Individual

- ❑ Science notebook
- ❑ 7.1.H1: Giant Sequoia Tree Probe
- ❑ 7.1.H2: Make a Model

Advance Preparation

1. Preview the growing tree video https://www.youtube.com/watch?v=RjnKAWxCK3k
2. Make copies of **7.1.H1: Giant Sequoia Tree Probe** and **7.1.H2: Make a Model**

Procedure

Engage

Develop a model to explain where all the matter in a tree comes from when it begins as a small seedling. Develop a model to describe the observable and unobservable variables that explain how trees rearrange matter to support growth.

Eliciting Prior Knowledge: Individual

1. Distribute **7.1.H1: Giant Sequoia Tree Probe** and ask students to respond individually to the prompts. Explain to students that they will have an opportunity to return to their answers later so it is not necessary to provide a "correct" answer. Tell students it is important to fully record their ideas. Provide 5-10 minutes for students to complete the probe.

> TEACHER NOTE
>
> Students who are learning English or who are below grade level may communicate their ideas more clearly using pictures or symbols. The intent here is not to make a model, but rather to give students another option for how to express their ideas. At this point, it is not necessary for students to communicate in complete sentences or with accurate grammar and spelling.

2. Ask students to put their response sheets into their science notebook or some other place where they can find it later.

> TEACHER NOTE
>
> This can also be presented on a display so that students can record their thinking in their science notebook. See an example of this modification in **7.1.R1: Display Idea for Giant Sequoia Tree Probe.**

Making Prior Knowledge Public

3. Explain to students that you will now how them the growing tree video. Direct students to take notes on the events that occur and any information that they think might explain the events. Show the video twice to provide sufficient time for students to make observations.

> **TEACHER NOTE**
>
> The growing tree video shows a seedling growing into a large tree. ▶ This is an opportunity to assess students' prior knowledge about the phenomenon and determine what knowledge they are bringing to the unit. Students should notice the addition of a significant amount of matter to the tree, the development of new branches, and green leaves. If the majority of your students bring up ideas such as photosynthesis or chemical reactions, this could be an indication that the students have advanced knowledge of the phenomenon. However, it may also be an indication that students have heard of these terms but do not have a deep understanding of the underlying concepts. Monitoring their conversations and science notebook entries will help to determine students' level of understanding.

4. Ask students to think about the questions they have about what they saw in the growing tree video. Direct students to record those questions in their science notebook.
5. Ask students to consider where they have seen or heard of similar phenomena. Record their ideas on a chart in the classroom. Students might suggest growing vegetables, shrubs, or trees in their neighborhood or other plants they encounter in their daily lives. Students who share experiences growing plants should be asked to describe those experiences, including what they did to help the plants grow.
6. Consider taking students on a short walk around campus to observe plants in the schoolyard or presenting photos of plants in a nearby park. Students can record observations of plants they see during their walk, possibly taking photos.

> **TEACHER NOTE**
>
> These experiences do not need to be scientific. Encourage students to share experiences related to growing plants that reflect their home and family experiences. It is also appropriate for students to share experiences that they cannot fully explain such as why a family member planted something in a particular area or repotted plants. The intent is to gather personal and community connections to the phenomenon.

To help students engage with the phenomenon, consider bringing in a small seed and a large piece of wood. Let students hold both the seed and the piece of wood and compare the mass of each. Ask students their ideas and questions about how something so tiny can grow into a very massive tree.

7. Ask students to share their questions with a partner. When pairs have had a chance to discuss, ask students to share some of the questions they developed with their table. As students share, walk around and monitor their conversations.

TEACHER NOTE

Students learning English can be encouraged to use their drawings in their science notebook to communicate with their partners. As students share their ideas with the class, revoice student ideas so that students who are learning English or may have limited academic vocabulary can have the opportunity to hear their ideas again and in a variety of contexts. For example, you might say, “So you noticed that the tree grew taller faster than it grew wider.”

8. Facilitate a class discussion around which particular question or questions to investigate further. Direct students to write their questions on individual sticky notes. Individual student questions can be gathered, or you can ask table groups to share their questions to select one or two questions for the table. Ask students to share their questions by reading one question aloud at a time. After the first question is read, ask the class if anyone has a similar question. If so, ask the student who had a similar question to read aloud their question and then place it next to the first question, clumping both questions together in a clump. If there are no other similar student questions, ask students for a different question. Once all the questions have been read and “clumped,” facilitate a class conversation about possible categories or titles of each clump. As clumps are assigned a “title,” circle the clump and record the title above the clump. You should now have a series of possible question clumps to investigate.

9. At this point, groups of students could select different questions to investigate, the class could decide to investigate one particular question, or the class could be directed to investigate the clump related to “tree growth” with a question such as: How the tree grew from a small seedling to a larger tree. Where did the matter come from? If you are going to move forward in the lesson sequence as written, explain that the class will continue investigating how the tree gets the matter to grow by focusing on the question: Where does the matter come from for the tree to grow from a small seedling to a larger tree? If this exact question was not suggested by students in the previous discussion, adjust the prompt to connect to students’ questions. If students generate questions related to the notion of “tree growth” such as what makes the tree grow so tall? or would all trees grow at the same rate?, the guiding question can be replaced with one that was generated from the students.

Making a Model

10. Distribute **7.1.H2: Make a Model**. Tell students to create a model that includes both drawings and words. Their model should represent their initial ideas about the focus question related to the increase in tree mass.

TEACHER NOTE

▶ This is an opportunity to assess students' prior knowledge about developing and using models to determine what knowledge they are bringing to the unit. Record if students are using observations from the video or the list of related phenomena in their models (evidence), if the models contain visible and invisible components, and if the models show relationships. If this is the first time students have made a model, they may need some encouragement to record their ideas. Remind students that this model will represent their initial thinking, and there will be opportunities to add or revise their models later.

This is also an opportunity to assess students' prior knowledge related to the CCC Energy and Matter. For example, are students including both energy and matter elements in the model? Is matter represented as particles in any part of the model? Are there indications that matter is changing form or transported through the system?

11. Direct students to share their ideas with their team (2–4 students) in order to create a group model. Distribute chart paper or large whiteboards for students to create their group model. As student groups work, ask the groups to consider.
    a. What are the parts (components) that are part of this process? Are any of these parts invisible? If so, how did you/could you represent the "invisible" parts on your model?
    b. What are the relationships between these parts?
    c. How does your model show what is happening at the beginning, middle, and end of the process?
    d. How is the matter transported into, out of, and within the tree or system?
    e. How much matter is there before, during, and after the process? Does it change?
12. Explain to the students that this is their first opportunity to explain this phenomenon with their model, and as they learn more, they will have additional opportunities to add and revise this model.
13. Once the groups have had sufficient time to record their ideas, you may choose to have a few groups share their models, depending on how much time you can provide.
14. Five minutes before the end of the class, direct students to add to or revise their initial model and record it in their science notebook based on discussions in their group.
15. End class by asking students to record any new questions they might have about the phenomenon.

16. ▶ Collect **7.1.H1: Giant Sequoia Tree Probe** and **7.1.H2: Make a Model** and assess student prior knowledge. Prior knowledge should be evaluated in all three dimensions. For example, consider student models. Were they able to describe the phenomenon accurately using words and pictures? Do their models show visible and invisible components? Relationships? Student understanding of concepts related to Organization for Matter and Energy Flow in Organisms (DCI) and Energy in Chemical Processes and Everyday Life (DCI) may include inaccurate ideas such as the mass comes from soil or lack an awareness that invisible gases have mass and enter the plant. Do students include some description of the conservation of mass or the role of energy in moving matter? If they use terms like photosynthesis, is there evidence that these terms are applied accurately to explain the phenomenon? These student work pieces can be used to make instructional decisions as you move through the series of lessons; indicating areas where you may need to slow down to allow more processing time or areas where students may have more understanding than the lesson anticipates. Return **7.1.H1: Giant Sequoia Tree Probe** and **7.1.H2: Make a Model** to students after you have reviewed them. These should be placed in their science notebook.

References

Keeley, P., Eberle, F., & Tugel, J. B. (2007). *Uncovering Student Ideas in Science, 2:25 More Formative Assessment Probes*. Arlington: National Science Teachers Association.

Muviag. (2011, March 2). The growing tree / Timelapse Animation. Retrieved from https://www.youtube.com/watch?v=RjnKAWxCK3k.

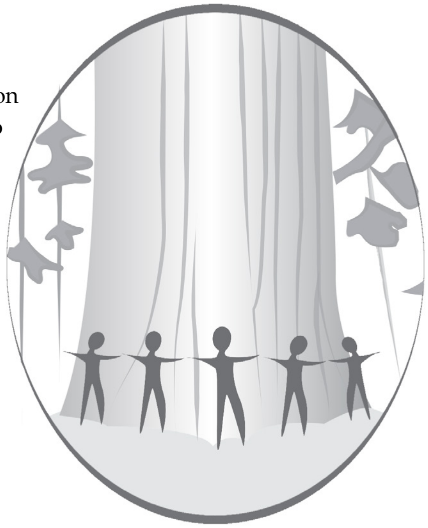
Toolbox Table of Contents

Giant Sequoia Tree Probe

Giant Sequoia Tree

The giant sequoia tree is one of the largest trees on earth. It starts as a small seedling and grows into an enormous tree. Five children can stretch their arms across the width of the trunk of one of the large sequoia trees!

Where did most of the matter that makes up the wood and leaves of this huge tree originally come from? Use words and pictures to explain your ideas.



Explain your thinking. How did you decide where most of the matter that make up this tree came from?

Modified from P. Keeley Uncovering Student Ideas in Science, Vol 2

Make a Model

Make a model of how a seedling becomes a large tree. Remember to show the parts you can and can't see. Show where the matter comes from and how it gets into the tree.

Seedling

Image via iStock.com/ermingut

Large Tree

Image via iStock.com/vandervelden

Draw your model here.

Display Idea for Giant Sequoia Tree Probe

Phenomenon

The giant sequoia tree is one of the largest trees on Earth.

It starts as a small seeding and grows to an enormous tree.


Image by iStock.com/Andrei Stanescu

Essential Question

Where did most of the matter that makes the wood and leaves of this huge tree come from?

Use words and pictures to explain your ideas. Also, record any wonderings you have in your science notebook.

Image by iStock.com/Meinzahn

Explain Your Thinking How did you decide where most of the matter that makes up this tree came from?	 Image by iStock.com/RiverNorthPhotography

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Developing and Using Models

- Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- Develop a model to describe unobservable mechanisms.

DISCIPLINARY CORE IDEAS (DCI)

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.

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.

CROSSCUTTING CONCEPTS (CCC)

Energy and Matter

- Energy can be transferred in various ways and between objects. (From Grades 3–5)
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Appendix 7.1

Common Core State Standards (CCSS)

CCSS ELA SPEAKING & LISTENING
CCSS.ELA-LITERACY.SL.7.1.B
Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

California English Language Development (ELD) Standards

CA ELD		
Part 7.I.3 Offering and justifying opinions, negotiating with and persuading others in communicative exchanges		
EMERGING	EXPANDING	BRIDGING
P1.7.3 Negotiate with or persuade others in conversations (e.g., to gain and hold the floor or ask for clarification) using learned phrases (e.g., *I think . . . , Would you please repeat that?*) and open responses.	**Part 1.7.3** Negotiate with or persuade others in conversations (e.g., to provide counterarguments) using learned phrases (*I agree with X, but . . .*), and open responses,	**Part 1.7.3** Negotiate with or persuade others in conversations using appropriate register (e.g., to acknowledge new information) using a variety of learned phrases, indirect reported speech (e.g., *I heard you say X, and I haven't thought about that before*), and open responses.

Planning Plant Investigations 7.2


Image via iStock.com/ArisSu

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Plan an investigation that would provide evidence to explain where all the matter in a tree comes from when it begins as a small seedling.

Investigative Phenomenon

Continuation of the anchoring phenomenon: Tiny seedlings grow and transform into trees with a great quantity of matter.

Standards

Refer to Appendix 7.2 for NGSS, CCSS (ELA), and California ELD Standards.

7.2 Planning Plant Investigations

Storyline Link

This lesson follows Lesson 7.1: Tree Matter where students modeled their thinking of where the matter comes from that makes up a tree. The students build on their thinking by planning an investigation to test where the matter of a tree comes from. The students will not carry out the investigation but will use this planning to further understand the elements of a scientific investigation. The use of the crosscutting concept Systems and System Models is used to discuss the possible components that are involved in the phenomenon of a tree gaining mass. In the next lesson, they will obtain information from a resource that describes the historical investigations that eventually led to the understanding of photosynthesis. Pre-read the historical investigations in order to help guide your students to create investigations that mimic the actual investigations. Do not tell the students about the investigations. Students' understanding and use of the practice Planning and Conducting Investigations is limited to designing a plan. This will be their initial opportunity in the unit to consider independent and dependent variables and controls, tools that they need to gather data, how measurements will be recorded, and how many data are needed to support a claim. In 7.4: Investigating Gases they will have another opportunity to develop an investigation and carry it through to data collection.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

60 minutes

One 60-minute session

Materials

Whole Class

- ❑ Chart paper

Groups (Groups of 4)

- ❑ 7.2.G1: Plan an Investigation
- ❑ Sticky notes

Individual

- ❑ Science notebook

Advance Preparation

1. Make copies of **7.2.G1: Plan an Investigation** (optional)

Procedure

Engage (45 minutes)

Plan an investigation that would provide evidence to explain where all the matter in a tree comes from when it begins as a small seedling.

1. During Lesson 1: Tree Matter, students modeled their initial thinking of where the matter comes from that makes up a tree.

   Ask students to review their models from Lesson 7.1: Tree Matter. Ask students to consider whether they are satisfied with their model's ability to explain the phenomenon. Where is the model limited? What additional information would strengthen their model? Students should also consider the system described in the model. Ask students to consider which components of the system are uncertain and in need of further investigation.

TEACHER NOTE

The student suggestions might vary depending on whether you provided choices for the students in Lesson 7.1: Tree Matter or if you made the initial question open-ended. If you use an open-ended question, students often suggest that the tree gets its mass from the soil, water, or nutrients but rarely mention air or carbon dioxide. The students may have had lessons in fifth grade around the DCI LS1.C: Organization for Matter and Energy Flow in Organisms: *Plants acquire their material for growth chiefly from air and water*. (5-LS1-1) If they have, they may have suggested air as the source for the matter that makes up a tree. The idea of this lesson is that students plan an investigation to test their ideas. In Lesson 7.3: Historical Investigations, the students will obtain information about the historical investigations that led to the understanding of photosynthesis.

2. Have a class discussion about the student ideas. Allow all ideas. Do not confirm or dismiss any ideas at this time. The idea of photosynthesis will be uncovered in future lessons.

TEACHER NOTE

If students are struggling to share their models, you may need to do a think-aloud in front of the class first. Verbally describe, as if you were thinking aloud, the components seen in the model (*I have included a tree, because that is the thing that is growing*) and ideas they were not sure how to include (*I wanted to show the tree GROWING but was unsure how to do that so I just made a small tree and then a bigger tree*). Some students may need more processing time or opportunities to practice communicating their ideas. You may want to have students discuss their models in small groups before going to a whole-class discussion. This will give English Learners a different linguistic register in which to communicate. It will also allow students more processing time with peers and an opportunity for you to interact with students and ▶ to assess their ideas about the phenomenon and their model.

3. During the class discussion, elicit and make public student ideas about components that enter the system (the tree). Students might suggest soil, water, nutrients, air, and maybe even carbon dioxide. (Do not suggest air or carbon dioxide if the students don't bring it up.) Ask students to think about if and how matter is flowing in their model. What do they currently think about how matter might be tracked in terms of amount of weight before it enters the system, during its time in the system, and after it leaves?
4. In their small groups (3–4 students) ask the students to think about how they would plan and carry out an investigation to test their ideas of which components are entering the system such as soil, water, nutrients, etc. Ask students what information they would want to gather to improve their models. Allow teams time to discuss their ideas and generate consensus. Suggest that teams sketch their current thinking for investigation ideas. English Learners will benefit from the option to express their ideas in a different modality, such as drawing images. Tell students to record their ideas from the group discussion in their science notebook.
5. Conduct a whole-class discussion. Ask students to review their notes and think about what things they considered when developing their investigation plan. What makes an investigation scientific? Listen for student responses that mention that investigations should produce data (grade K–2 band), have fair tests where variables are controlled, and have more than one trial (grade 3–5 band). If students are not aware of these elements of a scientific investigation you may need to adjust the lesson to address where students are in the practice of planning and conducting an investigation. Record their ideas on chart paper so they can be referenced later in the lesson.

TEACHER NOTE

This is the first point in the unit that students are engaging in the practice of planning and conducting an investigation. In Lesson 7.3: Historical Investigations, students will focus on planning an investigation that will then be extended through comparisons of historical investigations. In Lesson 7.4: Investigating Gases, students plan and conduct an investigation about gases that are exchanged within a plant. Students may need support in identifying independent and dependent variables in their designs rather than simply considering which variables will be controlled (grade 3–5 band). In the grade 3–5 band, students are asked to consider what data is needed to serve as the basis for evidence. In this lesson, students may also need support in identifying what they will measure and what tools are needed to gather the data. If students are struggling to identify variables, they can brainstorm the possible things they could change in the experiment (independent variable) by writing each on a different sticky note. They can also identify all the possible things they could measure on different sticky notes. With the sticky notes in two clumps (things we could change and things we could measure), instruct students to identify ONE sticky note in the "things we could change " clump. Explain that this is their independent variable. All the other sticky notes in that clump are controls, or things that they should make sure do not change. Do the same with the "things we could measure" clump and explain that these are dependent variables. However, you may decide to allow students to measure more than one dependent variable. This sticky note strategy could be modified for English Learners by adding symbols or drawings to the text on the sticky note. For students above the target level, measuring multiple dependent variables in the lesson is an option as well.

6. Direct students to again focus on their small group model Students should be encouraged to consider their current model of the system and look for areas where their model may be limited. What evidence would improve their model? Listen in and guide the discussion to encourage the students to be explicit in describing variables and controls, tools needed, what will be measured, how much data is needed, and how the data support the claim. Continue recording ideas that have class consensus. When reasonable, represent ideas with both visuals and words. For example, if a group suggests having two plants, one a control and the other experimental with less soil, draw a picture of two plants with varying amounts of soil below the sentence.

7. Allow time for the groups to share their ideas with the whole class. If you observed particularly useful conversations regarding variable control or tools from the small group, you can ask those teams to share some of their discussion. After a few teams have shared their ideas, tell the students to listen to the ideas of other students so they can add new ideas to their science notebook.

TEACHER NOTE

During the discussion, probe students to find out what they would measure and what different results would mean depending upon where the matter came from. For example, if the students suggest that soil makes up the matter of the tree, the students could think about how they would measure soil before and after a seedling grows into a tree and compare the mass of the leftover soil with the mass of the tree. If the students suggest water makes up the matter of a tree, they could plan an investigation where they keep track of the water they add to the tree. The idea of this lesson is to have the students think through the investigations that actually occurred in history. They don't know about these investigations yet but will read about them in Lesson 7.3: Historical Investigations. Because they are encouraged to wonder how someone might go about finding out if the matter of the tree came from soil, water, nutrients, air, etc., they will be very interested in reading about the historical investigation in Lesson 7.3: Historical Investigations.

8. Students will now use their preliminary ideas and the ideas gained from the class discussion to enhance their plan for their investigation. Tell students to work individually or in groups to plan an investigation. Suggest that students use template **7.2.G1: Plan an Investigation** (scaffold for English Learners or students working below grade level) or allow the students to plan in their science notebooks. Since the plan won't be carried out, the students don't need to be limited by classroom supplies and time. However, students should produce clear and coherent written plans that convey a clear sequence of events.

Explain (15 minutes)

Plan an investigation that would provide evidence to explain where all the matter in a tree comes from when it begins as a small seedling.

9. This is the first time students are planning an investigation in this unit. Students will increase their use of variables, controls, and measurement tools throughout the unit. In this initial plan, it is important that students consider what question they are trying to answer as well as what evidence they want to collect and construct a plan that matches the cause-and-effect relationship between the two. If students need additional support, consider having them work in small groups, rather than individually, to allow for peer-to-peer collaboration. While groups are working, you can provide additional guidance to groups or individuals. As students near consensus, remind them to record their plan in their science notebook for use later.

TEACHER NOTE

This step of the lesson is about having the students be sure they have included the elements of a scientific investigation for the grade 6–8 band. Two different ways of achieving this are suggested here.

1. Have the students find each element of a scientific investigation (the questions listed below) in their preliminary plan that they created during steps 5–7, make a note next to the element, and add the elements that they have not included.
2. Use **7.2.G1: Plan an Investigation** and have the students work individually or in groups to complete it. Students who are investigating the same thing such as soil making up the matter can be put in groups to complete their plan for the investigation on **7.2.G1: Plan an Investigation**.

<u>Elements of a Scientific Investigation</u>

a. What are you trying to figure out? *Expected Student Response (ESR): If the type of soil or amount of water or type of nutrients, etc. will affect the amount of matter within a plant.*

b. What is the plan for your investigation? *ESR: We are going to set up several tests that will isolate the factor that we think causes the plant to add all of its matter over time as it grows from a seedling to a large tree.*

c. What are the independent and dependent variables? *ESR: The independent variable is the type of soil or amount of water or type of nutrients, etc. The dependent variable is the change in mass or matter in the plant.*

d. What variables will you control? *ESR: Possible variables that can be controlled can include the intensity of light, type of seeds, amount of water, soil type, temperature, etc.*

e. What tools are needed to do the gathering? What tools are needed to gather the data? *ESR: a triple beam balance or scale to measure the mass, a thermometer, photometer, etc.*

TEACHER NOTE (Continued)

f. How will measurements be recorded? *ESR: Data will be collected using the tools listed above and recorded in the science notebook or data will be collected using collaborative digital spreadsheets.*

g. How much data is needed to support your claim? *ESR: Multiple data will be recorded from the experiments which include the mass, the temperature of the soil, the intensity of light, etc.. A minimum of 5 tests will be made to provide evidence for our claim.*

h. How accurate are your methods for collecting data? *ESR: We will use the same methods for collecting data throughout the experiment to ensure accurate results.*

i. Draw a picture of your plan for your investigation.

j. Think of the different results you might get. What will the results tell you about what you were trying to figure out? *ESR: We are trying to determine how a plant gets all of its matter and increases in mass. Our data will show if the matter came from the soil/water/nutrients/light. If our results are inconclusive, we might need to reevaluate our data collecting methods and/or run more tests to collect more data.*

k. Why is it important for us as scientists to figure out how trees gain their mass? How could our research positively benefit our community?

**ESR Expected Student Response*

Students explain their plan to other groups. This could be done as a whole class or in small groups. Encourage the students to be explicit about how their investigations fit the elements of a scientific investigation listed in #2 in the Teacher Note above and also in the **7.2.G1: Plan an Investigation.** Tell students that they will be providing feedback to each other during this sharing. Students will need support or protocols for providing feedback to each other. A suggested feedback protocol is provided.

a. Structured Talk Scaffold
    1. Group/Person A explains their idea verbally and shows representations/drawings. Group or person B listens.
    2. Group/Person B builds on what was shared verbally and shows representations/drawings.
    3. Group/Person A responds to those ideas or challenges.
    4. This is repeated with Group/Person B sharing their ideas and plans.

b. These sentence frames for feedback can be placed on a card to support student discussion and feedback.
    - I am not sure I understood ______. Can you tell me more?
    - I agree with ______ because ______.
    - I disagree with ______ because ______.
    - What you said ______ about ______ made me wonder ______.
    - I want to build on your idea about ______.

10. Ask questions about what the students are measuring and what the different results would indicate. For example, if students plan an investigation to find out if soil makes up the mass of the tree, then they should mention that they will measure the soil before and after the tree grows. Also, they should say that if the mass of the tree does not match the mass of the missing soil, then that would be evidence that the mass came from somewhere else. Ask students to consider the system under investigation. How is their design related to identifying specific components of the system? How will their design produce fair and accurate information that will help to improve their model?

11. Five minutes before the end of the class, direct students look at their initial model in their science notebook from day one and add any new ideas or wonderings they have to their model. Tell them that they will be adding to this model throughout their learning experiences.

12. End class by returning to the questions that were generated during Lesson 7.1: Tree Matter. Ask the members of the class if they have any additional questions or wonderings to add.

13. ▶ You may wish to collect science notebooks at this point to informally evaluate and identify trends in student progress towards Planning and Conducting Investigations or System and System Models. You may consider focusing on a small section of **7.2.G1: Plan an Investigation** as a review before moving on in this unit. For example, if while reviewing the science notebooks you identify a mismatch between what students say they are trying to figure out and the evidence being collected, you may need to review the cause-and-effect relationships in an investigation plan or review the system components and which component their investigation is testing. You could identify some representative samples of high, medium, and low understanding of these elements of a scientific investigation and review with the class before moving on to Lesson 7.3: Historical Investigations. You could also use this science notebook analysis to guide their work in the next lesson by selecting a few areas of weakness to focus on, such as providing additional support when considering historical investigations.

Toolbox Table of Contents

Plan an Investigation

Group Members:

1. What are you trying to figure out?

2. What is the plan for your investigation?

3. What are the independent and dependent variables?

4. What will you control?

5. What tools are need to gather the data?

6. How will measurements be recorded?

Plan an Investigation (continued)

7. How many data are needed to support your claim?

8. How accurate are your methods for collecting data?

Draw a picture of your plan for your investigation.

Think of the different results you might get. What will the results tell you about what you were trying to figure out?

Appendix 7.2

Planning Plant Investigations

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Planning and Carrying Out Investigations
• Plan an investigation individually and/or collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

DISCIPLINARY CORE IDEAS (DCI)
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.

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Matter is conserved because atoms are conserved in physical and chemical processes.
• Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. (From Grade 3–5)

Appendix 7.2

Common Core State Standards (CCSS)

CCSS ELA WRITING AND ELA SPEAKING AND LISTENING
ELA-LITERACY.W.7.3.C Use a variety of transition words, phrases, and clauses to convey sequence and signal shifts from one time frame or setting to another.
ELA-LITERACY.W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
ELA-LITERACY.SL.7.1.B Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.
CCSS ELA WRITING
CCSS.ELA-LITERACY.W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic, and provide some sense of closure.
CCSS.ELA-LITERACY.W.1.8 With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question.

California English Language Development (ELD) Standards

CA ELD		
Part 1.7.1 Exchanging Information/ideas		
EMERGING	**EXPANDING**	**BRIDGING**
P.1.7.1 Engage in conversational exchanges and express ideas on familiar topics by asking and answering yes-no and wh- questions and responding using simple phrases.	**P.1.7.1** Contribute to class, group, and partner discussions by following turn-taking rules, asking relevant questions, affirming others, adding relevant information, and paraphrasing key ideas.	**P1.7.1** Contribute to class, group, and partner discussions by following turn-taking rules, asking relevant questions, affirming others, adding relevant information and evidence, paraphrasing key ideas, building on responses, and providing useful feedback.

Historical Investigations

7.3

Image via iStock.com/Zoinierek

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Obtain and evaluate information about historical investigations that sought to explain where all the matter in a tree comes from when it begins as a small seedling.

Investigative Phenomenon

Data from historical investigations show that plants don't add mass from water or soil, but they do purify the air when in sunlight.

Standards

Refer to Appendix 7.3 for NGSS, CCSS (ELA), and California ELD Standards.

Storyline Link

In the previous lesson, Lesson 7.2: Planning Plant Investigations, students planned investigations to test where the matter comes from that changes a seedling into a tree. In this lesson, students will obtain information about historical investigations that led to our understanding that plants change the composition of air. In the next lesson, Lesson 7.4: Investigating Gases, students will carry out an investigation to gain evidence that a gas exchange is involved when plants gain matter (live and grow). Students will continue to develop and use models to communicate their thinking by extending to the development of models to represent information obtained from the text about historical investigations. Students will also consider the components of the system and focus on how investigations might provide additional evidence regarding what is entering and leaving the system.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

60 minutes

One 60-minute session

Materials

Group

- ❑ 7.3.G1: Information about Historical Investigations
- ❑ Chart paper, butcher paper, or 11"x 14" sheet of paper
- ❑ Markers

Individual

- ❑ 7.3.H1: Modeling Historical Investigations
- ❑ 7.3.H2: Exit Ticket
- ❑ 7.3.H3: Exit Ticket Assessment Rubric

Teacher Use

- ❑ 7.3.R1: Exit Ticket Assessment Rubric: Possible Instructional Responses

Advance Preparation

1. Print one set per group of **7.3.G1: Information about Historical Investigations** or give students digital access.
2. Print one copy per student of **7.3.H1: Modeling Historical Investigations** or provide the template on the screen (when indicated in the lesson) so students can use their science notebook to record their ideas instead of the handout.

3. Print one copy per 2 students of **7.3.H2: Exit Ticket** or post the question and have students answer the question on a card or in their science notebook.
4. Print one copy per student of **7.3.H3: Exit Ticket Assessment Rubric.**

Procedure

Explore (30 minutes)

Obtain and evaluate information about historical investigations that sought to explain where all the matter in a tree comes from when it begins as a small seedling.

1. In Lesson 7.2: Planning Plant Investigations, students planned investigations to try to determine where the matter that makes up a tree comes from. Have students review/share their plans. Provide sheets of chart paper, butcher paper, or 11" x 14" sheets of paper for students to draw the main details of their plan as a poster.

TEACHER NOTE

If students did not collaboratively develop a plan in Lesson 7.2: Planning Plant Investigations, ask the students to share ideas and either pick one person's plan or develop a common plan now. The goal is to have students collaborate in groups and to have their ideas visible to the class and for you to assess how students are thinking about how the transfer of energy drives the motion and/or cycling of matter. This is also an opportunity for students to move their verbal conversations to a public, written format. The scaffolds for discussion described in Lesson 7.2: Planning Plant Investigations can be used to support student discussion.

2. Facilitate a class discussion as students share their plans. Direct students to visit at least two other groups and review their plans. Tell students to review in pairs or trios and direct them to look for things that are similar and different in the plans.

TEACHER NOTE

English Learners may benefit from linguistic scaffolds to support their ability to express and share their ideas. A few sentence starters can be provided such as: *The dependent variable in both plans ______, but the independent variables ______. The plans use different/similar tools to measure ______.The plans are different because the data collected ______.* Allowing the use of native language, non-standard, or social language can be productive in this process.

3. Tell students that people wondered about similar things in the past and did investigations to find out more information. Sequence the ideas in order so that you can provide the handouts when the ideas are brought up by the students.

4. Explain to students that they will read and discuss information from past investigations. Review the student-generated questions from Lesson 7.1: Tree Matter. Ask students which questions they were attempting to answer when they designed their investigation. Tell students that they worked on developing investigations in Lesson 7.2: Planning Plant Investigations, and now they will have an opportunity to compare their plans to investigations that were actually conducted by scientists in the past. As they discuss the readings, students should evaluate the scientist's plan, the data collected from the plan, and the conclusions drawn from the data. Explain to students that we are analyzing these historical investigations to help us answer our questions related to how matter flows in and out of the plant or tree.
5. Have students obtain information from **7.3.G1: Information about Historical Investigations**. As they read, they should make notes about their evaluation of the plan, the data collected from the plan, and the conclusions drawn from the data. They should also make notations, revisions, and additions to their group poster. As students work, visit each group, listen to their discussion, and review their work on the group poster. If there is no evidence on the group poster that students have considered how the investigation can provide evidence about how the transfer of energy is driving the motion of matter flowing into the tree (system), facilitate their thinking with a few questions:
   - Which component of the system is the focus of the investigation?
   - What inputs were manipulated? Controlled? Measured?
   - What outputs were manipulated? Controlled? Measured?
   - What forms of energy are involved in this system?
   - What molecules are involved in this process?
   - How are the molecules being rearranged?

For English Learners or students reading below grade level, the text of **7.3.G1: Information about Historical Investigations** may be challenging. Before they read, preview the reading to look for terms that are unfamiliar. Annotate the text by identifying words that they won't understand, ideas that relate to their plans, and ideas that bring up questions. This will help them to understand the investigation and its results. Students who are above the target level for this lesson may wish to conduct some individual research. Suggested websites are provided at the end of this lesson.

TEACHER NOTE

The goal of this experience is that students see that their ideas are similar to what scientists actually did. It is important to relate the historical investigations to the student ideas. Conduct a discussion where the students describe their investigations and then provide the matching historical investigation when needed. It is also important to sequence the discussion in the order of questions in **7.3.G1: Information about Historical Investigations**. For example, if a student or group planned an investigation seeking to find out if soil made up the matter of the tree, the student could share that investigation, and then you could provide the part of the reading that describes Helmont's investigations of

TEACHER NOTE (Continued)

"Is soil the source of matter in plants?". Another group may have planned an investigation about water. This group could share their plan, and then you could provide the information on "Is water the source of matter in plants?" The discussion should lead to reading all of **7.3.G1: Information about Historical Investigations**. The main idea is that the students see that the historical investigations relate to the investigations they planned in Lesson 7.2: Planning Plant Investigations.

"Is water the source of matter in plants?" on page 7.3.10 of **7.3.G1: Information about Historical Investigations** includes some flawed logic on the part of the researcher. The stated reasoning is that because MOST of the water was not going into the plant, one can reject the idea that water is the source of the extra 1 g of mass in the plant. While the conclusion to the experiment is reasonable and accurate, there is a discrepancy in the reasoning that students may need support to identify and reconcile.

Explain (30 minutes)

Obtain and evaluate information about historical investigations that sought to explain where all the matter in a tree comes from when it begins as a small seedling.

6. Give students **7.3.H1: Modeling Historical Investigations** or display the template on a screen so the students can enter their work directly into their science notebook.

TEACHER NOTE

These historical investigations are designed to elicit and address some common alternate conceptions common in middle school students. For example, many middle-age students think that plants gain mass from the soil or use soil for food. This can lead to the prediction that when a plant grows, the soil will lose weight. This idea is brought up in the Van Helmont investigation. Similarly, middle school students often think that plants gain mass from water, which is addressed in the Woodward investigation. Other student alternative conceptions include seeing food as a requirement for growth, rather than a matter for growth; seeing organisms, such as plants, as very different types of matter from other materials in the environment such as water or air. The connection between matter, energy, and food will start to be addressed in this lesson and developed over the next several lessons in the unit.

7. Ask the students to think about what each investigation was trying to figure out. To which component of the system does the investigation relate? Does it connect to some aspect of their model? Direct students to part 1 of **7.3.H1: Modeling Historical Investigations**. Have students process the information they obtained in the reading by creating models of the investigations using **7.3.H1: Modeling Historical Investigations**. The models should include words and drawings that show the steps of the investigations and conclusions. Any critiques

(good or bad) about each investigation should also be included in each model. As students work in their groups, walk around the room, and visit groups to assess their progress. This is another opportunity to check for evidence that students have considered how the investigation can provide evidence about how the transfer of energy is driving the motion of matter flowing into the tree (system). Facilitate their thinking with the same questions used in step 3:

- What component of the system is the focus of the investigation?
- What inputs were manipulated? Controlled? Measured?
- What outputs were manipulated? Controlled? Measured?
- What forms of energy are involved in this system?
- What molecules are involved in this process?
- How are the molecules being rearranged?

8. Have students compare their drawings with other students and make changes or add information if necessary. At this point, students should be able to produce models that accurately display the steps of each investigation (first drawing includes a sprig of mint under an enclosed clear jar with a burning candle, the second drawing shows a similar set-up with candle burned out, etc.), the data collected (burnt-out candle is capable of relighting and burning after 27 days with the plant) and conclusion (plants change the composition of the air). Remind students to use the discussion prompts introduced in Lesson 7.2: Planning Plant Investigations when they share their models:

   - I am not sure I understood ______. Can you tell me more?
   - I agree with ______ because ______.
   - I disagree with ______ because ______.
   - What you said ______ about _____ made me wonder ______.
   - I want to build on your idea about ______.

   After students have discussed their models with another group and received feedback, allow them a few minutes to consider the feedback they received and revise their models.

9. Direct students to Part II of **7.3.G1: Information about Historical Investigations**. Tell students that if they have not considered how each investigation contributes to our understanding of the flow of matter, they can add that to their models now. Tell students that at this point, their models should use evidence from these investigations about how matter can be tracked in terms of weight.

10. Direct students to consider how they can add details about how the transfer of energy is contributing to how matter is flowing in and out of the tree. These points should have been discussed in steps 3 and 5, but students may not have recorded their ideas in their science notebook yet. These ideas will be built on later, so it is important they are recorded in their science notebook.

11. Ask a few groups to share their thinking or select groups to share based on conversations you have had while observing their group work. If students are uncertain how to include energy transformation to their models, ask them what evidence there is that the plant is getting the energy it needs (it is growing, it is healthy, etc.) and then how they might indicate that on their models (additional arrows or labels). Students who are not yet proficient in English may feel uncomfortable sharing with the entire class. You can ask those students ahead of time if they would be willing to share something in the small group, providing additional time to prepare what they want to say. Other options are suggesting that students use the visual model as support or co-sharing the idea with a table partner.

12. Direct students to add a short paragraph summary of each model in their science notebook. Remind students that the summaries should identify the main ideas of each handout without directly repeating information. Students above the target level should be encouraged to include descriptions of matter cycling and energy flow in the investigation descriptions. If students are having trouble summarizing in paragraphs, they could summarize using the models constructed during their group work and add a few sentences about the model. English Learners would benefit from this multimodal strategy as well as a few sentence frames to describe the investigations:

    - The variable changed was ________.
    - The data ______ was measured.
    - The conclusion was ________ because _______.

    ▶ These summaries can be reviewed to assess both whole class and individual student progress and combined with the exit ticket assessment data (step 14.) However, students need to have a record of these discussions in their science notebook to refer back to later in the unit as they plan and conduct their own investigations.

13. Five minutes before the end of the class, direct students to look at their initial model from Lesson 1: Tree Matter and add any new ideas or wonderings they have to their model. Remind them that they will be adding to this model throughout their learning experiences. Ask students to consider ways in which their models are limited in describing the phenomenon of the tree growing and what information would be useful to improve their model.

14. Distribute **7.3.H2: Exit Ticket** or post the question and have students answer the question on a card or in their science notebook. Tell students: Now that we have learned about results from investigations done in the past, what can we say about where a tree's mass comes from? What cause-and-effect relationships are supported with evidence from the historical investigations? What cause-and-effect relationships are not supported? What is a question that you still have?

15. ▶ Direct students to record their ideas on a slip of paper or notecard and hand it to you as they leave the class. These notecards can provide you with evidence of student learning (FORMATIVE ASSESSMENT) and help plan for the next series of lessons. At this point, students should state that plants need sunlight to add mass, but soil and water are not adding to the new mass or growth of the tree.

TEACHER NOTE

▶ **7.3.H2: Exit Ticket** is answered individually by each student. The exit tickets should be reviewed and returned to the individual students with your evaluation using the **7.3.H3: Exit Ticket Assessment Rubric**. Mark each row of the rubric with yes/no to provide feedback to each student. As you have judged each students work, put a tally in the yes or no column of **7.3.R1: Exit Ticket Assessment Rubric: Possible Instructional Responses** to identify trends across the entire class. Suggestions located in the last column of **7.3.R1: Exit Ticket Assessment Rubric: Possible Instructional Responses** may be used to support individual students as well as used with the entire class.

References

Rubin, J. T. (n.d.). The Discovery of Photosynthesis. Retrieved from http://www.juliantrubin.com/bigten/photosynthesisexperiments.html

Toolbox Table of Contents

Information about Historical Investigations

Is soil the source of matter in plants?

In the 1600s, a man named Jan Baptista van Helmont was investigating how plants take in mass. He asked the question, “Do plants get their mass by taking up minerals from the soil?” For 5 years, he grew a tree inside a pot and measured the mass of the tree and the soil. His measurements showed that the tree weighed 74 kg more compared to the start of his experiment, but the mass of the soil had hardly changed at all. He concluded that the increase in mass as a plant grows does not come from the soil. Van Helmont thought that the extra mass was coming from the water that plants absorb.

Things to consider:

Evaluate the investigation plan, the data collected from the plan, and the conclusions drawn from the data.

How do the results of the investigation help us think about how the transfer of energy is driving the motion of the matter moving into and out of the tree (system)?

Information about Historical Investigations (continued)

Is water the source of matter in plants?

Building on the work of Van Helmot, John Woodward designed an experiment to test the idea that the increase in tree mass comes from water. In the late 1600s, he conducted a series of experiments to measure the water consumed by plants.

Over the course of 77 days, Woodward's evidence showed that plants gained very little mass compared to the amount of water they absorbed. For example, one plant had gained 1 gram of mass but had received almost 76,000 grams of water. Woodward concluded that most of this water was not staying in the plant itself but was absorbed and then moved through the pores of the leaves and released into the air. This led him to reject the hypothesis that water was the source of the additional mass.

Things to consider:

Evaluate the investigation plan, the data collected from the plan, and the conclusions drawn from the data.

How do the results of the investigation help us think about how the transfer of energy is driving the motion of the matter moving into and out of the tree (system)?

Information about Historical Investigations (continued)

Does the air have something to do with the source of matter in plants?

It would not be until 1771 that Joseph Priestley designed an experiment to investigate how plants interact with the air. In his experiment, Priestley placed a branch of mint (plant) and a candle in a transparent closed space. He observed that the candle would burn until the air was used up (oxygen was not discovered yet) and then the candle would quickly go out. He waited 27 days and then he relit the extinguished candle without opening the closed space. Priestley observed that the candle was able to burn again in the same air that had previously failed to support it. To light the candle without opening the space, Priestley focused beams of sunlight with a mirror onto the candlewick.

Priestly's evidence showed that plants somehow change the composition of the air.

In another experiment, Priestley kept a mouse in a closed jar of air until it collapsed. When he placed a plant in the jar with the mouse, the mouse would survive. DO not repeat this experiment. Do not endanger animals.

His observations from these experiments led Priestley to an interesting hypothesis: plants put back into the air whatever material is taken out by breathing animals and burning candles.

Things to consider:

Evaluate the investigation plan, the data collected from the plan, and the conclusions drawn from the data.

How do the results of the investigation help us think about how the transfer of energy is driving the motion of the matter moving into and out of the tree (system)?

Information about Historical Investigations (continued)

Even though light is not matter, why is it important to plants?

Jan Ingenhousz built upon Priestley's work. In 1779, Ingenhousz placed a plant and a candle into a transparent closed space. This was similar to the design of Priestley's experiment, but Ingenhousz did not light the candle. Ingenhousz let the system stand in the sunlight for two or three days. He wanted to make sure that the plant had made the air inside the container pure enough to support a candle flame. He then placed a black cloth over the closed container and left it covered for several days. When Ingenhousz tried to light the candle, it would not light.

Ingenhousz concluded that plants must act like breathing animals when placed in darkness. Plants must also breathe, and plants need sunlight in order to purify the air.

In his next experiment, Ingenhousz, placed a small green aquatic plant in a transparent container of water. He placed the container in bright sunlight and observed the plant. He saw gas bubbles forming around the leaves and around the green parts of the stems. When Ingenhousz moved the system into darkness, the bubbles stopped forming. Ingenhousz thought that the bubbles could be the material produced by plants that purifies air after it has been changed by animals or candles.

His experiments showed, for the first time, that light is needed for plants to complete the process that purifies the air.

Things to consider:

Evaluate the investigation plan, the data collected from the plan, and the conclusions drawn from the data.

How do the results of the investigation help us think about how the transfer of energy is driving the motion of the matter moving into and out of the tree (system)?

Modeling Historical Investigations

Part 1: In each box, draw a model that shows the steps of the investigations and the conclusions the scientists made.

Is soil the main source of matter in plants?	***Is water the main source of matter in plants?***
Does the air have something to do with the source of matter in plants?	***Even though light is not matter, why is it important to plants?***

Part 2: Add to your model: how does the investigation provide evidence the flow of matter in terms of weight was involved in the investigation and how the transfer of energy is driving the flow of matter.

Exit Ticket

Name: ________________

What do the historical investigations tell us about where a tree's mass comes from? What cause-and-effect relationships do we have evidence for?

What questions do you still have?

Exit Ticket

Name: ________________

What do the historical investigations tell us about where a tree's mass comes from? What cause and effect relationships do we have evidence for?

What questions do you still have?

Exit Ticket Assessment Rubric

Name: ___________________________

	Yes	No	Comment
Components			
Historical investigations show that new mass is not coming from the soil.			
Historical investigations show that new mass is not coming from water.			
Historical investigations show that sunlight is needed for new mass.			
Cause-and-Effect Mechanisms Response indicates a reasonable connection between evidence of source such as water or soil (cause) and claim for source of new mass (effect).			
Questions New questions posed are based on evidence from historical investigations OR seek to clarify additional information to explain tree growth.			

Exit Ticket Assessment Rubric: Possible Instructional Responses

Possible Student Responses	Yes	No	Possible Instructional Response To Trends in Student Work
Components			Review evidence from each investigation. Record data in a table to clarify evidence gathered and draw a conclusion about growth. Group: Review evidence on the class chart with columns titled YES adds mass, NO does not add mass, and UNCERTAIN.
Historical investigations show that new mass is not coming from the soil.			
Historical investigations show that new mass is not coming from water.			
Historical investigations show that sunlight is needed for new mass.			
Cause-and-Effect Mechanisms Response indicates a reasonable connection between evidence of source such as water or soil (cause) and claim for source of new mass (effect).			Review cause-and-effect relationships in more familiar examples or examples related to students' lives. Introduce the cause and effect sentence stems: If this ______ then ______. If ______ happens then ______. The _____ caused _____ the effect of _____.
Questions New questions posed are based on evidence from historical investigations OR seek to clarify additional information to explain tree growth.			Gather questions from exit tickets and summarize new questions into groups. Review these chunks of questions with students highlighting questions that connect to the historical discussions and would lead to investigations that could add to or clarify aspects of our current understanding. Invite students to reword or revise other questions so they connect or clarify or add to our understanding.

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

DISCIPLINARY CORE IDEAS (DCI)

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.

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.

Appendix 7.3

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.
Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within a system. (From Grade 3–5)
Cause and Effect
• Cause and effect relationships are routinely identified, tested, and used to explain change. (From Grade 3–5)

Common Core State Standards (CCSS)

CCSS ELA READING
CCSS.ELA-LITERACY.RI.7.1 Cite several pieces of textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
CCSS.LA-LITERACY.RI.7.2 Determine two or more central ideas in a text and analyze their development over the course of the text; provide an objective summary of the text.

California English Language Development (ELD) Standards

CA ELD		
Part I 7.6 Reading/viewing closely		
EMERGING	EXPANDING	BRIDGING
P1.7.6a Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-appropriate texts and viewing of multimedia with substantial support.	**P1.7.6a** Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with moderate support.	**P1.7.6a** Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with light support.

Investigating Gases

7.4

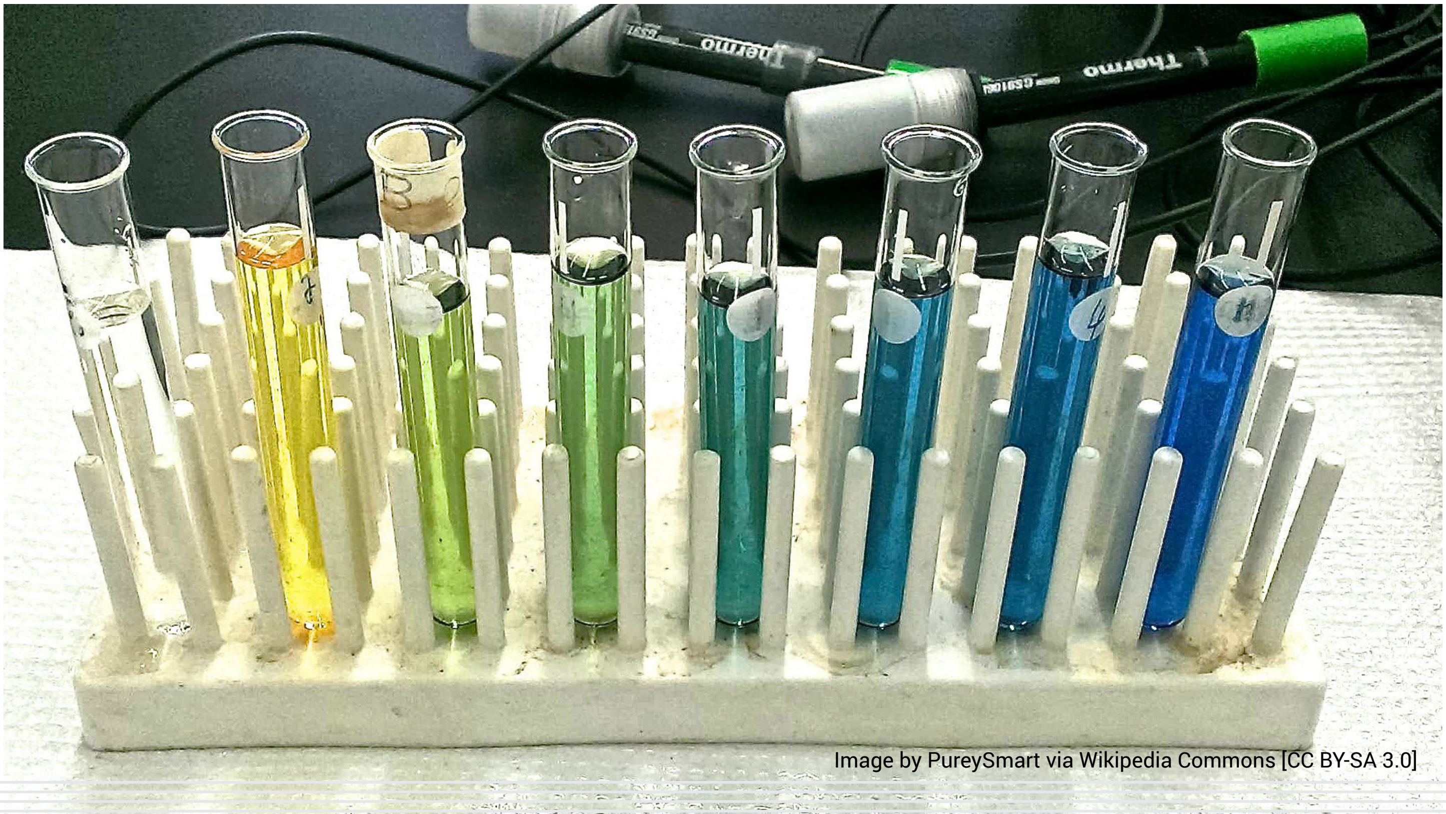


Image by PureySmart via Wikipedia Commons [CC BY-SA 3.0]

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Conduct an investigation to produce data to explain that carbon dioxide gas is involved when plants matter (live and grow).

Investigative Phenomenon

The amount of carbon dioxide in the water surrounding aquatic plants increases and decreases depending on the amount of light.

Standards

Refer to Appendix 7.4 for NGSS, CCSS (ELA), and California ELD Standards.

Storyline Link

In this lesson, students will build on the learnings from the previous lesson that plants need sunlight to add mass, but soil and water are not part of the additional mass. In this lesson, students investigate the gases that are exchanged within the plant. They will continue to use models to explain their thinking about the phenomenon, extending their models to include components too small to be seen (invisible). Students will plan and conduct another investigation by building on their understanding of variables and tools from the previous lesson to plan and conduct the investigation. Students will apply the concept of stability and change to think about how changing the inputs in one part of the system (amount of light, amount of CO_2), affect other parts of the system as they analyze evidence collected from their investigations.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

120 minutes

Part I	60 minutes	Explore
Part II	60 minutes	Explain

Materials

Group

- ❑ 2–4 Elodea sprigs (found at pet stores)
- ❑ 2–4 125 ml Flasks
- ❑ 2–4 Rubber stoppers (#5) or other sealant such as wax
- ❑ Diluted 0.1 solution of bromothymol blue (BTB) by adding seven drops to 30 ml of water
- ❑ Water
- ❑ 1 Light source (full spectrum if possible—can be purchased at home improvement or pets stores)
- ❑ 1–2 Drinking straws
- ❑ Chart paper and markers

Individual

- ❑ Science notebook
- ❑ Safety goggles
- ❑ 7.4.H1: Storyboard Template (optional)

Advance Preparation

1. Create enough BTB 0.1 percent solution for each team to have enough solution to fill two flasks, plus extra solution in case students need to set up their investigation a second time.
2. Practice with blowing into the BTB solution (while blue) to create a color change.
3. Review safety procedures for working with chemicals and glassware in your state safety handbook such as chapter 7 of https://www.cde.ca.gov/pd/ca/sc/documents/scisafebook2014.pdf.
4. Print one copy per student of **7.4.H1: Storyboard Template** (optional).

Procedure

Part I

Explore (60 minutes)

Conduct an investigation to collect data on observable and unobservable variables to explain how trees rearrange carbon dioxide and water into complex molecules to support growth.

1. Ask students to review their notes from Lesson 7.3: Historical Investigations. Ask them to think about what they know so far about where plants get the matter to grow from a seedling into a tree. Review the student questions collected at the end of Lesson 7.3: Historical Investigations. Explain that students will have an opportunity to plan another investigation to answer some of their questions in this lesson.
   - Ask students to think about the models they created. Students should review the entries of their models in their science notebook from Lesson 7.3: Historical Investigations (step 11). How do the models describe how the tree is getting energy to gather more mass? With which parts of their model are they satisfied? For which parts do they think need more information? What did they include in their models about energy?
   - Tell students that all models are revised with new evidence. In the next part of the lesson, they will have an opportunity to evaluate the limitations of their model and design an investigation to collect evidence that may improve their model.

TEACHER NOTE

▶ This is another opportunity to assess what students understand about the crosscutting concept of Energy and Matter, similar to the assessment in Lesson 7.3: Historical Investigations. New aspects to consider in this lesson include: Does the model include a representation that matter is made of particles? Are students thinking about the amount of matter before, during, and after the process? Do they include energy in different forms? If they do not, you may want to consider pausing the sequence here and returning to previous lessons on matter taught prior to this sequence. Students may need an opportunity to reconnect with these concepts via a brief review of their science notebook, additional reading or video, or brief small group discussion.

2. Chart student responses as they share. Summarize their thoughts once all have had a chance to discuss what we know so far on the chart. Explain to students that they have developed their models and will continue to consider the limitations of their models to decide what additional evidence they need to revise and improve their models. Tell students that they are also deepening their use of the crosscutting concept Energy and Matter to help think about ways in which the plant is transferring energy to gain matter for growth. Direct students to their previous questions (in the class chart and their science notebook) and ask them to consider what questions they have developed that relate to how the plant is getting energy or how the plant is using energy to get more matter.

3. Use the ideas that students shared to facilitate a discussion about gases and how to find out more about them (in the next investigation). Ask students to consider which part of the system gases might exist. Direct students to write out their ideas in their science notebook before continuing with a class discussion. If the issue of gas exchange has not come up yet, ask students to think about the historical investigations. What did they tell us about gases? (Gases are exchanged, but the historical studies did not provide evidence about what gases were involved.) Students may bring up oxygen or carbon dioxide from personal experience. If students bring up these gases, acknowledge the idea, and suggest that we need additional data to understand this better. Acknowledge that while we know a great deal about how trees rearrange matter to gain mass, we need additional information about how gases are moving through the system to improve our models and explanations. Provide a few minutes for students to record any new ideas into their science notebook from the class discussion.

Demonstration of Technique

TEACHER NOTE

You will want to review safety procedures with the class prior to starting the investigation. Important safety issues to reinforce basic safety rules include do not put any materials in your mouth, wear goggles when working with liquids, and use care when using glassware. You should have a special container to collect any broken glass so it is not placed in the classroom trash can. Bromothymol blue is a relatively safe chemical, but you should review the material safety data sheet prior to using it: http://www.labchem.com/tools/msds/msds/75033.pdf.

4. Explain to the class that they will plan and conduct their own investigation to collect more evidence in their table groups (2–4 students). During this investigation, students will be able to use a special chemical called bromothymol blue or BTB for short. Demonstrate with the BTB:
   - Fill a beaker half-full with the diluted BTB.
   - Tell the class that you are going to blow into the liquid with a straw. Ask the class to think about what you will probably add to the liquid when you blow into it. (What gas is in our breath when we breathe out?)
   - Insert a straw into the liquid and gently blow until the color changes from blue to green to yellow. It is useful to stop when the liquid begins to change color and ask the class what they think is happening. What do they think will happen when you continue to blow into the liquid? WEAR GOGGLES WHEN DEMONSTRATING.
   - Ask the class to discuss with a partner what they think is happening. Solicit a few suggestions from the groups. Students should connect the blowing breath into the liquid with the color change. Ask students what they know about the gases in their breath. What is in your breath? Confirm that you are adding CO_2 to the liquid when you blow through the straw.

TEACHER NOTE

BTB is an indirect indicator that CO_2 is present. BTB is normally blue (as the name indicates), but when CO_2 is added, it will cause the BTB to change to green, and with increasing amounts of CO_2, to yellow. When CO_2 is taken out of a BTB solution, the color change reverses back toward blue. For English Learners, it is useful to have a visual reminder of terms such as CO_2 on a yellow card, some CO_2 on a green card, and no CO_2 on a blue card.

- Ask students to think about how they might investigate their question using the BTB. This is a good place to introduce roles for discussion. If you already have an established protocol for roles during group work, this is a good point to use them. Otherwise, introduce the following roles to be used as groups plan their investigation:
  - **Facilitator:** This person makes sure that the group is on task and the discussion is moving. The facilitator can remind the group about the purpose of your tasks or ask questions to keep the discussion going. He or she also makes sure that everyone is contributing to the discussion and all ideas are included.
  - **Timekeeper:** This person's job is to watch the time and make sure the group is moving along in the task at an appropriate pace. The timekeeper can alert the group of certain points in time with comments such as half our time has passed or there's *5 minutes left*.
  - **Summarizer:** This person will record the important ideas from the group discussion and provide a summary of the discussion for the group. The summarizer may summarize ideas in words, symbols or pictures. Other students then suggest edits and additions or simply approve the summary.
  - **Presenter:** This person will share the group's ideas with the class. The presenter should discuss with the group how much of the discussion/information will be shared.

  You can assign roles randomly or allow students to select. It is useful to provide descriptions of these roles on a student handout or as a table placemat.
- Allow students to discuss in their groups, and listen to their discussions as they work. As students consider using the BTB to investigate their questions, ask the groups to consider how the BTB might provide evidence about how gases are consumed over time and how they might use the color changes. Have students identify in which part of the system to use BTB to develop a deeper understanding. How might the color change (effect) help us to understand the phenomenon (what cause)? Direct students to record their ideas in their science notebook. For struggling students, you can provide a template or a table with these three headings: Part of the System to Investigate, Changes in Gases to Investigate, and What a BTB Color Change Tells Us About Gases. This is a good time to remind students that they created a plan for an investigation in Lesson 7.2: Planning Plant Investigations and evaluated plans in Lesson 7.3: Historical Investigations. Ask students to refer back to these plans and the ways in which they identified independent and dependent variables in those plans. Students should also consider what they learned about selecting which data measurements to collect and the tools needed to do so.

- After a few minutes of discussion, ask the groups to review their science notebook, and provide time for the summarizer and presenter to get ready to share their ideas with the class. Record possible ideas shared by the students on the board or chart paper. This will provide an opportunity to check if students have any questions about what BTB is, what the colors indicate, and how to use BTB to further their investigation. Allow student teams to revise their plan based on any ideas from the whole group discussion. Look for evidence that students are considering the inputs and outputs of the phenomenon in their design. Students should be able to justify the use of BTB to revise weak parts of their model (by adding additional evidence).

Planning Their Investigation

5. Tell students that they will be given 20 minutes to discuss/plan and write their procedure. Remind students that their investigation should gather evidence to help explain what gases are exchanged within a plant/tree system as it lives and grows. Advise students to consider whether the transfer of energy is affecting the motion of gases in and out of the plant (system) when they select a question to investigate. Remind them that they are using the crosscutting concept of Energy and Matter to think about their investigations.
6. Tell students that they will need to draw or storyboard their plans and have them approved by you before gathering materials. (If needed, a template for storyboard is provided in **7.4.H1: Storyboard Template**). Teams can continue using the roles from the prior group or switch roles. Clarify that the “summarizer” for the group takes responsibility for writing the storyboard. Provide feedback during the planning time as students work. Explain to students that they will be able to leave their experiments set up overnight. Explain that they will collect data on the next day. Remind students that they have planned investigations in Lesson 7.2: Planning Plant Investigations and Lesson 7.3: Historical Investigations) If necessary, you can clarify elements they have considered in the development of their previous plans:

    - identify the scientific question that you will be testing in your experiment
    - choose the independent and dependent variable(s)
    - select variable controls
    - decide what tools are needed to do the gathering
    - determine how measurements will be recorded

    Possible student investigations might include changing the number of plants in each tube, the amount of light exposure, the amount of carbon dioxide placed in the water (students can add CO_2 into the liquid using the method modeled earlier). Students may want to put a flask in a cabinet or cover it with paper to reduce its access to light. Others may decide to change the initial color of the liquid in which the plants are placed. As students begin to develop their plans, monitor that they are using the crosscutting concept of Energy and Matter as they select variables and tools for measuring. Ask students to explain how their design will gather evidence about the motion of gases in and out of a plant. Did students consider the transfer of energy (such as availability of light) in their design? These questions are to ensure that students have considered these concepts thoughtfully in their plans, but do not direct students on how to conduct their investigations. You will want to make sure that at least one group's investigation has a plant in yellow BTB in the light and one plant in yellow BTB in the dark. However, running two plants in blue BTB (one in the dark and one in the light) is also useful to the class discussion.

TEACHER NOTE

This is an opportunity to differentiate for students progressing more rapidly or slowly with the SEP through the complexity of the investigation design. Since students will conduct this investigation, the sophistication of data collected and the complexity of the design can be adjusted. For example, some groups may want to collect data of multiple variables (multiple set-ups) or run part of the investigation outside of the classroom.

7. As students work collaboratively to develop their investigation plans, encourage teams to think about how to create a "fair test" and how to take accurate measurements. Remind students that they have considered these elements before, and if they are struggling, students can review their previous plans from Lesson 7.2: Planning Plant Investigations and Lesson 7.3: Historical Investigations. These details should be included in their plans or storyboards. Students may need help limiting their investigation to one variable or including some type of control for comparisons. This activity works best when there is a control set-up (no change) and an experimental set-up (change based on variable selected) in order for a color change to be interpreted accurately. If teams have not thought about what or how they will record their data, ask them to think about how they might do this. Move teams along to get their plans completed within the 20-minute time window.

8. Once students have completed their plan, direct table groups to swap their plan with another group. Tell students to provide feedback to the other group on their investigation plan. Student teams should record their questions and suggestions on sticky notes on the other team's plan. Students may need support on how to give feedback. Tell students that feedback has to be detailed and suggest some action. You may choose to provide feedback sentence stems, such as:

   Need Clarification

   - What do you mean by _____?
   - Can you elaborate on _____?

   Suggestions for Improvement

   - It seems like you are measuring _____. We agree/disagree because _____.
   - You are controlling _____. We think you should ALSO _____.
   - Your plan says _____. We disagree because _____ and think you should change_____.
   - We agree/disagree with the plan to _____ and think you should add _____ because _____.
   - We do not think _____ in the plan matches _____.

Select which groups will share and provide feedback by common design elements or complementary areas of strengths and weaknesses.

9. After 10 minutes, direct the class to return the plans to the original team and give students a few minutes to consider the feedback and revise their plans before bringing it to you for approval. Remind students that it is useful to get ideas from our peers about ways we might improve our designs. Tell students that they should read the feedback carefully as a group. If the feedback is unclear, they can ask the other group for clarification. Discuss whether or not you agree or disagree with the feedback and revise your work accordingly.

10. Once teams have completed their plans and they have been approved, direct them to get their supplies and set up their experiments before the end of the class period. Remind students to record the initial conditions of their experiments in their science notebook before leaving for the day.

Conducting the Investigation

11. Provide another 10–15 minutes for students to set up the experiment according to their design. The experiments will need to be left overnight (24 hours). For those that include light, the lights should remain on for the entire 24 hours.

Part II

Explain (60 minutes)

Analyze and interpret data to provide evidence for how trees rearrange carbon dioxide and water into complex molecules to support growth.

12. The next day, quickly review the purpose of the investigations (to find out additional information about how trees rearrange matter to improve our models). Students should review their plans in their science notebook and then move on to collect data from their experiments. Students should be recording data in the data table in their science notebook. Rotate to each group and ask the teams to tell you what they observe in their data. Students may respond by talking about the color change observed in one but not both conditions (control and experimental). If this happens, ask students to tell you about both conditions. Ask students, “What was similar? What was different?” Depending on the variables selected, there may not be any noticeable difference in the results. Assure students that “no change” may still be an important finding.

13. Allow time to consider what they will share with the class. In the grade 3–5 band, students make observations and/or measurements to produce data to serve as the basis for an explanation. In this lesson, students are extending that previous learning to use data to serve as the basis for evidence to answer a scientific question. Students may need facilitation in their small teams to support the connection between the question they were attempting to answer and the data they are selecting as evidence.

14. Once teams have collected data from their experiments, ask each team presenter to report the team's findings. Tell teams to report on the variables they tested and the results after 24 hours. Students should be encouraged to ask questions as teams report their findings. However, instruct students to ask clarifying questions, rather than evaluating the experimental design. Critiquing the design of an investigation is an important skill, but the focus at this point of the lesson is to provide students with enough data to make a claim. Remind students to use the discussion prompts from Lesson 7.2: Planning Plant Investigations.

15. As teams report, chart the results on a class chart. For teams who chose to test the same variable, ask the teams to discuss whether their data are consistent with that of the other team. If not, what might be the cause? Providing a set of sentence frames around discussing ideas will support English Learners in the classroom discussion. Examples can be found at https://www.fossweb.com/delegate/ssi-wdf-ucm-webContent?dDocName=D567151.

16. After each team has presented their results, students will have all the data from the class, not just their own data. They can use all the data to revise their previous models about what is happening with matter in the growth of the sequoia tree or plants at their home/school. Tell students that they will now work on summarizing the class results and generating questions that still remain.

17. Distribute chart paper and markers to each team. Provide 10 minutes for teams to review and think about their previous models. On the chart paper, teams should represent their new understanding of how trees gain mass, integrating their new data into their model.

    - Encourage students to include information about the variables selected by their team and other teams into their revised model.
    - Ask students to consider how the movement and rearrangement of gas particles explain what was observed over time as the seedling grew into a large tree. How does the behavior of particles on a very small scale explain the observations of things at a large scale?
    - Ask students if their models explain how changes in the variables would lead to growth over time. How might changes in one part of a plant cause large changes in another part?
    - Ask students to consider where energy is entering the system. How is that shown in the model? How do you see that energy transferring into the system?
    - Ask students to consider if changing the inputs in one part of the system (amount of light, amount of CO_2), would affect other parts of the system. For example, how does changing the amount of light change the amount of CO_2 produced?

    Students should include ideas about how matter moves into and out of the plant in different conditions. (The plant absorbed CO_2 when placed in sunlight but not when placed in the dark. Plants only absorb CO_2; they do not produce it. Without sunlight or CO_2, the plants die and start to decompose). Their models may include ideas about how access to light energy affects how plants cycle matter into and out of the plant. At this point, students should have a conceptual idea that some matter (CO_2) moves into a plant in the presence of light energy (Energy and Matter) and that the energy transfer is a driver for more CO_2. However, this is the first time that students have been asked to use the crosscutting concept Energy and Matter with matter that they cannot see or touch (CO_2). In Lesson 7.5: Matter Models, students will investigate the particles involved in the phenomenon. Students' ability to connect this crosscutting concept to the molecular nature of the phenomenon may not develop fully until the end of the next lesson. They may start to include the reference to particles in their models and arrows to show how specific particles are moving into the plant with arrows or other drawings (Modeling) to explain how plants use energy to grow (LS1.C & PS3.D).

18. Tell students to record their new ideas about plants, matter, and their models in their science notebook. Ask students to consider what questions they now have about how plants get and use energy and matter, the relationship between energy and matter, their models, or any other thoughts about the phenomenon. Explain that in the Lesson 7.5: Matter Models they will continue to investigate the phenomenon.

19. ▶ Assessing student progress: Multiple student artifacts were developed during this lesson including group investigation plans and models and individual science notebook entries including revised models. This would be a good opportunity to review individual student models in their science notebook. You could also ask students to record their model on a separate piece of paper in step 20. Reviewing these individual models will give you an opportunity to assess class progress and in particular, students above or below the learning target. This is also an opportunity to provide individual student feedback. As you review the student models, provide specific feedback about where the model is effective and points that need clarification or addition. Some suggested areas to review include:

    - Are the variables selected by the team included in the model?
    - Does the model indicate the movement and rearrangement of gas particles? Is this connected to tree growth?
    - Does the model show energy is entering the system? Does it clearly show how energy transfers within the system?
    - Does the model show how changing the inputs in one part of the system affect other parts of the system? Does it show how modifying the amount of light changes the amount of CO_2 produced?

TEACHER NOTE

The intent is not to "correct" students' models but to provide guidance that will help students reflect on their model and provide suggestions for things they may have not considered. When you return the feedback to students, tell them to read the feedback and consider what they could use to improve their models. Tell them if something in the feedback is unclear, they should ask you for clarification. Remind students that the feedback is intended to be useful and is not an indication of a good or bad model.

References

California Department of Education. (2014). Science Safety Handbook for California Public Schools. Retrieved from https://www.cde.ca.gov/pd/ca/sc/documents/scisafebook2014.pdf

FOSS, & The Regents of the University of California. (n.d.). Science-Centered Language Development. Retrieved from https://www.fossweb.com/delegate/ssi-wdf-ucm-webContent?dDocName=D56715

LabChem.com. (n.d.). Material Safety Data Sheet. Retrieved from http://www.labchem.com/tools/msds/msds/75033.pdf

Toolbox Table of Contents

Storyboard Template

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.*]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Planning and Carrying Out Investigations

- Plan an investigation collaboratively and in the design identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded and how many data are needed to support a claim.
- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions.

Engaging in Argument from Evidence

- Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.

Developing and Using Models

- Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution (from Grade 3–5).

Appendix 7.4

DISCIPLINARY CORE IDEAS (DCI)
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.
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.

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within a system. • Models are limited in that they only represent certain aspects of the system under study.

Common Core State Standards (CCSS)

CCSS SPEAKING AND LISTENING
ELA-LITERACY.SL.7.1.B
Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

Appendix 7.4

California English Language Development (ELD) Standards

CA ELD		
Part I 7.3 Supporting opinions and persuading others		
EMERGING	**EXPANDING**	**BRIDGING**
P1.7.3 Negotiate with or persuade others in conversations (e.g., to gain and hold the floor or ask for clarification) using learned phrases (e.g., *I think … , Would you please repeat that?*) and open responses.	**P1.7.3** Negotiate with or persuade others in conversations (e.g., to provide counter-arguments) using learned phrases (*I agree with X, but …*), and open responses.	**P1.7.3** Negotiate with or persuade others in conversations using appropriate register (e.g., to acknowledge new information) using a variety of learned phrases, indirect reported speech (e.g., *I heard you say X, and I haven't thought about that before*), and open responses.

Matter Models

7.5

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Develop a model to explain how plants use the Sun's energy to recombine carbon dioxide and water into oxygen and carbon-based organic molecules, like sugar.

Investigative Phenomenon

When matter exits a plant, the molecules are in a different arrangement from when the matter entered.

Standards

Refer to Appendix 7.5 for NGSS, CCSS (ELA), and California ELD Standards.

Storyline Link

In previous lessons, the students developed an understanding of inputs and outputs related to photosynthesis, including those not observable with the unaided eye. In this lesson, students will think about what is accumulated in the plant due to photosynthesis. Students use different-colored sticky notes to model the creation of glucose and cellulose through chemical processes. Students also extend their use of written models to the use of physical models to explain the photosynthesis process and the relationship between inputs, processes, and outputs at the atomic scale. Students continue to use concepts of systems and stability and change to think about how energy is used to rearrange matter at a very small scale, connecting changes at a small scale to the macro-scale observations of the overall phenomenon.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

120 minutes

Two 60-minute session

Materials

Whole Class

- ❑ Chart paper
- ❑ Markers

Group (Groups of 4)

- ❑ Sticky notes (assorted colors)
- ❑ 7.5.G1: Flowchart

Individual

- ❑ 7.5.H1: Photosynthesis Reading
- ❑ 7.5.H1a: Photosynthesis Reading Alternate Text
    - ❑ Overview of Cellular Respiration video (link in Photosynthesis Reading) https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/overview-of-cellular-respiration-steps/v/overview-of-cellular-respiration
    - ❑ Lactic Acid Fermentation video (link in Photosynthesis Reading) https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/variations-on-cellular-respiration/v/lactic-acid-fermentation
- ❑ Science notebook
- ❑ Baggies

- ❏ Sticky notes (assorted colors)
- ❏ Pieces of paper

Advance Preparation

1. Review **7.5.H1: Photosynthesis Reading** and **7.5.H1a: Photosynthesis Reading Alternate Text**.
2. Print one copy per student of **7.5.H1: Photosynthesis Reading** or **7.5.H1a: Photosynthesis Reading Alternate Text**
3. Print one copy per two students of **7.5.G1: Flow Chart** and have a copy ready to display to the class.
4. Assemble sticky notes and paper in baggies.

Procedure

Explore/Explain I (120 minutes)

Develop a model to explain how plants use the Sun's energy to recombine carbon dioxide and water into oxygen and carbon-based organic molecules, like sugar.

Review Previous Learnings

1. Ask students to use their science notebook to review the materials (matter) they have in their current model to represent the matter that allows a tree to grow and gain mass. Ask students to refer to the questions generated about trees and the matter they accumulate and consider if there are any new questions they want to add. Add new questions if necessary. This would also be a good time to review the previous class questions and identify those which have been answered and those which remain.

> **TEACHER NOTE**
>
> We are reaching the end of the unit. It is highly likely that there will be student questions left unanswered. It is important to acknowledge the questions that have been answered while recognizing that some questions have not. At this point in the lesson, it is appropriate to add questions that may not be resolved before the end of the unit. Post them and consider which ones might become options for individual student research or which ones might be connected to future units.

2. Tell the class that they will now consider their current models and reflect on how they might improve them. Remind students that they started with their initial model and have revised those models multiple times as they have gathered new information. Ask the class to consider the following questions:
   a. With what parts of their model are they satisfied?
   b. What parts of the model do they think could be improved?
   c. What information do they need to improve their models?
   d. What questions do they still have about how the plants are using energy to recombine matter?
3. Students should discuss these questions with a peer and then with their table groups before you conduct a whole-class discussion. This progression of sharing allows students time to develop their ideas and confidence in those ideas. English Learners will benefit from communicating ideas in varying types of interactions (peer-to-peer, small group, student-to-teacher, whole class). Ask students to consider if pursuing any of the questions on the class chart could be useful to improve their current models. Record student ideas on a chart. You may want to use multiple charts to separate their ideas about their models and energy and matter. Note: this should be a quick discussion for the purpose of linking their prior learnings to the next activity. Don't spend more than 15 minutes on this unless you want to extend the overall time of this lesson. However, if students are unclear about how their

model represents visible and invisible components in their model (Lesson 7.4: Investigating Gases) or how they represent the flow of matter through the system as a tree grows, pause to review concepts in each dimension before moving on in the lesson.

4. Ask students to record in their science notebook any ideas they want to remember from the class discussion.

Flowchart

5. Present **7.5.G1: Flowchart** and explain that this flowchart will help to answer questions related to the process that plants use to live and grow. The term photosynthesis is not necessary at this point unless students have already brought up the term during class discussions. Show students how the flowchart has areas to show the inputs and outputs of the process, as well as an area to indicate any accumulated materials. Remind students that they have used and developed models before. Ask students, “What do you remember about how they have used or developed models throughout the learning sequence? How have your models changed to improve their ability to describe the phenomenon? What aspects of your models have been useful?”
6. Distribute **7.5.G1: Flowchart** to each table group. Direct students to use the information gathered from their previous investigations to identify the inputs and outputs of the process. Students may need additional support locating information in their science notebooks. Students can work in groups and use sticky notes to flag information.
7. There is also a space for accumulation (things that are made but not released as waste). Tell students to write materials on sticky notes and to place each different material on its own sticky note. Instruct students to keep track of questions that come up and place those on sticky notes, too. Those can be placed on a corner of the chart. At this point in the learning sequence, students should know that carbon dioxide and water are inputs, matter is accumulated, and water and oxygen are outputs. These details were discussed in Lesson 7.3: Historical Investigations and Lesson 7.4: Investigating Gases.
8. Rotate around the room as groups discuss and create sticky notes with inputs and outputs. If students are struggling, remind them to look through their notes for useful evidence. Students can use previous models to identify inputs and outputs. If students have questions, encourage them to record those on sticky notes.
9. Once students have completed **7.5.G1: Flowchart**, create a class consensus chart on a board or document camera. Circulate from group to group and ask teams to share one sticky note from anywhere on their chart. As groups share, ask the class if they agree or disagree with the suggestion. Generate consensus around the inputs. Students may need support in separating material that plants need (sunlight) from those that contribute to new mass during growth (water and carbon dioxide). Sunlight is a required component, but it is energy and not matter. Ask students to consider how they might represent the “input” materials. How might you physically represent water? carbon dioxide? sunlight? Accept any student suggestions for a representation as long as there is a reasonable rationale behind it.

Explore

Modeling Matter Rearrangement

10. Refer to the student questions and review any that relate to matter being taken in by the plant, released by the plant, or rearranged within the plant. Explain to the students that they will now address these questions by focusing on the molecules that make up the input materials: water and carbon dioxide. Students can use previous models to identify inputs and outputs. If students have questions, encourage them to record those on sticky notes.

> TEACHER NOTE
>
> This next part of the lesson is designed to address common alternative conceptions related to matter and energy. Middle school students often fail to see material from the air (CO_2) as having enough mass to contribute to growth in plants. They also do not always understand that plants are chemical systems, converting matter taken in from the environment into food molecules. Manipulating the physical models is a strategy to help students understand what happens to the matter that is taken in by plants, how it is converted to new molecules, and how this increases the mass of the plant.

11. Distribute baggies filled with different-colored sticky notes or pieces of paper. Ask the class to discuss how they might represent the particles that make up the "input" materials.
12. Tell students that we are going to use the sticky notes to represent the atoms that can be joined (stuck together) to represent molecules. Tell students to work with the "atoms" to try and arrange molecules of carbon dioxide and water on the "inputs" side of their **7.5.G1: Flowchart**. Do not try to explain the bonding rules for atoms; simply facilitate students' understanding that water is an oxygen atom with two hydrogen atoms and carbon dioxide is made of one carbon atom and two oxygen atoms. The point is not to understand bonding in molecules but to represent the matter that creates water and carbon dioxide and to physically represent how they are arranged and rearranged during photosynthesis. Allow students to discuss how they want to represent the molecules with different colored paper or sticky notes. If students are unable to explain their representations, ask them to consider what they know about a water molecule and how they might represent those characteristics.
13. Once students have water and carbon dioxide molecules arranged using paper, tell students that plants take these materials, "break" them apart, and then rearrange them into new materials. Ask students to think about these questions: How are these materials are rearranged? Why does the plant rearrange the atoms in water and carbon dioxide? What are the implications for this rearranging of material? Ask students to discuss their ideas in their groups and record some possible ideas in their science notebook.
14. End the lesson by explaining to students that this unit is building on their previous lesson related to PS1 and extending their understanding of how Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. PS1.A.

TEACHER NOTE

This unit is intended to follow units related to PS1. It is expected that students enter this lesson with an understanding that Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. PS1.A.

Students can use this modeling strategy in later units when cellular respiration is discussed to build an understanding of how the two processes are related.

This is a good stopping place if you need to break the lesson into two days. Before proceeding to the next part, make sure students understand that the physical models of carbon dioxide and water represent the inputs of photosynthesis and connect these inputs to previous models of energy flow (in particular Lesson 7.3: Historical Investigations and Lesson 7.4: Investigating Gases) and evidence gathered through investigations (Lesson 7.3: Historical Investigations and Lesson 7.4: Investigating Gases). Students should also recognize that energy from sunlight is necessary for the matter to "break" apart. If these concepts are not clear to students, stop, and direct students to review their notes and previous models to clarify these ideas.

Reading to Enhance Explanations

15. Introduce **7.5.H1: Photosynthesis Reading** and tell students that this reading contains information about the process plants use to live and grow. For English Learners or below-grade-level readers, an alternate reading is provided (**7.5.H1a Photosynthesis Reading Alternate Text**) that has the same information presented through simpler text. Explain to students that they will use the reading to evaluate their current ideas in light of this new information. Distribute the reading and tell students to annotate the text by:

    a. circling information that is consistent with your current ideas

    b. highlighting information that is missing from your current ideas but can strengthen your ideas

    c. underlying information that is inconsistent with your ideas and brings up a question.

    Give students 10 minutes to read and annotate.

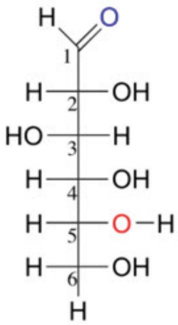
16. Once students have completed their annotations, tell them to discuss their annotations with their groups. Remind students of the group roles introduced in Lesson 7.4: Investigating Gas; however, students will not be presenting their ideas to the larger class. They may decide to have two students summarize. Direct students to start with the information from the reading that was consistent with their previous ideas. Tell students that each person in the group should share one "consistent" annotation at a time, rotating until all group members have shared this type of annotation. Next, students should share the information they found that could strengthen their current ideas, rotating around group members as they did before. Finally, students should share their questions about information that was inconsistent with the representations of "inputs" on the chart. As students share their annotations, check that students are citing specific textual evidence to support their analysis of what the text says. Allow time for the summarizer to review the important points of the conversation. Students should add or edit the molecules on the input side of **7.5.G1: Flowchart**.

17. Direct students to take their carbon dioxide and water molecules apart and try to create the "sugar" molecule described in the reading. Remind students that they can use additional sticky notes or paper to do so.

Image by WestEd

TEACHER NOTE

Students may need help finding the pattern of sugar. It is good to let students work through possible arrangements before providing suggestions, such as sugar has a carbon backbone, or providing a visual of a sugar molecule. Students should explore possible arrangements but avoid unproductive levels of frustration. Initially, students will make a simplified model of sugar. An example is provided below.



However, plants typically produce starch which links sugar molecules in chains.

18. As students work with their paper models, ask students to consider how the materials in the original CO_2 and water were rearranged. Facilitate small group discussions as you circulate around the room. How has the matter they started with changed? As matter has rearranged, what has happened to the original oxygen, hydrogen, and carbon atoms? How is energy involved in this process (beginning, middle, and end)? Students should use the crosscutting concept of Energy and Matter to make sense of how photosynthesis takes in matter and rearranges that matter without losing or gaining new matter in the process (it is conserved). Students should also consider how energy flows through the system as this process occurs.
19. Once students have created a sugar molecule, they should notice leftover “oxygen” atoms. Ask students why they think there are leftover oxygen atoms. Note: it is important that students recognize that the “extra” oxygen is simply leftover from the process. Emphasize that plants do not create oxygen; it is simply a byproduct of the process.
20. Ask students to repeat the process again with different amounts of inputs such as less water. How does this affect the outputs? What if there is more carbon dioxide inputted into the system? How are the outputs affected? Tell students to repeat the process with different amounts of inputs into the system to investigate how the outputs of matter are affected.

TEACHER NOTE

Students may have lingering alternative conceptions or fragile understandings at this point. The reading and the previous activities are intended to address lingering alternate conceptions like the confusion between energy and food, plants getting food from the environment rather than combining matter internally, and that CO_2 from the air is too small to become tangible matter. If students are still struggling with the notion that CO_2 is a gas AND has matter, you can show students dry ice and explain that dry ice is CO_2 as a solid. Students should use protective gloves when handling dry ice.

Explain

21. Ask students to consider the following questions in their groups.
    a. How do plants rearrange matter? What energy is used to do this?
    b. How do changes in the inputs of the system affect the processes and outputs?
    c. How does the rearrangement of matter at this small scale explain the observations of the seedling growing into a large tree?

    Summarizers should record the group’s ideas on their charts after they have discussed and reviewed the summary. Encourage students to use evidence from their sticky note models and the reading to support their explanations. Circulate around the room and observe student discussions and explanations. You can ask questions such as “how do you know?” and “What evidence can you use to support that idea?” If students are using terminology like photosynthesis or glucose, ask students to define the terms to check that they fully comprehend what these terms mean in this context. Energy is needed for matter to be rearranged. If students have not considered this, ask them about the role of sunlight in the process: “Why do you think sunlight is necessary?” Allow students 15 minutes to work on their group explanations.

22. As students share their developing explanations with you while they work in their small groups, encourage students to clarify what evidence they are using to justify their ideas. Students should include evidence from their use of the physical models as well as the text. When students use the text in their justification, check that they are able to trace and evaluate the argument and specific claims in a text. Ask students to consider whether the reasoning is sound and if the evidence is relevant and sufficient to support their claim.

TEACHER NOTE

At this point, you should hear students connecting details from the sticky note models and the reading to the idea that plants take in CO_2 (and other materials) and rearrange the atoms to make sugars and oxygen. Students should also explain how this process requires energy from the Sun to create two types of new arrangements of matter: glucose for energy and cellulose for growth. Students should be able to apply these concepts to energy driving the flow of matter in and out of the system.

23. Conduct a whole-class discussion by having groups share their explanations. Once groups have shared, ask the class "What ideas were consistent across the explanations?" and record these ideas on a chart or whiteboard. Ask the students if there were any conflicting ideas. Discuss the conflicting ideas. In the discussion, ask students to consider what evidence was used to develop each explanation. Was it the same evidence? Different evidence? If it was the same evidence, did each group interpret the evidence in the same way? Continue to discuss until the class either has reached consensus or identified an area for further investigation.
24. Close this part of the lesson by providing students 5 minutes to record their own explanation of why plants rearrange matter in their own science notebook. Tell students that they can copy their group explanation into their science notebook if they are satisfied with that explanation, or they can modify that explanation with information from the class debrief. ▶ Science notebooks can be collected at the end of this lesson so you can assess students' understanding of each of the three dimensions from their individual explanations. It is not recommended that the student explanations be evaluated for a grade or score. This type of artifact will be produced in Lesson 7.6: Return to Seedling Growth Models. ▶ However, it is important to provide student feedback in the science notebooks. The rubric in Lesson 7.6: Return to Seedling Growth Models can be used as a guide for the type of feedback that should be provided to students. Similar to the feedback provided in Lesson 7.4: Investigating Gases, remind students that they should consider the feedback as suggestions for areas that were unclear to the reader (you) or not yet included. Tell them if something in the feedback is unclear, they should ask you for clarification.
25. In addition to providing feedback to individual students, the science notebooks should be reviewed to identify trends in student understanding before moving onto the end of the unit. If you find a significant number of students have not reached the expected goal in any of the three dimensions or not achieved an overall understanding of how plants add mass from the environment, this is a good time to pause and revisit previous activities or insert additional readings or activities.

TEACHER NOTE

Suggested resources for additional activities or videos:

- Modeling Photosynthesis and Cellular Respiration
  https://www.calacademy.org/educators/lesson-plans/modelling-photosynthesis-and-cellular-respiration
- Photosynthetic Floatation
  https://www.exploratorium.edu/snacks/photosynthetic-floatation
- Photosynthesis
  https://media.hhmi.org/biointeractive/click/photosynthesis/?_ga=2.43879269.1128105118.1549560377-1245758253.1535231461

Suggested sources for additional activities or readings for students above the target level

- Photosynthesis Colors
  https://www.calacademy.org/explore-science/photosynthesis-colors
- Leaf Filter
  https://www.exploratorium.edu/snacks/leaf-filter

Returning to Student Questions and Models

26. Review the charts created at the beginning of the lesson and ask students to review the questions. What questions have been answered? What questions remain? Tell students to review their current models and compare them to the explanation they just completed. Can they add or revise their model now? Does their model adequately explain how energy is used to rearrange matter? At this point, students should understand that trees use light to rearrange the molecules in water and carbon dioxide to create sugar for energy needs as well as cellulose that creates new mass in the tree.

TEACHER NOTE

Students should revise their model to accurately communicate how molecules of CO_2 and H_2O are taken in by trees and rearranged to create new material. The models should indicate that CO_2 and water molecules are broken apart and rearranged as sugar for energy or cellulose for growth. Photosynthesis should be identified as the process that plants use to convert matter on the model, and the model should indicate that oxygen is released during the process as well. The model should include some explanation that light/solar energy is required for this to happen and that the transfer of solar energy into food (chemical energy) drives the entire process of rearranging matter but that the energy is not lost, only rearranged.

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Flowchart

INPUT

OUTPUT

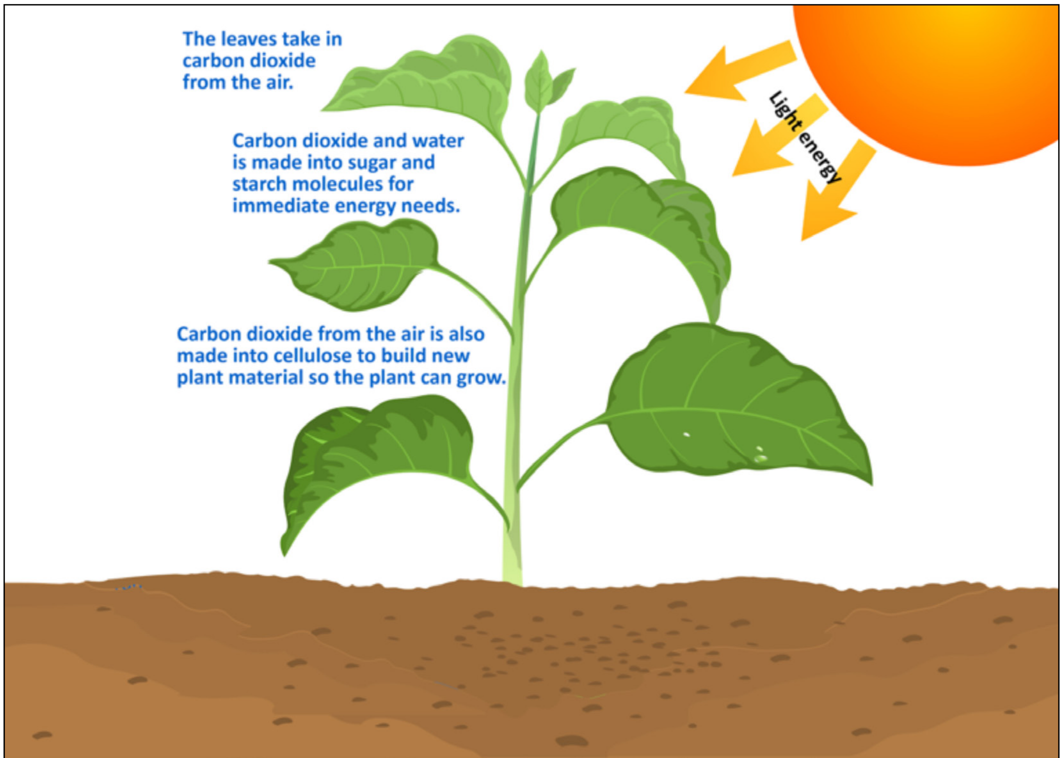
Photosynthesis Reading

Have you thanked a tree today? We all owe our lives to plants and other organisms that absorb light. All living things, including humans, need energy for growth, repair, and reproduction. However, most organisms are not able to use light energy directly for these energy needs. We need some way to change that light energy into chemical energy. Plants change light energy into chemical energy through a process called photosynthesis.

Photosynthesis is the process in which plants take sunlight energy and convert it into energy that can be stored as carbohydrates. This process provides the chemical energy that almost all species use. Glucose, an energy-rich sugar molecule, is the most essential carbohydrate molecule. This process is driven by light energy to build glucose molecules from water and carbon dioxide. A byproduct of this process is oxygen, some of which is released. These glucose molecules provide two important resources to organisms: immediate energy and material for growth.

- **Energy**. The glucose molecules provide fuel for cells. The chemical energy in glucose can be then used through processes like cellular respiration or fermentation and meet the cell's immediate energy needs. Starches are a group of molecules that connect many sugar molecules together and provide energy for later needs.
- **Growth**. Air is mostly composed of three gases: nitrogen, oxygen, and carbon dioxide. In order to get the carbon to grow, plants absorb carbon dioxide from the air.

Photosynthesis Reading (continued)



$$6CO_2 + 6H_20 \rightarrow C_6H_{12}O_6 + 6O_2$$

Image via iStock.com/mapichai modified by WestEd.

The carbon taken from the carbon dioxide in the air can be integrated into other organic molecules besides sugar. This carbon makes up most of the material that plants use to build new leaves, stems, and roots. The carbon that's used to make sugars during photosynthesis can be used to build other types of organic molecules that cells need. Cellulose is similar to starches. It is a molecule that is made from long strings of glucose molecules. In cellulose, long chains of glucose molecules are linked together as in starch, but the arrangement is different. This is why humans cannot digest cellulose, but we can digest starches.

Photosynthesis Reading Alternative Text

We are alive because plants and other organisms take in light. All organisms, including humans, need energy for growth, repair, and reproduction. However, most living organisms can't use light energy directly for their energy needs. We need some way to change that light into chemical energy. Plants change light energy into chemical energy through photosynthesis.

What is photosynthesis?

Photosynthesis is the way plants change sunlight energy into energy that is stored. It gives chemical energy for almost all types of living things. Glucose is an energy-rich sugar molecule. It is the most essential carbohydrate molecule. The process of photosynthesis is driven by light energy to make glucose molecules from water and carbon dioxide. Oxygen is let go as waste. The glucose molecules give living things two important resources: energy and material for growth.

- **Energy**. Energy. The glucose molecules give cells fuel. This chemical energy can be made through processes like cellular respiration or fermentation and used for the cell's immediate energy needs. Starches are a group of molecules that link many sugar molecules together. They give the plant energy for later.
- **Growth**. Air is mostly made of nitrogen, oxygen, and carbon dioxide. Plants take in carbon dioxide from the air.

Photosynthesis Reading Alternative Text (continued)

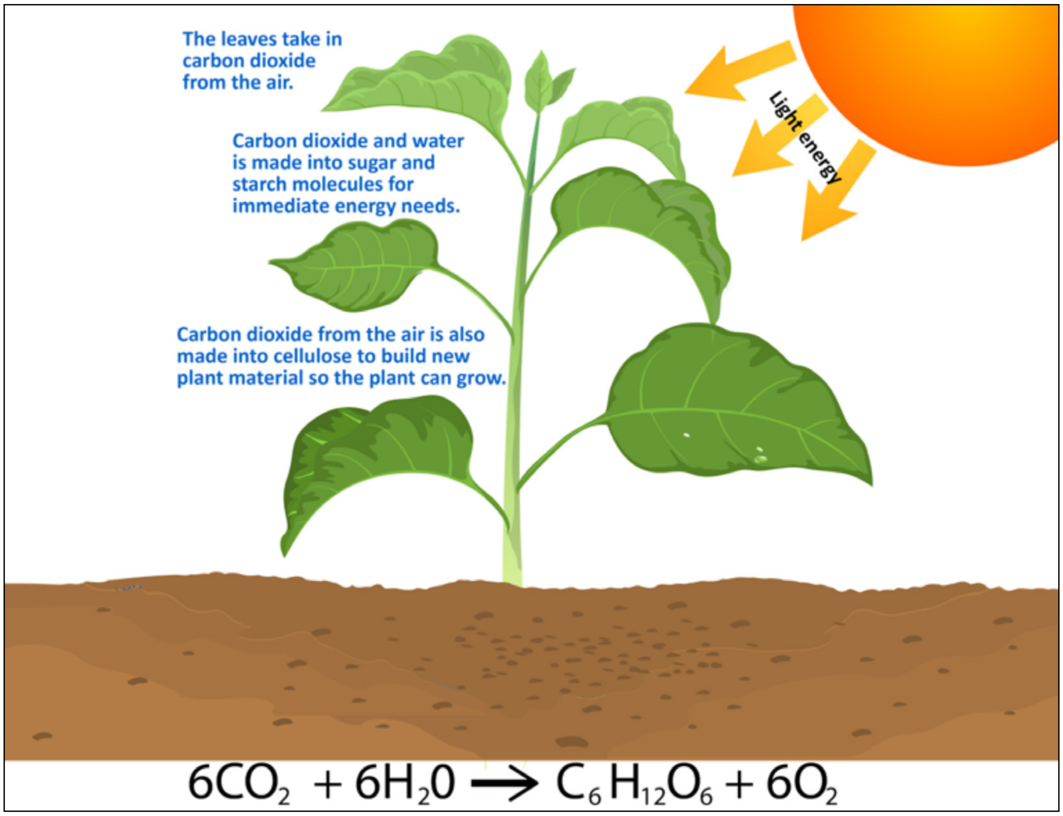


Image via iStock.com/mapichai modified by WestEd.

Carbon from the carbon dioxide in the air can be put into other molecules besides sugar. Carbon makes up most of the building blocks that plants use to build new leaves, stems, and roots. The carbon that is put into sugars during photosynthesis can be used to build other types of molecules cells need. Cellulose is a molecule. It is made from long strings of glucose molecules, as in a starch. In cellulose, the glucose molecules are put together in a different way than starch. Humans can digest starch. They cannot digest cellulose.

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis*.]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Developing and Using Models
• Develop a model to describe unobservable mechanisms.
Obtaining, Evaluating and Communicating Information
• Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
Constructing Explanations and Designing Solutions
• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. (From Grade 3–5)

DISCIPLINARY CORE IDEAS (DCI)
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.
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.

Appendix 7.5

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Matter is made of particles, Energy can be transferred in various ways and between objects. (From Grade 3–5) • Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within a system. • Systems may interact with other systems; they may have sub-systems and be part of larger complex systems.

Common Core State Standards (CCSS)

CCSS READING
ELA-LITERACY.RST.6-8.1
Cite specific textual evidence to support analysis of science and technical texts.
ELA-LITERACY RI.7.8
Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims.

California English Language Development (ELD) Standards

CA ELD		
Part I 7.6 Reading/viewing closely		
EMERGING	EXPANDING	BRIDGING
P1.7.6a Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade appropriate texts and viewing of multimedia with substantial support.	**P1.7.6a** Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade level texts and viewing of multimedia with moderate support.	**P1.7.6a** Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade level texts and viewing of multimedia with light support.

Return to Seedling Growth Models 7.6

Image via iStock.com/hunter13

Anchoring Phenomenon

Tiny seedlings grow and transform into trees with a great quantity of matter.

Lesson Concept

Develop a model to explain where all the matter in from the Sun to a tree comes from when it begins as a small seedling.

Investigative Phenomenon

Return to the Anchoring Phenomenon: Tiny seedlings grow and transform into trees with a great quantity of matter.

Standards

Refer to Appendix 7.6 for NGSS, CCSS (ELA), and California ELD Standards.

7.6 Return to Seedling Growth Models

Storyline Link

This lesson follows Lesson 7.5: Matter Model lesson where students gained an understanding of the role of photosynthesis and the processes that occur at small scales that are relevant to the overall phenomenon. Students will apply their understanding of matter conservation and how the transfer of energy drives the motion of matter to a final model of the phenomenon. This is the final lesson of the sequence. Students will revise their initial individual models from Lesson 7.1: Tree Matter and apply the learning they gained from the previous lessons. Students will reflect on their own learning as they share their final models with others and provide/receive feedback. At this point in the sequence, students should develop models that indicate both visible and invisible components and how those components interact within the system to produce the growth and increase of mass seen in the video.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.

Time

80–110 minutes

Two 40- to 55-minute sessions

Materials

Whole Class

- ❑ The growing tree video https://www.youtube.com/watch?v=RjnKAWxCK3k

Individual

- ❑ Science notebook
- ❑ 7.1.H1: Giant Sequoia Tree Probe (from Lesson 7.1: Tree Matter)
- ❑ 7.1.H2: Make a Model (from Lesson 7.1: Tree Matter).

Teacher Use

- ❑ 7.6.R1 Model Rubric

Advance Preparation

None

Procedure

Evaluate (80–110 minutes)

Develop a model to explain where all the matter in a tree comes from when it begins as a small seedling.

Review Previous Learnings (50 minutes)

1. Show the growing tree video from Lesson 7.1: Tree Matter (5 minutes)
2. Direct students to take out their **7.1.H2: Make a Model** (from Lesson 7.1: Tree Matter) and review their initial ideas about how seedlings gain mass. In particular, ask the students to think of the tree as a system and to reflect on where the energy for this system comes from and where it goes. Then, ask the students to think about where the matter comes from in this system and where it goes. Students should also review the feedback received from you and consider what feedback they want to use to improve their model and what feedback is not clear. Walk around the room checking in with each student and answering any questions about the feedback you provided.
3. Tell the students that they will be revising their model to include the ideas they have gained through the series of previous lessons. Remind them to include the parts of the process that are not visible, including parts of the system or processes that are too small to be seen. The goal is three-dimensional models that include:
    a. concepts about modeling (SEP) such as developing and revising a model to show the relationships among the variables of photosynthesis, including those that are not observable but predict the observable phenomenon of tree growth and to describe the unobservable mechanisms that drive photosynthesis.
    b. concepts related to the DCIs LS1.C (Organization for Matter and Energy Flow in Organisms) and PS3.D (Energy in Chemical Processes and Everyday Life) to demonstrate an understanding that plants use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which releases oxygen. These sugars can be used immediately or stored for growth or later use AND the chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur.
    c. concepts related to the crosscutting concept of Energy and Matter (CCC) to demonstrate an understanding that matter is conserved. Atoms are conserved in the physical and chemical processes within the natural system of a plant, the transfer of energy drives the motion and/or cycling of matter, and the transfer of energy can be tracked as energy flows through the natural system of the plant.

    As students work, ask them to think about how their model represents the interactions of the tree system. How does their model represent the flow of matter into, within, and out of the tree?
4. Allow about 20 minutes for students to revise their models independently. Students may need support to identify areas in their science notebooks that contain evidence or reasoning that can be used to support the details of their models. Students should also cite specific evidence from the photosynthesis reading in Lesson 5: Matter Models to support their claims or provide reasoning.

5. Ask students "How has your model changed?" Tell students to find their initial models from **7.1.H1: Giant Sequoia Tree Probe** and **7.1.H2: Make a Model** (from Lesson 7.1: Tree Matter). Tell students to record their thinking in their science notebook.
6. Next, instruct students to share their new models with another student. Tell students that when they share they should explain how their models show what inputs, processes, and outputs are occurring. Emphasize that students should explicitly explain how their model describes what they saw in the video of a tree seedling growing into a large tree. Students should also discuss: What aspects of the phenomenon does your model represent? Are there other parts or processes that are not in your model?
7. As students are listening to their partner's share, encourage students to provide feedback to each other. If necessary, provide sentences as a table handout or on a chart to support student discussion and feedback. You may choose to use the sentence frames from earlier lessons as well. This type of linguistic support might be necessary for English Learners or struggling students. Possible sentence stems include:
   - I agree with your idea about _____ because _____.
   - Can you tell me more about _____?
   - I disagree with _____ because _____.
   - I want to build on your idea about_____.
8. After students have shared their individual models, tell the students to create a consensus group model on chart paper or a dry-erase board. The consensus models should represent the thinking of everyone in the group. (10 minutes)
9. As they work on their models, ask students to consider how the rearrangement of molecules in this phenomenon relates to previous lessons on atoms and molecules. Ask students to review their previous questions. Were there any questions that our understanding of atoms and molecules helped us to answer? What other phenomena relate to the flow of matter through a system? As they respond to your questions, remind them to add those ideas to their models.
10. After the groups have finished with their consensus model, ask the class to identify what makes a model "good" or effective for explaining this phenomenon. (Consider asking students to discuss their ideas with a partner if you have significant numbers of English Learners or students who need additional processing time in the class). Remind students that they have made several models over the last few days, and they should review those models in their science notebook.
11. Ask students to share their ideas about effective models for this phenomenon. After confirming that the whole class agrees with a suggestion, record these ideas on a class chart. Listen for ideas such as:
    - the model includes things like such as light, water, carbon dioxide;
    - the model shows how the tree rearranges the matter;
    - the model shows how trees collect sunlight and use it to rearrange matter;
    - the model should be based on evidence we have collected;
    - the model explains HOW the tree adds mass clearly;
    - the model can be used to predict growth in other plants under certain conditions.

This list will become a checklist for students to use in the next part of the lesson, which is the evaluation. End the discussion by asking students to review the list. It is fine if there are missing elements on the checklist right now. Clarify any questions students still have.

Day 2 (30–50 minutes)

12. Before students return, review the model checklist and transfer it to a document. If there are components that were missing from the class list, add them to the checklist now if you think they will support students' thinking during the final evaluation. At the beginning of class, distribute your model checklist to each student. Direct students to discuss the checklist in pairs by discussing areas that make sense, that are unclear or are new. If you added any components, review them with the class now and explain why you thought it was a useful idea to add to the checklist. Note: do not add more than one element to the checklist. The checklist is supposed to be useful, not overwhelming. It is also important that students feel that they were the ones who developed it.

13. ▶ It is now time to individually assess student understanding of the phenomenon. Provide students with the following prompts and tell them to answer the prompts individually OUTSIDE their science notebook. Students are allowed to use anything in their science notebook to develop their response:

    a. Record your final model to show how matter moves through the plant system to develop small seedling into a large tree.

    b. Add a brief description of your model and how your model shows how a tree gains mass to develop into a large tree.

    This individual assessment allows students the opportunity to reflect on their learning. It also provides an individual piece of student work, separate from the science notebook, that can be assessed for student understanding of developing and using models (SEP), Energy and Matter (CCC) and Energy and Matter flow in organisms, and Chemical Processes and Everyday Life (DCI). **7.6.R1 Model Rubric** Part I can be used to provide feedback to students and assess their individual progress towards the unit objectives.

    c. There is an optional third part of the assessment. This optional portion could be used to extend the assessment for an advanced class of students. The optional portion could also be used as an extension to the unit. If you choose to use part C as an extension, use **7.6.R1: Model Rubric** Part II only for informing instruction and not for evaluation/grading purposes.

    Use your model to predict what would happen to the tree growth if a large store was built next to the tree, blocking the sunlight for a large portion of the day. How is your model accurate and useful in predicting the outcome?

14. English Learners or students who are not currently at grade level may benefit from a few sentence starters to complete the description. These can be provided as table cards or on a sheet attached to the model checklist. Examples are provided here:
    - My model shows _____ because _____.
    - The evidence from _____ shows that _____.
    - The _____ causes _____.
    - The effect of _____ was _____.
    - The _____ enters the system and _____ leaves.
    - _____ happens _____.
15. Collect the assessments. End the learning sequence with a class discussion about how the models have changed in the three dimensions of the modeling practice (SEP), the core science idea of photosynthesis (DCI), and the crosscutting concept of Energy and Matter (CCC).
16. An optional ending to the unit is to assign a writing prompt that students complete individually.
    - Return the model and explanation collected in Lesson 7.1: Tree Matter to the students.
    - Have them respond to the following prompt: Look at both your models. Analyze your thinking and understanding. Describe the changes you made and why you made these changes.
17. After you have collected the final model and descriptions, ask the students to review the question chart. Review the questions together one last time and discuss which questions remain unanswered. Move these questions to a "parking lot" chart. Explain to students that scientists often generate more questions than answers, and confirm that this is a normal part of doing science. If fact, you should always have more questions. Tell students that their remaining questions will be displayed on the parking lot chart during the year. Many questions may get answered later in the year. More questions will be added after other investigations. Parking lot questions can also be selected by students, one or many, for additional research if students want to pursue questions on their own.

References

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Model Rubric

Part I

A. Record your final model to show how cycles matter to develop from a small seedling into a large tree.

B. Add a brief description of your model and how your model shows how a tree gets mass to develop into a large tree.

	EMERGING	APPROACHING	MEETING	ADVANCED
Description of the Model	States that photosynthesis is the cause of the tree growth but does not include a clear statement about what matter is involved or statement contains inaccuracies, such as mass is obtained from water or soil.	States that photosynthesis is the cause of tree growth. Includes a clear statement that matter is cycling [states that plant gathers matter from the air and/or water and converts that matter to add mass] but response lacks specifics about how the matter is conserved [CO_2 is taken from the air and with water is reorganized into sugar and oxygen] OR does not describe the role of energy in the cycling of matter [does not specify that solar energy is needed to reorganize CO_2 and water].	States that photosynthesis is the cause of the cycling of matter and specifies that CO_2 from the air and water is converted into sugar and oxygen AND describes the role of light energy in the rearrangement of CO_2 and water into sugar and oxygen for growth and energy for the tree.	States that photosynthesis is the cause of the cycling of matter and specifies that CO_2 from the air and water is converted into sugar and oxygen AND describes the role of light energy in the rearrangement of CO_2 and water into sugar and oxygen for growth and energy for the tree AND describes specific pathways for carbon [converted to sugar for immediate energy or cellulose for growth].
Developing a Model	Constructs a model (drawing, words, symbols) that is relevant, but the model is lacking major conceptual components (sunlight, CO_2), has major errors, or is composed of irrelevant details.	Constructs a model to represent the process of photosynthesis but minor errors or omissions are present. For example, the cycling of carbon is incomplete AND information about how energy was used to change matter into new tree mass is missing.	Constructs an accurate model but the model has some vague information about how matter was converted to form new tree mass. For example, only the conversion of CO_2 to glucose is discussed but fails to address the role of water or resulting O_2 in the process. [model is missing some necessary variables in the photosynthesis process]. OR The model does not show how the transfer of energy drives the cycling of matter [develop a model to describe unobservable mechanisms]	Constructs an accurate and complete model that includes the necessary components of photosynthesis (sunlight, CO_2, water, sugar) and indicates how matter from the air (CO_2) and water is rearranged to form oxygen and new tree mass and energy for the tree (sugar and cellulose) [develop a model to show the relationships among variables, including those that are not observable but predict observable phenomena]. AND The model shows how the transfer of energy drives the cycling of matter [develop a model to describe unobservable mechanisms].

Model Rubric (continued)

Part II

C. Use your model to predict what would happen to the tree growth if a large store was built next to the tree, blocking the sunlight for a major portion of the day. How is your model accurate and useful in predicting the outcome?

	EMERGING	APPROACHING	MEETING	ADVANCED
Prediction of Model: Strengths and Limitations	Prediction is inaccurate AND The model's ability to provide an accurate prediction is not discussed.	Makes an accurate prediction (tree growth will likely be slowed since energy from the Sun is needed to rearrange the matter) BUT the prediction is not consistent with the model AND does not evaluate the accuracy of the system or process.	Makes an accurate prediction (tree growth will likely be slowed since energy from the Sun is needed to rearrange the matter) AND prediction is consistent with the model. BUT does not evaluate the accuracy of the system or process.	Makes an accurate prediction (tree growth will likely be slowed since energy from the Sun is needed to rearrange the matter) AND is consistent with the model AND evaluates the accuracy AND limitations of the system or process.

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
MS-LS1-6	Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [*Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis*.]

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Developing and Using Models

- Develop and revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- Develop a model to describe unobservable mechanisms.

Constructing Explanations and Designing Solutions

- Construct an explanation using models or representations.

DISCIPLINARY CORE IDEAS (DCI)

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.

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.

Appendix 7.6

CROSSCUTTING CONCEPTS (CCC)
Energy and Matter
• Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
Systems and System Models
• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Common Core State Standards (CCSS)

CCSS ELA SPEAKING AND LISTENING
ELA-LITERACY.SL.7.1.D
Acknowledge new information expressed by others and, when warranted, modify their own views.
ELA-LITERACY.SL.7.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.
CCSS ELA WRITING
CCSS.ELA-LITERACY.W.7.4 (If optional individual assessment is done).
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

California English Language Development (ELD) Standards

CA ELD		
Part I 7.11a,b Justifying/arguing		
EMERGING	EXPANDING	BRIDGING
P1.7.11a,b a) Justify opinions by providing some textual evidence or relevant background knowledge with substantial support. b) Express attitude and opinions or temper statements with familiar modal expressions (e.g., *can*, *may*).	**P1.7.11a,b** a) Justify opinions or persuade others by providing relevant textual evidence or relevant background knowledge with moderate support. b) Express attitude and opinions or temper statements with a variety of familiar modal expressions (e.g., *possibly/likely*, *could/would/should*).	**P1.7.11a,b** a) Justify opinions or persuade others by providing detailed and relevant textual evidence or relevant background knowledge with light support. b) Express attitude and opinions or temper statements with nuanced modal expressions (e.g., *possibly/potentially/absolutely*, *should/might*).