8 Forests

At-a-Glance:

In the last unit, students learned how complex living things are made up of specialized cells, tissues, organs, and organ systems that have particular functions. In this unit, they move beyond individual organisms to populations. They focus on forest ecosystems, studying the interactions between living things and the environment. They then analyze how resource availability affects the growth of different organisms.

Common Misconceptions:

- **Misconception**: Food must come from outside of an organism.
  - ✓ **Fact**: Plants make their own food through photosynthesis, unlike animals, which must eat other organisms for food.
- **Misconception**: Arrows in a food web show which organisms eat other organisms.
  - ✓ **Fact**: Arrows show the flow of energy.
- **Misconception**: Healthy ecosystems do not change.
  - ✓ **Fact**: Healthy ecosystems are dynamic and constantly changing.

A Breakdown of the Lesson Progression:

1 Photosynthesis

In the first lesson, students explore how plants cycle matter and energy through photosynthesis. They focus on plants in a forest as they carry out an experiment in which they test how different light conditions affect the rate of photosynthesis in aquatic plants.

2 Forest Food Web

Once students understand how plants capture the sun's energy and turn it into energy they can use, students analyze how energy moves through a forest food web as organisms eat one another.

3 Drought and Tree Growth

Living things can only grow with sufficient resources in the ecosystem, and when there are limited resources, it affects the organisms in the ecosystem. Students analyze how water and nutrient scarcity impact the growth of trees.

Unit 8: Forests

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Overview:

There are both beech and fir trees in this forest.

Trees talk to each other, according to Suzanne Simard, a forest ecologist who has conducted numerous experiments to explore how forest trees communicate with one another and share resources.

In one of her early experiments, Simard learned that in the summer, birch trees share carbon with fir trees that are in the shade, while firs share carbon with birch trees in the fall when the birch trees lose their leaves. This benefits each tree at a time of year when it is less able to carry out photosynthesis.

In this unit, students begin with an experiment to test how a plant's ability to carry out photosynthesis is affected by how much sunlight it receives. Students then build on their understanding of how energy affects the growth of organisms by developing a forest food web model to help them analyze how a drought can have a ripple effect through the ecosystem. Students then examine tree rings to analyze how resource availability affects a tree's growth.

Unit Goals:

1. Use evidence to support an argument about how plants carry out photosynthesis to convert the sun's energy into a form of energy they can use to grow and develop.
2. Trace the flow of energy and the cycling of matter through a food web.
3. Evaluate how resource availability affects the ability of different organisms and populations to grow.

Applying Next Generation Science Standards

This unit covers the following **Next Generation Science Standards**. Each standard includes where it is found in the unit, as well as how it applies the relevant crosscutting concepts (listed in green) and disciplinary core ideas (listed in orange). **Note: Science and engineering practices are listed separately because all of the practices are incorporated into every unit.*

Focus Standards:

MS-LS1	From Molecules to Organisms: Structure and Processes
MS-LS1-2.	**Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.** ▪ **Structure and Function:** Students build on their knowledge of cell structure and function by focusing on chloroplasts in plant cells and their role in converting the sun's energy into usable chemical energy. Lesson 1 ▪ **Structure and Function:** Students connect the structure of plant cells—specifically the presence of chloroplasts—with the ability of plants to photosynthesize. Lesson 1
MS-LS1-4.	**Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** ▪ **Growth and Development of Organisms:** Students analyze how animals have different behaviors that increase their chances of successfully reproducing, and how sometimes these behaviors also increase the chances that plants will successfully reproduce. Lesson 2 ▪ **Cause and Effect:** Students describe the cause-and-effect relationship between particular animal behaviors and their ability to survive and reproduce. Lesson 2

MS-LS1	From Molecules to Organisms: Structure and Processes
MS-LS1-5.	**Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** ▪ **Growth and Development of Organisms:** In the first lesson, students carry out an experiment to observe how the availability of sunlight affects a plant's ability to grow. In the third lesson, students evaluate data to determine how the availability of water affects a tree's growth. Lessons 1 and 3 ▪ **Cause and Effect:** Students build on their knowledge of adaptations to explore how both environmental and genetic factors affect the growth of organisms. Lessons 1 and 3

Supporting Standards:

MS-LS1	From Molecules to Organisms: Structure and Processes
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.** ▪ **Organization for Matter and Energy Flow in Organisms:** Students carry out an experiment in which they measure how much carbon dioxide is removed from water when plants have access to different amounts of sunlight to help them analyze how plants use the energy from light to make glucose during the process of photosynthesis. Lesson 1 ▪ **Energy in Chemical Processes and Everyday Life:** Students analyze the importance of the sun in providing plants with the energy they need to carry out the chemical reaction of photosynthesis. Lesson 1 ▪ **Energy and Matter:** Students explore how photosynthesis requires an input of energy to change matter from one form to another. Lesson 1

MS-LS2	Ecosystems: Interactions, Energy, and Dynamics
MS-LS2-1.	**Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.** ▪ **Interdependent Relationships in Ecosystems:** Students analyze how resource availability impacts the growth of trees by evaluating the width of tree rings. Lesson 3 ▪ **Cause and Effect:** Students observe how resource availability affects the growth and survival of organisms. Lesson 3

MS-LS2	Ecosystems: Interactions, Energy, and Dynamics
MS-LS2-2.	**Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.** ▪ **Interdependent Relationships in Ecosystems:** Students compare the different ways that organisms interact within a forest ecosystem. Lesson 1 ▪ **Patterns:** Students analyze patterns of interactions that occur within all forest ecosystems. Lesson 1
MS-LS2-3.	**Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.** ▪ **Cycle of Matter and Energy Transfer in Ecosystems:** Students create a forest food web to model how energy and matter move through ecosystems. Lesson 2 ▪ **Energy and Matter:** Students compare and contrast the transfer of energy and matter in ecosystems. Lesson 1
MS-LS2-4.	**Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.** ▪ **Ecosystem Dynamics, Functioning, and Resilience:** Students discuss how ecosystems are changed by both natural and human disturbances. Lesson 3 ▪ **Stability and Change:** Students evaluate the stability and change of forest ecosystems by discussing different ways that ecosystems can change. Lesson 3

Science and Engineering Practices

Students use the following science and engineering practices in the unit's lessons.

Lesson 1: Photosynthesis

1. Asking questions (for science) and defining problems (for engineering)

- Student teams work together to develop a question that will guide them through an experiment that investigates how the intensity of light affects the ability of plants to carry out photosynthesis.

2. Developing and using models

- Students create a visual model (scientific diagram) of their experiment-in-progress. Students use the model to visualize the materials and methods of the experiment, and to communicate their experiment to others.

3. Planning and carrying out investigations

- Student teams collaboratively develop a plan, which they then follow to compare how much carbon dioxide aquatic plants remove from water when exposed to three different light intensities over 24 hours.

4. Analyzing and interpreting data

- Students collect and analyze data on the change in pH and water color in each test condition over 24 hours.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gathered in the experiment to construct an explanation (conclusion) that either supports or rejects their hypothesis about the relationship between the intensity of light and the ability of plants to carry out photosynthesis, as measured by the amount of carbon dioxide removed from the water.

7. Engaging in argument from evidence

- Students engage in argument within their teams. Student teams then come together as a class to respectfully present their results to the class, using their data from the experiment as evidence to support their claims about photosynthesis and light intensity. Students work through any points of disagreement or confusion.

8. Obtaining, evaluating, and communicating information

- Students use information from the discussion, experiment, background reading, and any personal experiences to communicate how plants use light energy from the sun, along with water and carbon dioxide, to produce glucose, which they need for growth and development.

Lesson 2: Forest Food Web

1. Asking questions (for science) and defining problems (for engineering)

- Students use a model to help them answer the question: "How could long-term drought conditions in Massachusetts affect the food web in temperate deciduous forests in the state?"

2. Developing and using models

- Students create a model of a temperate deciduous forest food web that includes the source of energy, producers, consumers, and decomposers.

3. Planning and carrying out investigations

- Students plan and carry out an investigation that traces the flow of energy through a Massachusetts forest food web.

4. Analyzing and interpreting data

- Students use their food web models to analyze how the flow of energy in a forest food web changes during a period of severe drought, causing a ripple effect in the populations of other organisms as a result.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use their food web models and analysis to construct an explanation about how environmental factors influence the growth of organisms and populations.

7. Engaging in argument from evidence

- Student teams respectfully provide and receive critiques about their food web model and the models of other teams, as well as the explanations for what the model shows.

8. Obtaining, evaluating, and communicating information

- Students use information from their investigation, lab manuals, and class dialogue to communicate how a change in the availability of a resource such as water in an ecosystem affects the organisms that live there.

Lesson 3: Drought and Tree Growth

1. Asking questions (for science) and defining problems (for engineering)

- This lesson has two parts. In the first part, students investigate the question: "How can tree ring data be used to reveal patterns of growth in trees over time?"
- In the second part, students investigate the question: "From 1985-1995, West Virginia experienced some times of increased precipitation and some times of decreased precipitation, including a drought from 1987-88. How did changes in precipitation during this time most likely affect the growth of

yellow poplar trees in West Virginia?”

3. Planning and carrying out investigations

- Students carry out two investigations to explore how environmental conditions affect the growth of different kinds of trees.

4. Analyzing and interpreting data

- In the first part, students collect observational data about two tree cross-sections. In the second part, students analyze tree ring width and precipitation data in West Virginia, looking for patterns in the data that will help them answer the focus question.

5. Using mathematics and computational thinking

- In the second part, students graph the average yellow poplar tree ring width from 1985 to 1995, as well as the precipitation in West Virginia during that same time period. Students use their graphs to help them identify patterns in the data.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use their data collection and analysis to construct an explanation about how changes in precipitation during this time affected the growth of yellow poplar trees in West Virginia.

7. Engaging in argument from evidence

- Students engage in argument within their teams as they move through the investigation, reaching agreement as they construct their explanation about their findings. Student teams then present their explanation to the class, respectfully evaluating and critiquing the explanations of other teams and using evidence to support their own arguments.

8. Obtaining, evaluating, and communicating information

- Students use the results of their investigation, along with information from the nonfiction reading and class dialogue, to communicate about how the width of a tree’s rings is affected by the amount of precipitation that year, and how this is evidence that environmental factors influence the growth of organisms.

Unit 8 Pacing Guide Example

All KnowAtom units are designed to take approximately one month. Lessons may span one or two weeks. This pacing guide provides one example for how to break down the lessons in this unit over a month. **Breakdown in this guide is based on 45- to 55-minute class periods.** Communities that have longer or shorter class periods or schedules where science class occurs more frequently can modify this guide accordingly.

Any days in this guide that appear unused take into account months with holidays, vacations, or times when a lab and/or investigation takes longer to complete. Note that at the beginning of the school year, when the engineering and scientific processes are new to students, labs may take longer to complete.

Unit 8: Forests**				
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Week 1				
Lesson 1** **Start:** As a class, read Section 1 of the KnowAtom student lab manual.* **Final Goal:** Transition to the Socratic dialogue.	**Lesson 1** **Start:** Socratic dialogue. **Final Goal:** Transition to lab question.	**Lesson 1** **Start:** Recap lab question. **Final Goal:** Students develop majority of lab with check-ins (up to scientific diagram).	**Lesson 1** **Start:** Teams complete lab development and may begin experiment. **Final Goal:** Students begin experiment.	**Non-Science Day**
Week 2				
Lesson 1 **Start:** Teams carry out experiment. **Final Goal:** Teams collect Day 1 data.	**Lesson 1** **Start:** Teams collect Day 2 data and evaluate results. **Final Goal:** Teams complete lab conclusions.	**Lesson 1** **Start:** As a class, review lab conclusions, wrap up the lab, and debrief. **Final Goal:** Review assigned assessment questions (optional).	**Lesson 2** **Start:** As a class, read Section 2 of the KnowAtom student lab manual.* **Final Goal:** Transition to the Socratic dialogue.	**Lesson 2** **Start:** Socratic dialogue. **Final Goal:** Transition to the Forest Food Web Investigation.

Week 3				
Lesson 2 **Start:** Teams begin the Forest Food Web Investigation. **Final Goal:** Teams cut out forest food web organisms and set up their model.	**Lesson 2** **Start:** Teams complete their food web models and analysis. **Final Goal:** As a class, review team models and analysis. Wrap up the investigation and debrief.	**Non-Science Day**	**Lesson 3** **Start:** As a class, read Section 3 of the KnowAtom student lab manual.* **Final Goal:** Transition to the Socratic dialogue.	**Lesson 3** **Start:** Socratic dialogue. **Final Goal:** Transition to the Tree Growth Investigation.
Week 4				
Lesson 3 **Start:** Students begin Part 1 of the investigation. **Final Goal:** Teams analyze tree cross-section samples.	**Lesson 3** **Start:** Teams start Part 2 of the investigation. **Final Goal:** Teams analyze and graph tree growth and precipitation data.	**Lesson 3** **Start:** Teams complete Part 2 analysis and conclusions. **Final Goal:** As a class, wrap up the lesson and debrief.	**Non-Science Day**	**Non-Science Day**

Pacing Guide Notes

* As the school year progresses, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue. When students read the lab manual outside of class time, this time can be used for deeper Socratic dialogue.

** Lesson 1 in this unit requires live materials (aquatic plants). See Lesson 1 for how to order these items. Live materials will take approximately two weeks to order, ship, and arrive at your school.

Science Words to Know:

This unit's vocabulary is divided into three lessons. Use a blank concept map visual to connect vocabulary once the unit is complete. An example concept map is displayed in Appendix 3.

Lesson 1

1. **canopy** – the upper layer of a forest where the treetops of most of the trees meet to form a layer of habitats for insects, birds, and tree-climbing mammals

2. **forest** – an area of land covered by trees

3. **forest floor** – the part of the forest that is blanketed with decaying leaves, twigs, fallen moss, and other organic particles

4. **oxygen cycle** – the back-and-forth exchange of carbon dioxide and oxygen between plants, animals, and the environment

5. **photosynthesis** – the process of turning sunlight, carbon dioxide, and water into glucose and oxygen

6. **understory** – the middle layer of the forest that contains a mixture of small and immature trees that provide shelter for animals

Lesson 2

7. **competition** – an interaction between organisms that occurs whenever two or more organisms require the same limited resource

8. **consumer** – an organism that eats other organisms; there are three possible levels of consumer in a food chain: primary, secondary, and tertiary

9. **decomposer** – an organism that breaks down organic waste and feeds on the nutrients

10. **disturbance** – an event that changes conditions in an ecosystem

11. **ecosystem** – a community of different species that depend on interacting with each other and their physical environment for survival

12. **food chain** – the path that energy travels as one organism eats another

13. **food web** – a visual that shows the network of food chains in an ecosystem

14. **predation** – an interaction between two organisms that occurs when one organism (a predator) eats another organism (prey)

15. **primary consumer** – the second level of a food web but the first level of organisms that get energy by eating producers

16. **producer** – an organism that captures energy directly from the sun to make its own food; trees, grasses, and some microbes do this with photosynthesis; the first level of organisms in all food webs are producers

17. **secondary consumer** – the third level of a food web; an organism that eats primary consumers

18. **tertiary consumer** – the fourth level of a food web; an organism that eats secondary consumers

Lesson 3

19. **annual ring** – the light- and dark-patterned wood that forms as a tree grows in diameter over time

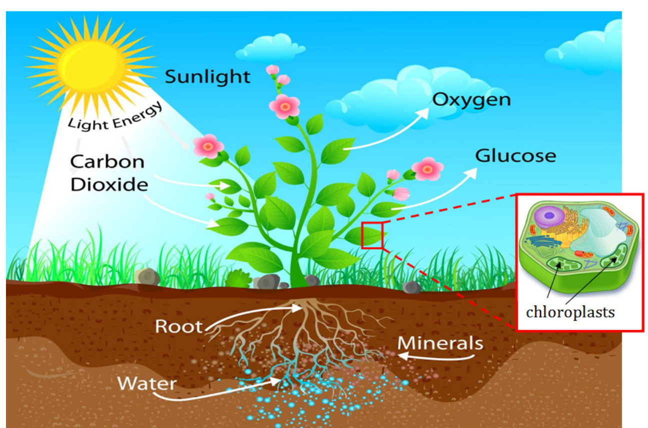
20. **drought** – a prolonged period of unusually low rainfall, resulting in water shortages

Teacher Background

Studying Trees

In her experiments with carbon, Suzanne Simard used carbon-14, which is a radioactive carbon isotope. All isotopes of an element have the same number of protons, but they have a different number of neutrons. Carbon-12 is the most common form of carbon, making up 99 percent of all carbon in Earth's atmosphere. Carbon-13 makes up 1 percent, and carbon-14 is found in trace amounts.

Simard knew that carbon-14 molecules would bond with oxygen molecules in the environment to form carbon dioxide (CO_2). She also knew that plants need carbon dioxide to survive because it is an important part of **photosynthesis,** which is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen. All plants carry out photosynthesis because it is how they make their own food.



Photosynthesis is the process in which plants make their own food.

Photosynthesis is a chemical reaction that requires an input of energy from the sun to change molecules of carbon dioxide and water into molecules of glucose and oxygen. The glucose is a kind of sugar that holds chemical potential energy, which plants need for growth and development. Plants use the glucose to carry out important life functions, and they store whatever they don't use. They use some of the oxygen they produce and release the rest back into the environment.

How Plants Make Food

Different parts of the plant work together so that photosynthesis can happen. Photosynthesis happens in the chloroplasts of plant cells. Remember that plant cells are the only kind of cells with chloroplasts, which make chlorophyll, a pigment that absorbs sunlight. Not all plant cells have chloroplasts. These organelles are most common in cells in plant leaves.

Plant leaves also have pores called stomata that allow plants to take in carbon dioxide from the environment and release oxygen. The stomata open and close so that plants can constantly exchange these gases, similar to how people always breathe in oxygen and breathe out carbon dioxide. The back-and-forth exchange of carbon dioxide and oxygen between plants, animals, and the environment is called the **oxygen cycle**.

The roots collect water and nutrients from the soil, and the stem transports the water and nutrients between the roots and the rest of the plant. The stem also absorbs some water, although not as much as the roots.

Geiger counters detect levels of carbon-14.

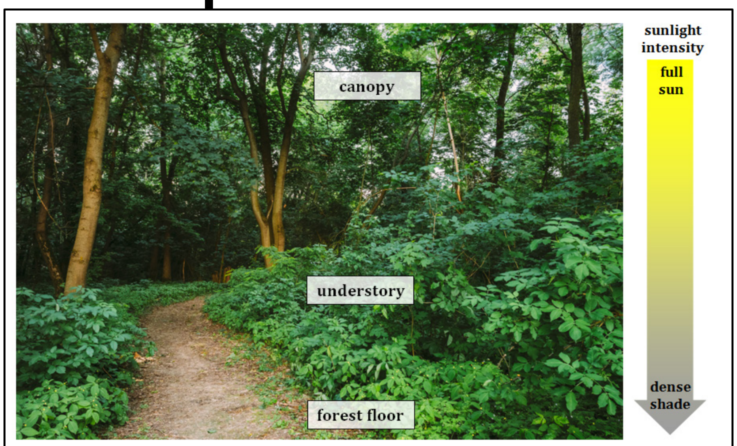
In Simard's experiment, she put plastic bags over individual trees. She then injected carbon-14 into one bag covering a birch tree to see if it would transfer some of the carbon to other trees nearby and waited for an hour. She then used a Geiger counter to detect whether the carbon-14 had been transferred to the other trees.

Simard's results showed that at that time of year, in the summer, the birch trees sent extra carbon to the fir trees. Suzanne believes this benefited the fir trees because the fir trees tended to be more shaded than the birch trees, so they receive less sunlight to carry out photosynthesis. Suzanne and her team did follow-up experiments that showed at later times of the year, the fir trees sent more carbon to the birch trees. She believes this is because birch trees begin to lose their leaves in the fall, making it harder to photosynthesize, while firs keep their leaves.

Sunlight in Forests

Simard and other researchers have found that trees in a forest are connected through a complex underground network made up of fungi mycelium that carry carbon molecules between the trees. A **forest** is any area covered with trees. "They're actually sending messages back and forth that balance the resource distribution among the community," Simard said in a 2017 interview with *TED Radio Hour*.

Simard's research has also led her to conclude that there are "hub trees," which she calls mother trees because they nurture their young. The mother trees have grown tall enough to reach the forest's **canopy**, which is the upper layer of the forest where the treetops meet and form a thick cover. Canopy trees access most of the forest's energy because of the amount of sunlight they receive.



the layers in a forest

The mother trees help their young, which grow in the understory. The **understory** of a forest exists below the canopy, which means that less sunlight reaches this layer because it has to filter through the canopy. As a result, plants in this layer must be able to make food with a limited amount of sunlight. Suzanne's research showed that mother trees send extra carbon to the seedlings growing in the understory, which helps the seedlings survive because plants use some carbon atoms to build and repair their different structures. It also benefits the mother trees. When their offspring survive, they are more likely to reproduce and pass their genes along to future offspring.

There is even less sunlight on the forest floor than in the understory. The **forest floor** is blanketed with decaying leaves, twigs, fallen trees, animal scat, moss, and other organic particles.

Forest Ecosystems

Simard's research has focused on interactions among different trees within a forest ecosystem. An **ecosystem** is a community of different species that depend on interacting with each other and their physical environment for survival. All ecosystems include living things that must eat one another for energy and nutrients, as well as nonliving things such as oxygen and carbon dioxide from the atmosphere, water, and energy from the sun.

An ecosystem can be as large as a forest or as small as an oak tree. Regardless of its size, all the parts of an ecosystem work together to make a balanced system.

Other researchers focus on different interactions within an ecosystem. For example, Michael Steele is a researcher who is particularly interested in interactions between the Eastern gray squirrel and oak trees. He has spent time observing squirrels eating seeds and burying them to eat later. He learned that right before a squirrel eats an acorn, it shakes it.

an Eastern gray squirrel

The shaking happens so quickly it can be hard to see. But Steele has videoed squirrels eating. When he watched the videos in slow-motion, he saw squirrels shaking the acorns. According to Steele, there is a simple explanation for why the squirrels do this: They want to know if the quality of the seed is good. Depending on what they sense from shaking, they will either eat the seed right away or bury it to eat later.

Squirrels bury seeds so they will have enough food to last them through the winter. Squirrels need to eat acorns and other plant materials because they are animals, so they cannot make their own food, as plants can. Instead, they have to eat other organisms for energy and nutrients.

Ecosystem Interactions

Steele has found that squirrels and oak trees have a mutually beneficial relationship, where both species benefit from their interactions. The squirrels benefit because they need the seeds' energy and nutrients. The oak trees benefit because acorns don't grow well if they are right beneath the parent tree, where the branches of the parent tree will block the sun.

This squirrel is burying food for later.

The squirrels move acorns to bury them. Gray squirrels are known as scatter hoarders because they bury acorns and other seeds in many places. Researchers have found that gray squirrels have a system when they bury acorns from an oak tree. They bury less-desirable acorns closest to the tree and the more-desirable acorns farther away from the tree.

If the squirrel doesn't make it back to its acorns, those acorns might grow into new trees. This benefits the oak tree because it has passed along its genes. It also benefits the squirrels because it means more food sources.

Squirrels have a competitive relationship with one another. **Competitive** interactions between organisms occur whenever two or more organisms require the same limited resource. Water and food are both resources, as is shelter. Squirrels will often take another squirrel's supply of buried seeds if they find them. Because of this, gray squirrels will bury thousands of seeds each season.

There are competitive and mutually beneficial interactions in every ecosystem. There are also predatory interactions in every ecosystem. **Predation** is an interaction that occurs when one organism (a predator) eats another organism (prey). Hawks and foxes are both predators of gray squirrels.

Forest Food Webs and Food Chains

Oak trees, squirrels, and hawks are all connected together in a forest food web. A **food web** is a visual that shows the network of food chains in an ecosystem. **Food chains** show specific paths that energy travels as one organism eats another. Scientists study how energy flows through ecosystems to better understand how different organisms are connected together, grouping organisms within an ecosystem according to how they obtain energy in a food web. Each level of a food web or food chain is called a trophic level.

All energy in a food chain begins with the sun. As it shines, oak trees and other plants capture the sunlight. For this reason, plants are producers. **Producers** capture energy directly from the sun to make their own food. Producers always make up the first trophic level of any food web. They are the link between the energy source—the sun—and the rest of the organisms that live in an ecosystem.

The next trophic levels of a food web are made up of consumers. **Consumers** are organisms that eat other organisms for energy. All predators are consumers. Consumers can be herbivores (animals that eat only plants), carnivores (animals that eat other animals), or omnivores (animals that eat plants and other animals).

There are three different trophic levels of consumer. The second level of a food web consists of a kind of consumer called a primary consumer. **Primary consumers** are the first organisms that get energy by eating producers. Many primary consumers are herbivores. Squirrels are primary consumers because they eat acorns and other plant seeds.

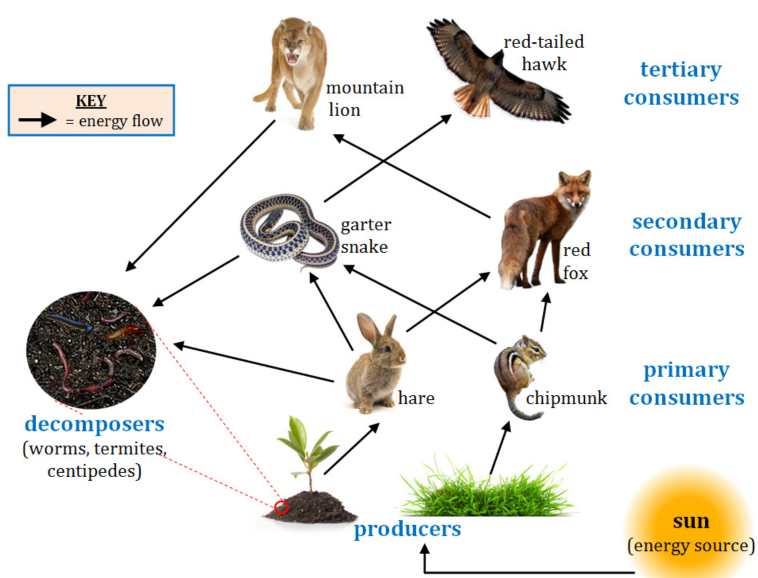
The third level of organisms in a food web consists of **secondary consumers**, which eat the primary consumers. In some food chains, there is a fourth level, which is made up of **tertiary consumers** that eat secondary consumers.

Forest Decomposers

Decomposers are their own level in a food web. Decomposers are organisms that break down organic waste and feed on the nutrients. When decomposers feed on the nutrients, they are also accessing some of the energy that is stored in the organic matter. As organic matter decomposes, the nutrients within it, including nitrogen and carbon, are recycled back into the environment. Plants can access these nutrients and use them as building blocks to help them grow.

Fungi are the primary decomposers of the forest floor. Their ability to branch into networks of hyphae allows them to cover more area than bacteria, which are restricted to growing and feeding on a single surface. Fungi are also the only species that have evolved enzymes to break down and absorb nutrients from large pieces of wood.

Insects such as beetles, beetle larvae, fly maggots, slugs, and worms are other decomposers. Earthworms consume dead leaves, manure, and soil particles, then partially digest the mixture and excrete it as casts. Casts contain nutrients such as nitrogen and phosphorous in a form that plant roots can easily absorb. Earthworms also help by loosening soil so air can circulate underground.



This diagram shows a forest food web. The arrows show the path that energy flows as organisms eat one another.

Flow of Energy and Cycling of Matter

All of the energy a tree gathers from sunlight is spread throughout the forest ecosystem. When organisms eat one another, energy gets passed along in the form of chemical bonds holding together the molecules of glucose. When plants make glucose during photosynthesis, or animals eat plants or other animals and absorb glucose, that glucose moves to the mitochondria of their cells.

It is the job of the mitochondria to perform a chemical reaction called cellular respiration. In cellular respiration, oxygen converts some of the energy in the glucose into energy that is stored in molecules called adenosine triphosphate, or ATP. The energy found in glucose cannot be used by cells until it is stored in molecules of ATP. Because of this, cellular respiration is always happening in cells.

As energy flows from the sun to producers and then to consumers and decomposers, it is always moving in one direction through the food web. As organisms eat one another, some energy is lost to heat as cells perform cellular respiration. As a result, life requires a constant supply of energy from the sun.

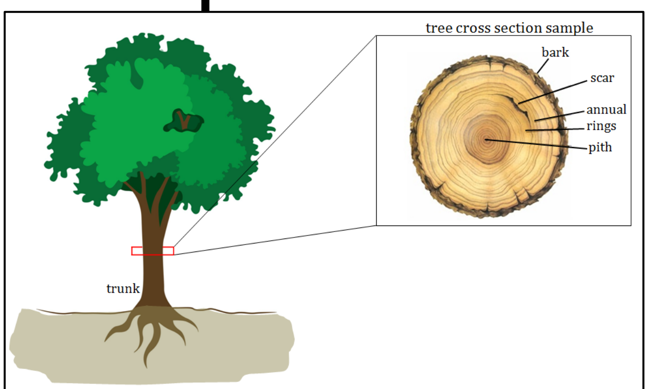
In contrast, matter is always cycling through ecosystems. Most of the matter that is on Earth today has been around since the planet first formed. Matter is transferred and recycled at every level of a food web.

Photosynthesis and cellular respiration cycle oxygen and carbon dioxide between the atmosphere and living things. In the atmosphere, carbon bonds with oxygen to form carbon dioxide. When plants take in carbon dioxide to perform photosynthesis, some of the carbon atoms are used for growth, becoming part of the plant. When animals eat plants, they absorb those carbon atoms. When plants and animals die, decomposers break down the carbon atoms and return them to the environment. This is called the carbon cycle, and it is closely linked to the oxygen cycle.

Ecosystem Disturbances

Ecosystems are dynamic, constantly adjusting to remain balanced. If there are too many organisms competing for the same resources, there will not be enough resources, and some organisms will not survive. Any event that changes conditions in an ecosystem is called a **disturbance**, and because ecosystems are so interconnected, a change to any part will impact the rest of the forest. Volcanoes, severe storms, drought, flooding, and disease are all natural disturbances that can alter the forest ecosystem.

Disturbances are a natural part of any ecosystem. A disturbance can be devastating, sometimes causing many organisms to die or move because their home or food source was destroyed. But healthy ecosystems are often able to adapt to the new situation. Sometimes the same kinds of organisms will reappear. Other times, the environment changes enough that new species move in. These changes can take place quickly, or they can take place over many years.



Christina Restaino is one scientist who looks for patterns in tree core samples to tell about past disturbances. These core samples are pencil-shaped sections of the trunk, which has different parts. As a tree grows, a new ring is added to its trunk each year. An **annual ring** refers to the light- and dark-patterned wood that forms as a tree grows in diameter over time. The light-colored layer grows in the spring. The dark-colored layer forms in the late summer.

The trunk, branches, and twigs of the tree are covered with bark. The bark protects the tree from insects, disease, storms, and extreme temperatures. Inside the bark is a pipeline of living tissue called the pith. The pith carries water and nutrients throughout the tree. The pith is surrounded by dense, hard, inner wood called heartwood. Sapwood is the softer wood between the heartwood and the bark.

Studying Tree Rings

Restaino has traveled around the western United States to study trees, and she spent three years collecting tree core samples from Douglas fir trees. She went to 122 different locations where the fir trees grow and used a tree corer, which looks like a large corkscrew, on more than 2,000 individual trees. By turning the tree corer again and again, she was able to pull out core samples without hurting the trees.

Restaino and her team found that the trees didn't grow as much during times of drought and increased temperatures. A **drought** is a prolonged period of unusually low rainfall, resulting in water shortages. They could read tree rings to tell them this. Thin rings mean the tree didn't grow as much as normal because of a lack of water. Thick rings mean the tree had plenty of water and so it grew a lot.

The scientists observed a cause-and-effect relationship between the amount of rainfall, the temperature, and the tree growth. The rising temperatures caused the amount of water in the soil and atmosphere to decrease, which meant the trees took in less water. In response, the trees closed their stomata to try to reduce water loss through their pores. This meant the trees weren't collecting carbon dioxide for photosynthesis, so they weren't getting the energy they needed to grow.

Other scientists study tree rings to look for patterns that can help them make predictions in the future. For example, one team of scientists used a variety of different data to evaluate how competition among trees affects which trees survive a drought and which ones die.

These scientists focused on forests in California during four years of extreme drought. They found that the driest and densest forests are most at risk of dying. These findings make sense. There is a limited amount of water in the area, and each tree in that area is competing for the same water. When there is plenty of water, this competition isn't as noticeable because trees get the water they need.

Drought in Trees

During a drought, however, the competition becomes a matter of life and death for the trees. This research can help forest managers help to protect forests during times of drought because it tells them to focus on watering trees in the driest and densest areas.

Other scientists have focused on genetics to determine which species of trees are more likely to survive a drought since some species of trees have adaptations that help them survive dry conditions. Remember that an adaptation is a trait that helps an organism survive in its environment. Those species that are adapted to dry conditions are more likely to survive periods of drought and reproduce, passing along their traits to offspring.

William Anderegg has studied this issue. Along with other scientists, William looked for patterns in data about tree mortality to see whether the species that survived drought had traits in common.

Junipers are well-adapted to dry conditions.

He found that the traits most likely to affect a tree's ability to survive drought had to do with how it pulled in water from the soil. When there is less water in the soil, a tree's roots have to pull harder to pull in water. Some tree species, such as junipers, are better adapted to dry conditions. They can pull in more water without harming themselves.

Aspen trees don't have adaptations to help them survive long periods of drought.

Other tree species, such as trembling aspens, are used to wet conditions. Because of this, they aren't as well adapted to dry conditions. In times of drought, they end up pulling so hard they harm themselves.

Bromothymol Blue 1% (pH Indicator) Safety

Students use several drops of bromothymol blue pH indicator in Lesson 1: Photosynthesis.

General guidelines: Bromothymol blue is a pH indicator for weak acids and bases. Review the official MSDS insert for bromothymol blue in the appendix in the back of your binder.

- slightly hazardous (irritant) in case of skin, eye, ingestion, or inhalation

Storage:

- Keep container tightly closed in a cool, well-ventilated area.

Handling in the lab: Students must wear properly fitting goggles and disposable gloves during the entire experiment. Wash hands thoroughly afterwards. Read and follow all safety warnings on the label and MSDS sheet.

- In case of ingestion, call a physician or Poison Control Center.
- In case of eye exposure, flush eyes thoroughly for 15 minutes. Get medical attention.
- In case of skin exposure, flush with mild soap and water.
- In case of inhalation, seek fresh air. If not breathing, give artificial respiration and get immediate medical attention.

Disposal: At the end of the lesson, have students pour their used solutions into a waste container. The waste container with diluted indicator can be disposed of via sewer/drain.

Lesson 1: Photosynthesis

Objective: Students carry out an experiment to test how different light conditions affect the rate of photosynthesis in aquatic plants.

Materials:

Consumable

A. Goggles – 1 per student
B. Laboratory notebooks
  – 1 per student
C. Aquatic plants – 15 leaves
  or 3 two-inch stems per team
  (**LIVE MATERIAL**)
D. Distilled water
  – 120 mL per team
  (teacher provides;
  not shown)
E. pH indicator
  – shared bottle(s)
F. Graduated cups (30 mL)
  – 1 per team
G. Plastic cups (10 oz)
  – 1 per team
H. Aluminum foil
  – 1 sheet per team
I. BTB pH color charts
  – 1 per team
J. Red cellophane – shared roll
K. Disposable gloves
  – 1 pair per student
L. Test tubes with covers
  – 3 per team
M. Straws – 1 per student

A


B

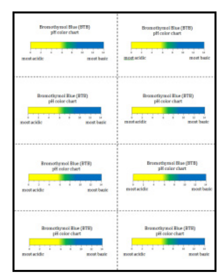

C


E


F


G


H


I


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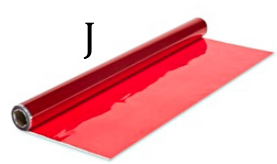


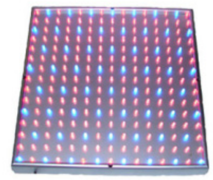
K


L


M


Non-Consumable
N. Grow light – shared
O. Plastic bin – shared
P. Graduated measuring
containers – teacher use
Q. Photosynthesis Visual
– (not shown)
R. Forest Layers and Sunlight
Visual – (not shown)

Teacher Tool Kit
S. Scissors – 1 per student
T. Masking tape – shared

N


O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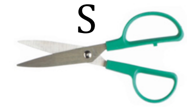
S


T


<u>Teacher Preparation</u>:

- Go to the KnowAtom Interactive to order live materials for this lesson (aquatic plants). Allow **<u>two weeks</u>** for delivery and shipment. Live materials are only shipped on Mondays and Tuesdays. When plants arrive, fill one or more graduated measuring containers with bottled water and submerge the plants whole. Plants should be used within 5 days of arrival.
- Bring in distilled water (~120 mL per team of two). Distilled water is used in this experiment because the minerals and chlorine found in tap water may interfere with the pH indicator.
- Review the MSDS sheet for bromothymol blue (pH indicator), located in the curriculum binder appendix. Cut the bromothymol blue (BTB) pH color charts from the template provided in the kit. Each team will use one color chart during the lab.
- Download the visuals from the KnowAtom Interactive website.

- To save time, prepare photocopies of the Blank Data Table and Facilitated Set-Up Procedure for each student using the copy masters on page 48.
- Data collection in this lab requires that test conditions be evaluated on two consecutive days. Reserve a space in your classroom for the plastic bin and grow light set-up. Test tubes prepared in the experiment will be placed on their sides in the plastic bin, and the grow light will be positioned over the opening of the bin and turned on for 24 hours.
- Arrange several pick-up stations for teams to collect the materials they will use at their desks. For example:
  - Pick-up Station 1: plastic cups (10 oz), graduated cups (30 mL), and distilled water
  - Pick-Up Station 2: pH indicator, BTB pH color charts, straws, and disposable gloves
  - Pick-Up Station 3: test tubes/covers, aluminum foil, and colored cellophane
  - Pick-Up Station 4: aquatic plants
  - Pick-Up Station 5: scissors and masking tape

Student Reading Preparation:

- Students read Section 1 of the student lab manual. In 6th grade, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue before the lab portion of the lesson. At the beginning of the school year (September-October), the lab manual can be read in class.
- If class time is used to read the lab manual together, model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.

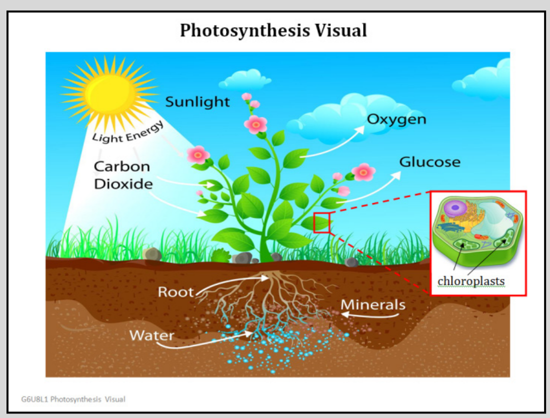
- Use “why” and “how” questions to connect ideas in the reading to student experiences.

Socratic Dialogue:

- The Socratic dialogue serves as the bridge between the nonfiction reading and the lab portion of the lesson.
- The example Socratic dialogue below describes one possible progression of ideas to engage students in higher order thinking. Blocks are used to divide the dialogue according to key organizing concepts. They are not meant to indicate how much time a dialogue should take; length of time may vary depending on the subject matter and student understanding of the concepts. Note that in a Socratic dialogue, the teacher is not the only one asking questions and challenging ideas. Students should be actively engaged in proposing questions, challenging assumptions, and using evidence to support their arguments. *Not sure how to set up a Socratic dialogue? Check out www.knowatom.com/socratic for an in-depth look at how to hold a next generation Socratic dialogue in the classroom.*

Block 1: How Plants Access Energy for Everyday Life

1. Display *Photosynthesis Visual*. Begin a dialogue with students about how like all living things, plants need energy to grow and develop. However, unlike most other living things, including fungi and animals, plants make their own food using sunlight, carbon dioxide, and water.



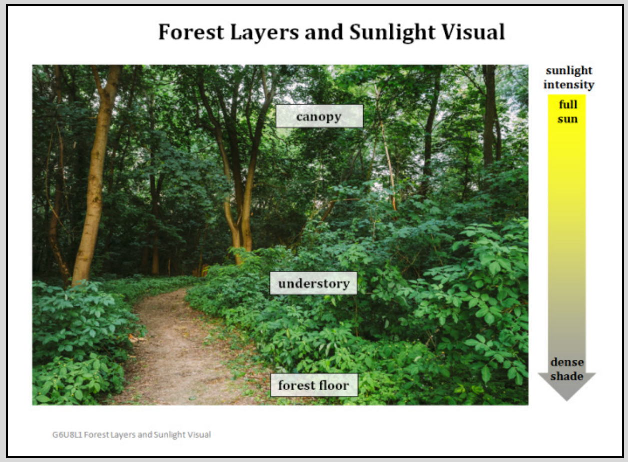
- ☐ **Big Idea 1**: Coach students toward the idea that plants cycle both matter and energy in photosynthesis. For example:

- *Ask one student how plants get the energy they need to survive. (Like all living things, plants need food, which holds chemical potential energy. However, unlike other living things, plants make their own food through photosynthesis.* ***Photosynthesis*** *is a process of turning sunlight, carbon dioxide, and water into glucose and oxygen.)*
- *Ask another student what kinds of matter plants need to take in to carry out photosynthesis. (This question asks students to apply what they know about matter and photosynthesis. Matter is anything that has mass and takes up space, so both water and carbon dioxide are matter. Water molecules are made up of hydrogen and oxygen atoms, while carbon dioxide molecules are made up of carbon and oxygen atoms.)*
- *If the previous student doesn't fully answer the question about the matter that plants need to carry out photosynthesis, ask the first student to add to what the previous student said, providing additional details to support their response or respectfully contradicting it.*
- *Ask another student where plants get their source of energy to carry out photosynthesis. (Plants get energy from the sun.)*

- [ ] **<u>Big Idea 2</u>:** Coach students toward the idea that plants need sunlight to carry out photosynthesis because it is a chemical reaction. The sunlight is the input of energy that turns carbon dioxide and water into glucose and oxygen. For example:
  - *Ask one student how matter is changed in photosynthesis. (The process of photosynthesis turns molecules of carbon dioxide and water, along with the input of sunlight, into molecules of glucose and oxygen.)*
  - *Ask another student why glucose is an important output of photosynthesis. (Glucose is a kind of sugar that holds chemical potential energy. Plants need this energy for*

growth and development. They store any extra glucose in their different structures.)
    - *Ask the first student what plants do with the oxygen they produce in photosynthesis. (Plants use some of the oxygen they produce. They release the rest back into the environment.)*
- ☐ **<u>Big Idea 3</u>:** Coach students toward the idea that different parts of the plant work together to collect what the plant needs to carry out photosynthesis. For example:
    - *Ask one student why plants are able to capture the sun's energy, but other living things, including animals and fungi, cannot. (Unlike other living things, plants have chloroplasts in their cells. Chloroplasts make chlorophyll, which is a pigment that absorbs sunlight.)*
    - *Ask another student why a plant's leaves are important for photosynthesis. (Chloroplasts are most common in cells in the plant's leaves. This is important because photosynthesis happens in the chloroplasts. Leaves also have stomata, which are pores that open and close to take in carbon dioxide and release oxygen.)*
    - *Ask the first student how a plant gets the water it needs to carry out photosynthesis. (The roots collect water and nutrients from the soil. The stem transports water and nutrients between the roots and the rest of the plant. The stem also absorbs some water, although not as much as the roots.)*
    - *Assess student understanding of where plants get food by challenging another student about why plants take in minerals from the soil if they make their own food. (A common misconception among students is that plants get food from the soil. While plants do absorb minerals and other nutrients from the soil, these substances aren't food. Instead they are building blocks for the plants' structures. Plants make all of their food through photosynthesis.)*

2. Display *Forest Layers and Sunlight Visual*. Continue the dialogue with students about photosynthesis, focusing on how there are layers in any forest, and different amounts of energy reach each layer.



- **Big Idea 4:** Transition to the experiment by coaching students toward the idea that a plant's ability to carry out photosynthesis depends on how much sunlight it can access, which is partly dependent on which layer of the forest it is in. For example:
    - *Ask one student why trees that grow in the canopy access most of the forest's energy. (The* ***canopy*** *is the upper layer of the forest. It is where the treetops meet and form a thick cover. Canopy trees access most of the forest's energy because of the amount of sunlight they receive.)*
    - *Ask another student why there is less sunlight available in the understory. (The* ***understory*** *of a forest exists below the canopy. Less sunlight reaches the understory because it filters through the canopy. As a result, plants in this layer must be able to make food with a limited amount of sunlight.)*
    - *Ask the first student why the forest floor has even less sunlight than the understory. (There is even less sunlight on the forest floor than in the understory because the canopy and the understory prevent almost all of the sunlight from reaching the forest floor. The* ***forest floor*** *is blanketed with decaying leaves, twigs, fallen trees, animal scat, moss, and other organic particles.)*

<u>Experiment</u>: Lab 8 – Photosynthesis

SAFETY: Students must wear goggles and disposable gloves during this lab. Review the chemical safety information with the class from page 27 (teacher background) prior to starting the lab.

1. Divide students into teams of two. Students will have read and discussed how plants make their own food through photosynthesis. Use Socratic dialogue to guide students toward asking a question that they could answer with an experiment related to the concepts of light intensity and the rate of photosynthesis in plants. See if any students get close enough to a question that could be framed into something that is usable as the experiment question. If necessary, pull out some of the materials from your kit (aquatic plants, test tubes, grow light, pH indictor, cellophane, etc.) and point out the quantities each team has to work with.

- What sort of question could we answer about photosynthesis and light intensity with these materials?

See if any student gets close enough to a question that could be framed into something that is usable as the experiment question. For example: "How does the intensity of light affect the rate of photosynthesis in aquatic plants?

Question

As a class, discuss the possible questions for the experiment and decide which question to explore for the lab. For example: "How does the intensity of light affect the rate of photosynthesis in aquatic plants?" Once the experiment question is established for the lab, students record it in their lab notebooks. Students create a title for the new lab entry that is relevant to the question. In this example, a relevant title is "Photosynthesis" or "Photosynthesis in Aquatic Plants," but other titles can be used as well.

NOTE: Use the *Scientific Process Visual* and/or the *Who is a Scientist Poster* as a visual reference to guide students through the remaining steps of the lab process.

Research

For research, students list up to three facts relevant to the experiment question, using information from the student lab manual and/or discussion. For example:

- *Photosynthesis is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen.*
- *Carbon dioxide, water, and sunlight are needed for photosynthesis to take place.*
- *Carbon dioxide in water lowers the pH, creating an acidic environment.*

Hypothesis

Teams form their own hypothesis and record it in their lab notebooks. The following examples represent the types of hypotheses teams could develop in this lab:

- "The rate of photosynthesis in aquatic plants increases when the light intensity increases."
- "The rate of photosynthesis in aquatic plants decreases when the light intensity increases."
- "The intensity of light has no effect on the rate of photosynthesis in aquatic plants."

<u>Checkpoint #1</u>: After Question, Research, and Hypothesis
As teams are ready, they should check in with the teacher to review their question, research, and hypothesis. Do the lab notebooks of both team members match and meet expectations? Can both students within the team explain their reasoning? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. <u>Student lab notebook entries within the class will most likely have the same question, but variations from team to team in the remaining steps of the process are expected and encouraged</u>.

Summarize Experiment
Stand by the materials stations to explain how the materials function and the general amounts that teams can collect. If students do not have access to the pick-up stations at this point in the lab, a general list of the materials each team can use for the lab can be written or displayed on the board (if needed). Teams develop and record a summary of the experiment they plan to carry out in their lab notebooks. Summaries should note the independent and dependent variables, constants, and a control (if applicable) in the experiment. For example: "Our experiment will use a pH indicator to compare how much carbon dioxide aquatic plants remove from water when exposed to three different light intensities over 24 hours. Each test condition will receive the same number of plants, plant types, distilled water, and pH indicator. The independent variable is the light intensity the plants are exposed to in each test condition (high, low, and no light). We will create different light intensities by covering the aquatic plant test tube with different materials. The dependent variable is the pH change of the water in each test condition after 24 hours of light."

Checkpoint #2: After Experiment Summary
As teams are ready, they should check in with the teacher to review the experiment summary of their lab. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning? The summary should not include a detailed procedure or materials quantities.

- ✓ Students describe what data will be collected to serve as evidence to address the lab question. The summary should include the basics of the data to be collected, the number of trials students will conduct, the independent and dependent variables, and the parts of the experiment they will keep constant in each test or trial.

List Materials and Procedures
Students list materials and relevant safety precautions in their lab notebooks. For example:

- 120 milliliters of distilled water
- 40 drops of pH indicator
- 15 aquatic plant leaves/ or 3 stem sections
- 3 test tubes with covers
- 1 BTB pH color chart
- 1 straw
- 1 sheet of aluminum foil
- 1 sheet of red cellophane
- 1 graduated cup (30 mL)
- 1 plastic cup (10 oz)
- 1 roll of masking tape (for labels) – shared
- 1 grow light (shared)

Safety

- goggles
- disposable gloves

*Bromothymol blue (pH indicator) can mildly irritate the skin and eyes with contact. Goggles and disposable gloves must be worn at all times.

Due to the precision required in the experiment, students will not derive steps of the set-up procedure on their own. In this lesson, the set-up procedure is facilitated by the teacher. A copy master of this procedure is located at the end of the lesson under the blank data tables on page 48. Review the procedure with the class before distributing a copy for each student to add to their lab notebook under 'procedure.'

Set-Up Procedure (facilitated):

1. Pour 120 mL of distilled water into a large plastic cup.
2. Infuse the distilled water with carbon dioxide by blowing into the water with a straw for 60 seconds to lower the pH.
3. Add 40 drops of bromothymol blue pH indicator to the water. Use the BTB pH color chart to find initial pH of the water.

Once students have reviewed the set-up procedure, teams develop a standardized list of steps for their testing procedure. The procedure may vary from team to team depending on approach. Differences are expected and encouraged. Student procedures should include a level of detail comparable to this example procedure:

Test Procedure:

1. Divide the carbon dioxide-infused water evenly among the three test tubes. Add 5 aquatic plant leaves (or 1 aquatic plant stem 2 inches long) to the center of each test tube and seal with covers.
2. Wrap one test tube with a sheet of aluminum foil to block it from sunlight (no light). Wrap the second test tube with red cellophane to shade it from some of the light (low light intensity). Leave the third test tube uncovered (high light intensity). Label test tubes with names/initials, date.
3. Place the "no light" test tube in a dark environment and the remaining test tubes in a plastic bin under the grow light for 24 hours.

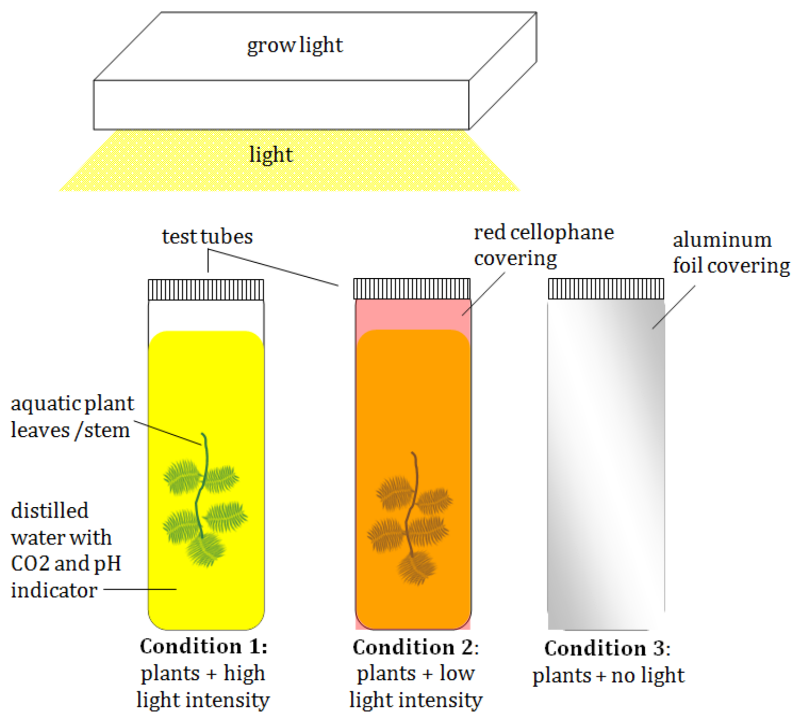
NOTE: The grow light must be kept on for 24 hours straight in order to see results.

Checkpoint #3: After Materials and Procedure
As teams are ready, they should check in with the teacher to review the materials and procedure steps of their lab. Do teams understand the facilitated set-up procedure? Are the materials and test procedure in vertical lists and quantities included with all materials? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead.

Scientific Diagram

Students draw a titled scientific diagram of their experiment-in-progress. For example:

Photosynthesis and Light Intensity Diagram



<u>Checkpoint #4</u>: After Scientific Diagram
As teams are ready, they should check in with the teacher to review their lab scientific diagram. Are the diagrams complete? Diagrams should be titled and materials labeled. If complete, students pick up blank data tables and graphs to tape inside their lab notebooks and then proceed to collect the materials needed to conduct their experiment after meeting at the checkpoint.

Data
Teams collect the materials from the pick-up stations to carry out their experiment. Students record data in their data tables as the experiment progresses. Students match the color of their test tube to the BTB pH color chart provided in the materials kit to determine the final pH of the test tube water. Photocopy and distribute blank data tables to save time.

Table 1: Comparing pH Change of Aquatic Plant Water After 24 Hours in Different Light Intensities

Test Conditions	Initial (0 hours)		Final (24 hours)	
	Water Color	pH	Water Color	pH
Condition 1 plants + high light intensity	yellow	5	blue-green	8
Condition 2 plants + low light intensity	yellow	5	greenish-yellow	6.5
Condition 3 plants + no sunlight	yellow	5	yellow	5

Photo shows test tubes after 24 hours: Condition 1 on left, Condition 2 in the middle, and Condition 3 on right.

Conclusion

Each student writes a conclusion that summarizes their findings and tells how the data did or did not support the hypothesis. For example: "Our hypothesis that the rate of photosynthesis in aquatic plants increases when the light intensity increases is true. The data show that the initial pH of the water in the high intensity light condition increased from 5.0 (acidic-yellow) to 8.0 (basic-blue) after 24 hours. The plants in the low light intensity condition only increased from a pH of 5.0 (acidic-yellow) to 6.5 (less acidic-greenish yellow), and the pH of the aquatic plant water that did not receive sunlight did not change pH. We can conclude that the rate of photosynthesis in aquatic plants increases when the light intensity is higher."

Final Checkpoint: After Data and Conclusion
As teams are ready, they should check in with the teacher to review the data and conclusion steps of their lab. One team member reads the team's conclusion aloud to you while you review the other team member's lab notebook. Do they restate the hypothesis? Have they made a true/false/inconclusive claim? Look for key data points that students used to form their conclusion. Is it clear? Is it persuasive? Do the data support the claim? If the results are contrary to their research, what might be responsible? How could they test for that in the future?

Wrap-Up:

1. Begin a dialogue with students to review team results from the experiment. For example:

- Were the data consistent with all teams in the class? If not, what may have caused some teams to have different data? [*Answers will vary. Ask students to compare their results and analyze possibilities for any differences. For example, some teams may have used different materials when covering one or more of their test tubes. Some teams may have chosen not to cover the tube in the "no light" condition, and so may not have seen as much of a difference between it and the "low-light" condition if some light made its way into the dark space.*]
- Ask a student from one team whether they experienced any challenges in conducting this experiment. If so, what were they? [*Answers will vary. Challenges are a part of conducting experiments, and discussing them can help students think through their process, comparing their method with other student teams.*]
- Ask a student from another team what patterns they noticed in the data about the relationship between the amount of light present and the change in the pH of the water, and what a likely explanation for this relationship is. [*As the amount of*

light increased, the pH of the water also increased. This is a sign that more carbon dioxide was removed from the water, which means the plants were photosynthesizing more.]

2. Continue the dialogue with the class, reviewing how the experiment provided evidence that photosynthesis causes matter to cycle between plants and the environment. For example:

- Ask one student what happens to the carbon dioxide that is taken from the water. [*The plants take in the carbon dioxide from the water because they need it, along with sunlight and water, to carry out photosynthesis. This process turns the carbon dioxide and water into oxygen and glucose.*]
- Ask another student how the absence of sunlight makes plants less able to cycle matter between plants and the environment. [*The experiment showed that without sunlight, plants do not take in carbon dioxide from the water, which means they aren't carrying out photosynthesis and so aren't producing oxygen or glucose.*]
- Ask the first student to connect the experiment results back to the story presented in the lab manual, which described how the scientist Suzanne Simard used carbon-14 to determine whether trees shared resources. How did the experiment support the fact that Suzanne knew the trees would take in carbon-14? [*The experiment showed that when plants receive enough sunlight, they will absorb carbon dioxide from the environment so they can carry out photosynthesis. The carbon dioxide is made up of molecules of carbon and oxygen, and Suzanne knew that carbon-14 molecules would bond with oxygen molecules in the environment to form carbon dioxide. This is how she was able to carry out her experiment.*]
- One at a time, provide multiple students with the chance to respond to this question. If needed, provide students with the chance to ask questions or to clarify what other students have said. Redirect if any misconceptions arise.

Unit 8: Lesson 1 – Example Lab Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Lab #8: Photosynthesis

Question: How does the intensity of light affect the rate of photosynthesis in aquatic plants?

Research: Photosynthesis is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen. Carbon dioxide in water lowers the pH, creating an acidic environment. Carbon dioxide, water, and sunlight are needed for photosynthesis to take place.

Hypothesis: The rate of photosynthesis in aquatic plants increases when the light intensity increases.

Summary of Experiment: Our experiment will use a pH indicator to compare how much carbon dioxide aquatic plants remove from water when exposed to three different light intensities over 24 hours. Each test condition will receive the same number of plants, plant types, distilled water, and pH indicator. The independent variable is the light intensity the plants are exposed to in each test condition (high, low, and no light). We will create different light intensities by covering the aquatic plant test tubes with different materials. The dependent variable is the pH change of the water in each test condition after 24 hours of light.

Materials:

- 120 mL of distilled water
- 40 drops of pH indicator
- 15 aquatic plant leaves/ or 3 stem sections
- 3 test tubes with covers
- 1 BTB pH color chart
- 1 straw
- 1 sheet of aluminum foil
- 1 sheet of red cellophane
- 1 graduated cup (30 mL)
- 1 plastic cup (10 oz)
- 1 roll of masking tape (shared)
- 1 grow light (shared)

Safety:

- goggles
- disposable gloves

* The pH indicator can mildly irritate the skin and eyes with contact. Goggles and disposable gloves must be worn at all times.

Unit 8: Lesson 1 – Example Lab Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Set-Up Procedure (facilitated):

Set-Up Procedure (facilitated):

1. Pour 120 mL of distilled water into a large plastic cup.
2. Infuse the distilled water with carbon dioxide by blowing into the water with a straw for 60 seconds to lower the pH.
3. Add 40 drops of bromothymol blue pH indicator to the water. Use the BTB pH color chart to find initial pH of the water.

Test Procedure:

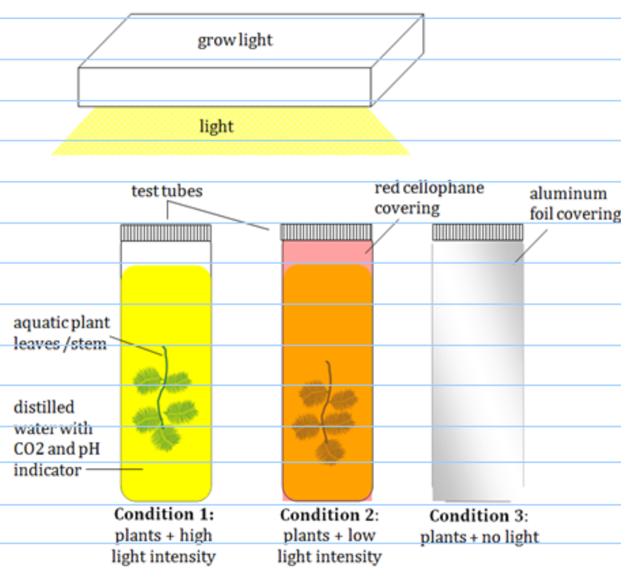
Step 1: Divide the carbon dioxide-infused water evenly among the three test tubes. Add 5 aquatic plant leaves (or 1 aquatic plant stem 2 inches long) to the center of each test tube and seal with covers.

Step 2: Wrap one test tube with a sheet of aluminum foil to block it from sunlight (no light). Wrap the second test tube with red cellophane to shade it from the light (low light intensity). Leave the third test tube uncovered (high light intensity). Label test tubes.

Step 3: Place the "no light" test tube in a dark environment and the remaining testing tubes in a plastic bin under the grow light for 24 hours.

Scientific Diagram

Photosynthesis and Light Intensity Diagram



Unit 8: Lesson 1 – Example Lab Notebook
This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Data:

Table 1: Comparing pH Change of Aquatic Plant Water After 24 Hours in Different Light Intensities

Test Conditions	Initial (0 hours)		Final (24 hours)	
	Water Color	pH	Water Color	pH
Condition 1 plants + high light intensity	yellow	5	blue-green	8
Condition 2 plants + low light intensity	yellow	5	greenish-yellow	6.5
Condition 3 plants + no sunlight	yellow	5	yellow	5

Conclusion: Our hypothesis that the rate of photosynthesis in aquatic plants increases when the light intensity increases is true. Our data show that the initial pH of the water in the high intensity light condition increased from 5.0 (acidic - yellow) to 8.0 (basic- blue) after 24 hours. The plants in the low light intensity condition only increases from a pH of 5.0 (acidic-yellow) to 6.5 (less acidic-greenish yellow), and the pH of the aquatic plant water that did not receive sunlight did not change pH. We can conclude that the rate of photosynthesis in aquatic plants increases when the light intensity is higher.

<u>Unit 8 Lesson 1</u>: Blank Data Table

Table 1: Comparing pH Change of Aquatic Plant Water After 24 Hours in Different Light Intensities				
Test Conditions	**Initial (0 hours)**		**Final (24 hours)**	
	Water Color	**pH**	**Water Color**	**pH**
Condition 1 plants + high light intensity				
Condition 2 plants + low light intensity				
Condition 3 plants + no sunlight				

<u>Unit 8 Lesson 1</u>: Facilitated Set-Up Procedure

<u>Set-Up Procedure (facilitated)</u>:

1. Pour 120 mL of distilled water into a large plastic cup.
2. Infuse the distilled water with carbon dioxide by blowing into the water with a straw for 60 seconds to lower the pH.
3. Add 40 drops of bromothymol blue pH indicator to the water. Use the BTB pH color chart to find initial pH of the water.

Lesson 2: Forest Food Web

Objective: Students develop models to analyze the impact of drought on temperate deciduous forest food webs in Massachusetts.

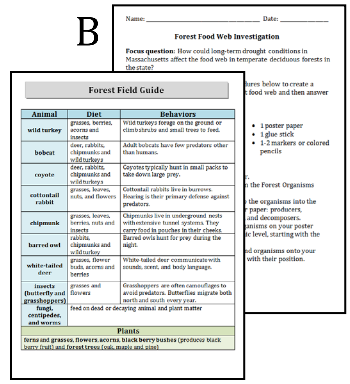
Materials:

Consumable

A. Goggles – 1 per student

B. "Forest Food Web Investigation"
– 1 per student (lab manual)

C. Forest Field Guide
– 1 per student
(lab manual)



Name: ______________________ Date: __________

Forest Food Web Investigation

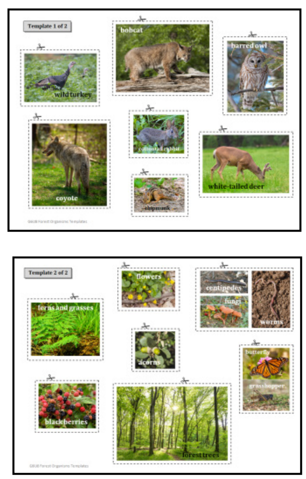
Focus question: How could long-term drought conditions in Massachusetts affect the food web in temperate deciduous forests in the state?

- 1 poster paper
- 1 glue stick
- 1-2 markers or colored pencils

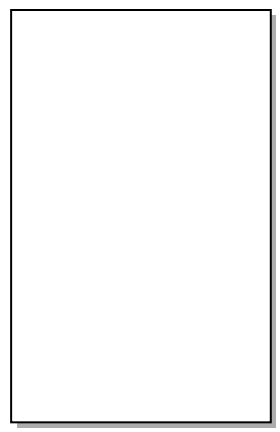
Forest Field Guide

Animal	Diet	Behaviors
wild turkey	grasses, berries, acorns and insects	Wild turkeys forage on the ground or climb shrubs and small trees to feed.
bobcat	deer, rabbits, chipmunks and wild turkeys	Adult bobcats have few predators other than humans.
coyote	deer, rabbits, chipmunks and wild turkeys	Coyotes typically hunt in small packs to take down large prey.
cottontail rabbit	grasses, leaves, nuts, and flowers	Cottontail rabbits live in burrows. Hearing is their primary defense against predators.
chipmunk	grasses, leaves, berries, nuts and insects	Chipmunks live in underground nests with extensive tunnel systems. They carry food in pouches in their cheeks.
barred owl	rabbits, chipmunks and wild turkey	Barred owls hunt for prey during the night.
white-tailed deer	grasses, flower buds, acorns and berries	White-tailed deer communicate with sounds, scent, and body language.
insects (butterfly and grasshoppers)	grasses and flowers	Grasshoppers are often camouflages to avoid predators. Butterflies migrate both north and south every year.
fungi, centipedes, and worms	feed on dead or decaying animal and plant matter	
Plants		
ferns and **grasses**, **flowers**, **acorns**, **black berry bushes** (produces black berry fruit) and **forest trees** (oak, maple and pine)		

D. Forest Organisms Templates
– 1 set per team
(two sheets per set)



E. Poster paper
– 1 per team



F. Yellow paper
– 1 sheet per team

Non-Consumable

G. Drought Investigation
Visual – (not shown)

H. Forest Ecosystem Visual
– (not shown)

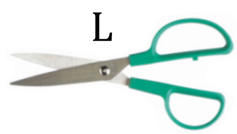
I. Food Web Visual
– (not shown)

J. Ecosystem Disturbances Visual
– (not shown)

Teacher Tool Kit

K. Markers – shared

L. Scissors – 1 per student



M. Glue sticks – 1 per student

<u>Teacher Preparation</u>:

- Download the visuals from the KnowAtom Interactive website. Print the <u>*Drought Investigation Visual*</u> for each student (optional).
- Arrange several pick-up stations for teams to collect the materials they will use at their desks during the investigation. For example:
  - <u>Pick-Up Station 1</u>: student lab manuals, Forest Organism Template set, Forest Field Guides (lab manuals), and yellow paper
  - <u>Pick-Up Station 2</u>: poster paper, scissors, glue sticks, and markers

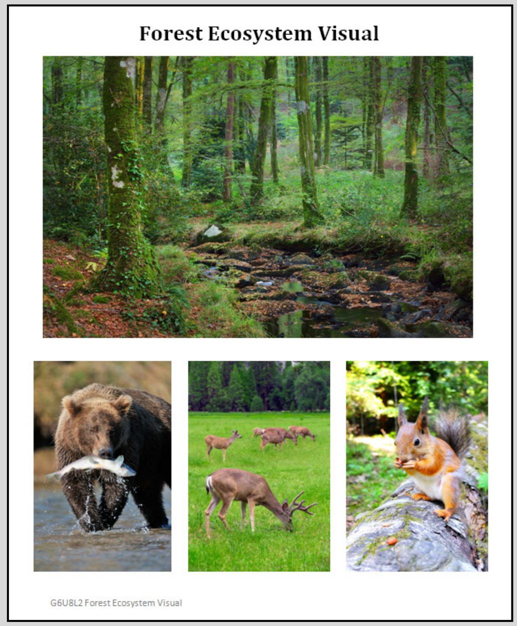
<u>Student Reading Preparation</u>:

- Students read Section 2 of the student lab manual. In 6th grade, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue before the lab portion of the lesson. At the beginning of the school year (September-October), the lab manual can be read in class.
- If class time is used to read the lab manual together, model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

Socratic Dialogue:

Block 2: Food Webs and Energy Flow

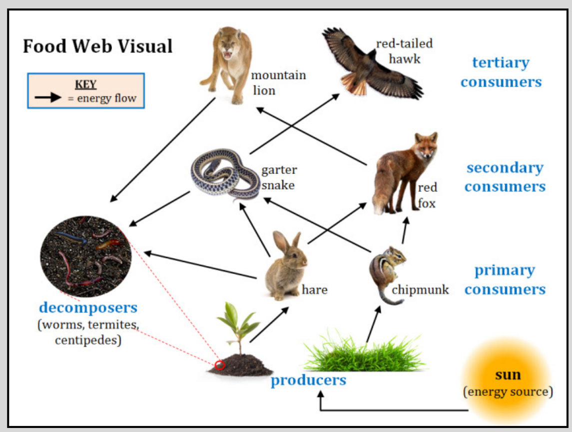
1. Display *Forest Ecosystem Visual*. Continue the dialogue from the last lesson about the importance of energy for living things, focusing on how the energy captured by plants through photosynthesis flows through ecosystems.



- **Big Idea 5:** Coach students toward the idea that **ecosystems** are communities of different species that depend on interacting with each other and their physical environment for survival. For example:
  - *Ask one student why a forest is an ecosystem. (Students should describe both the living and nonliving parts of a forest. A forest is made up of different organisms, including trees, other plants, squirrels, hawks, and many different kinds of animals. It also has nonliving parts, including sunlight, water, oxygen, and carbon dioxide.)*
  - *Ask another student to give an example of how an organism that lives in the forest interacts with other organisms and their environment. (There are many examples students might choose to describe. For example, the lab manual describes how squirrels and oak trees have a mutually beneficial relationship. The squirrels benefit because they need the seeds' energy and nutrients. The oak trees benefit because as squirrels bury acorns to save for later, they don't eat all of the acorns. If the squirrel doesn't make it back to its acorns, those acorns might grow into*

new trees. This benefits the oak tree because it has passed along its genes. It also benefits the squirrels because it means more food sources. Other interactions include a tree absorbing water from the soil through its roots, or plants and animals exchanging gases through the oxygen cycle.)

- *One at a time, provide multiple students with the chance to respond to this question so that students are describing different parts of an ecosystem and how those parts interact with one another.*
- *Ask the first student why water, sunlight, and carbon dioxide are important in all ecosystems. (This question asks students to apply what they learned in the last lesson about photosynthesis. Plants need sunlight, carbon dioxide, and water to carry out photosynthesis. Without these components, plants wouldn't be able to capture the sun's energy and turn it into glucose, which they need to grow and develop. In addition, all living things need water to survive.)*



2. Display *Food Web Visual*. Continue the dialogue with students about ecosystems, focusing on how the energy stored in glucose gets passed along from one organism to another when organisms eat each other.

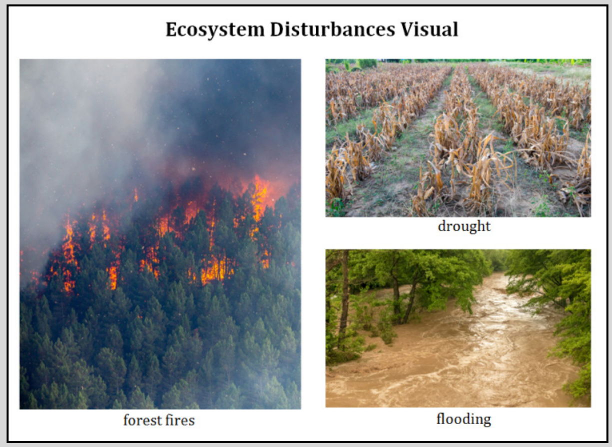
- ☐ **Big Idea 6**: Coach students toward the idea that all of the energy that organisms need to survive comes from the sun and then moves to producers. For example:
  - *Ask one student why the first trophic level of every food web is made up of **producers**—organisms that capture energy directly from the sun to make their own food. (Producers form the base of all food webs because they take energy from the*

sun and through photosynthesis, turn it into usable chemical energy. Producers are the only organisms that can do this, so all of the energy in food webs comes from the sun through producers.)

- *Ask another student how producers are different from consumers. (**Consumers** are organisms that eat other organisms. Unlike producers, consumers cannot make their own food from the sun. Instead, they must obtain it by eating other organisms.)*
- *Ask the first student what role squirrels play in a forest food web. (Squirrels are **consumers** because they eat other organisms for energy and nutrients.)*
- *Ask another student how consumers are related to predators. (All predators are consumers because they eat other organisms for energy.)*
- *Ask the first student to describe the difference between primary, secondary, and tertiary consumers. (These terms describe how close a consumer is to producers. For example, **primary consumers** are the first organisms that get energy by eating producers. Many primary consumers are herbivores, which means they eat only plants. **Secondary consumers** are called this because they eat primary consumers, and **tertiary consumers** eat secondary consumers.)*
- *Ask another student how decomposers are different from either producers or consumers. (**Decomposers** are organisms that break down organic waste and feed on the nutrients.)*
- *Ask the first student how a food chain is different from a food web. (A **food chain** shows the path that energy travels as one organism eats another. A **food web** is a visual that shows the network of food chains in an ecosystem. A food web shows the complex set of relationships within an ecosystem that are linked by the flow of energy.)*
- *Ask another student how food webs provide evidence that energy is transferred within an ecosystem. (Food webs show*

how energy flows (is transferred) as the three groups (producers, consumers, and decomposers) interact.)

3. Display *Ecosystem Disturbances Visual*. Have a dialogue with students about how any event that changes conditions in an ecosystem is called a **disturbance** and can disrupt the flow of energy.



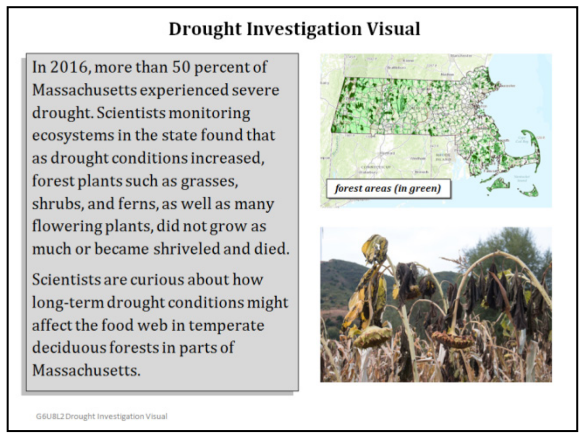
- **Big Idea 7**: Coach students toward the idea that a change to any part will impact the rest of the forest. For example:
  - *Ask one student why a change to one part of an ecosystem will have a ripple effect throughout the ecosystem. (This is the key idea that students will be exploring in the investigation. All of the parts of an ecosystem are connected. Organisms depend on other organisms and their environment for survival, so if one part is affected, that effect will be felt throughout the ecosystem.)*
  - *Ask another student to build on what the first student said, adding details to support their response or respectfully contradicting it with evidence.*
  - *Transition to the investigation by asking the first student why a drought would likely affect a forest ecosystem. (A* ***drought*** *is a prolonged period of unusually low rainfall, resulting in water shortages. Depending on your location, your students may have experienced periods of drought. Students can use any personal experience to respond to this question. For example, some students might focus on the importance of water for all living things, including for plants to carry out photosynthesis. Other students may draw upon personal observations of how drought makes plants shrivel up and die. There is no "right" answer*

because students will be investigating the effects of a drought on a forest food web.)

- *One at a time, provide multiple students with the chance to respond to this question so that students are thinking about the effects of drought and how it might affect a forest ecosystem.*

Investigation:

SAFETY: Students should wear goggles during this activity.



1. Introduce the investigation by displaying the *Drought Investigation Visual*. Read and discuss the scenario as a class: "In 2016, more than 50 percent of Massachusetts experienced severe drought. Scientists monitoring ecosystems in the state found that as drought conditions increased, forest plants such as grasses, shrubs, and ferns, as well as many flowering plants, did not grow as much or became shriveled and died. Scientists are curious about how long-term drought conditions might affect the food web in temperate deciduous forests in parts of Massachusetts."

2. Divide the class into teams of two. Students collect their lab manuals and turn to the "Forest Food Web Investigation." Explain that each team will:

- ☐ Use the "**Forest Food Web Investigation**" to explore the focus question of the investigation: How could long-term drought conditions in Massachusetts affect the food web in temperate deciduous forests in the state?

- Investigation Summary: Use the materials and procedures below to create a model of a temperate deciduous forest food web.

3. Stand by each station to explain how the materials will be used and the amount each team will receive. Teams should go to stations to collect the materials they will use at their desks.

Pick-Up Station 1:

- Forest Organism Template set – 1 per team (2 sheets per set)
- Forest Field Guide – 1 per student (lab manual)
- yellow paper – 1 sheet team

Pick-Up Station 2:

- poster paper – 1 per team
- scissors – 1 per student
- glue sticks – 1 per team
- markers – 1-2 per team

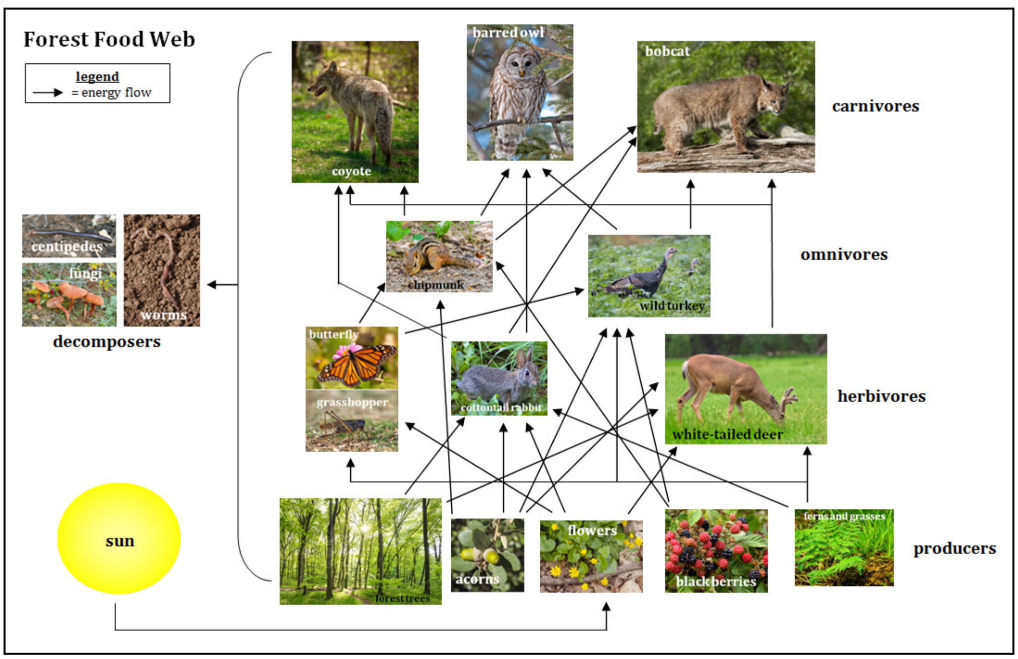
Each team will:

- Use the **model set-up procedure** to set up the poster paper with different groups of organisms:
  1. Cut out a sun from the yellow paper.
  2. Cut out the plants and animals from the Forest Organisms Templates.
  3. Use the Forest Field Guide to group the organisms into the following categories on your poster paper: producers, herbivores, omnivores, carnivores, and decomposers.
  4. Arrange the different groups of organisms on your poster paper in rows based on their trophic level, starting with the sun and producers.
  5. Use the glue stick to glue the sun and organisms onto your poster paper when you're satisfied with their position. Label the organism groups.

☐ **Food web procedure**

1. Use information from the Forest Field Guide to draw arrows from the sun in the direction that energy travels through the forest ecosystem as one organism eats another.
2. Create a title for your model and include a legend to show what the arrows represent.

4. Teams collect materials from the pick-up stations to develop their forest food web models. Circulate throughout the class to help troubleshoot or to ask questions that gauge student thinking as they analyze, compare, and arrange the organisms on their posters.



The image shows one example of a forest food web model. Student models will vary in layout and design.

5. When teams have completed their food web models, they use their models to independently answer the analytical questions for the investigation. Teams come together as a class to share their analysis in the lesson wrap-up.

- Use your forest food web model to identify which trophic level in the forest ecosystem would be most directly affected by a drought and to explain why.
- How do you expect changes to the trophic level you described in Question 1 to impact other trophic levels in the food web? Use your model to help you answer the question.

<u>Wrap-Up</u>:

1. Begin a dialogue with students to review their forest food web model and analysis. For example:

- Ask one student to present their food web model to the class, explaining why they organized it the way they did. [*Student answer should reflect an understanding of how the organisms in a food web are grouped according to how they obtain energy. Producers capture sunlight, which they use to carry out photosynthesis so they can produce energy stored in molecules of glucose. Primary consumers access some of that energy when they eat producers. Secondary consumers access some of the energy of primary consumers when they eat them, and tertiary consumers access some of their energy. Decomposers access the energy of all of these groups when they die and decompose.*]
- Ask whether any teams created a different model. If there are any differences among the teams, provide students with the chance to discuss their reasoning with each other. Once consensus is reached, moved onto student analysis.
- Ask another student to use their food web model to identify which trophic level would be most directly affected by a drought and to explain why (Question 1). [*The producers are the most directly affected by a drought because plants depend on water to carry out many of their life functions, including making their own food through photosynthesis. Without enough water, plants cannot produce the energy they need to survive.*]

- Ask the first student how they would expect changes to the trophic level described in Question 1 to impact other trophic levels in the food web (Question 2). [*Students should identify the importance of producers in any food web because they are the link between the energy source—the sun—and the rest of the organisms in the food web. If many of the plants don't survive, there is less food for the primary consumers, which means there is less food, and therefore energy, all the way up the food chain.*]

2. Continue the dialogue with students about their food web models and analysis, assessing whether students can make further connections about the interconnectedness of the organisms. For example:

- Ask one student how they think the bobcats and coyotes would be affected in drought conditions. [*Students sometimes don't think about the ripple effects of a change within an ecosystem and how those effects can reach all organisms. For example, bobcats and coyotes eat various primary consumers, including deer, rabbits, and wild turkeys. If many of the plants die out from lack of water, the primary consumers will lose much of their food source and so will begin to die off as well. This would result in less food for the secondary consumers as well.*]
- One at a time, provide multiple students with the chance to respond to this question so that students are thinking about the ripple effects of a drought on a temperate deciduous forest food web.

Name: ____ Date: __________________

Forest Food Web Investigation

Focus question: How could long-term drought conditions in Massachusetts affect the food web in temperate deciduous forests in the state?

Investigation Summary: Use the materials and procedures below to create a model of a temperate deciduous forest food web.

Materials

- 2 scissors
- 1 Forest Organism Template set
- 1 Forest Field Guide (lab manual)
- 1 sheet of yellow paper
- 1 poster paper
- 1 glue stick
- 1-2 markers or colored pencils

Model-Set Up

1. Cut out a sun from the yellow paper.
2. Cut out the plants and animals from the Forest Organisms Templates.
3. Use the Forest Field Guide to group the organisms into the following categories on your poster paper: producers, herbivores, omnivores, carnivores, and decomposers.
4. Arrange the different groups of organisms on your poster paper in rows based on their trophic level, starting with the sun and producers.
5. Use the glue stick to glue the sun and organisms onto your poster paper when you're satisfied with their position. Label the organism groups.

Food Web Procedure

1. Use information from the Forest Field Guide to draw arrows from the sun in the direction that energy travels through the forest ecosystem as one organism eats another.

2. Create a title for your model and include a legend to show what the arrows represent.

Analyze the Model

1. Use your forest food web model to identify which trophic level in the forest ecosystem would be most directly affected by a drought and to explain why.

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2. How do you expect changes to the trophic level you described in Question 1 to impact other trophic levels in the food web? Use your model to help you answer the question.

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Lesson 3: Drought and Tree Growth

Objective: Students examine tree ring cross-sections and analyze growth and precipitation data to observe how environmental factors can affect the growth of trees.

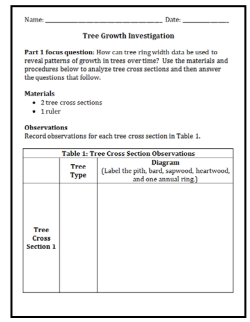
Materials:

Consumable
A. "Tree Growth Investigation"
– 1 per student (lab manual)

Non-Consumable
B. Tree cross-section samples*
– 2 per team
C. Tree Core Samples Visual
– (not shown)

Teacher Tool Kit
D. Rulers – 1 per student

A



Name: ______________ Date: __________

Tree Growth Investigation

Part 1 focus question: How can tree ring width data be used to reveal patterns of growth in trees over time? Use the materials and procedures below to analyze tree cross sections and then answer the questions that follow.

Materials
- 2 tree cross sections
- 1 ruler

Observations
Record observations for each tree cross section in Table 1.

Table 1: Tree Cross Section Observations

	Tree Type	Diagram (Label the pith, bard, sapwood, heartwood, and one annual ring.)
Tree Cross Section 1		

B

D

*Tree species may vary.

Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.
- Arrange several pick-up stations for teams to collect materials to use at their desks. For example:
  - Pick-Up Station 1: lab manuals, rulers, and tree cross-section samples

Student Reading Preparation:

- Students read Section 3 of the student lab manual. In 6th grade, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue before the lab portion of the lesson. At the beginning of the school year (September-October), the lab manual can be read in class.

- If class time is used to read the lab manual together, model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

<u>Socratic Dialogue</u>:

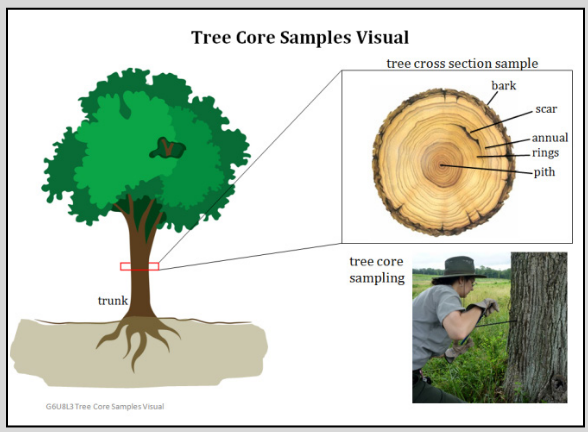
<u>Block 3: Tree Growth and Water Availability</u>

1. Continue the dialogue from the last lesson about how drought affects food webs, focusing on how scientists can evaluate past droughts by studying tree rings.

- **<u>Big Idea 8</u>:** Coach students toward the idea that there is a cause-and-effect relationship between the amount of rainfall, the temperature, and the ability of trees to grow. For example:
  - *Ask one student what their investigation in the last lesson showed them about the effect of drought on a forest food web. (Students should have observed that because forest plants such as grasses, shrubs, and ferns, as well as many flowering plants, did not grow as much or became shriveled and died, the entire flow of energy in the forest food web was affected. The primary consumers that relied on forest plants for energy were first affected because they lost their food source. This then affected the rest of the consumers and decomposers because there was less energy to go around.)*

- *Ask another student to add to what the first student said, providing additional details about their own observations and analysis of the forest food web. If needed, provide students with the chance to ask questions or to clarify what other students have said.*
- *Ask the first student to use evidence from the student lab manual to explain why trees grow less during times of drought. (The lab manual explains how when trees don't take in as much water, they close their stomata to try to reduce water loss through their pores. This means the trees aren't collecting carbon dioxide for photosynthesis, so they don't get the energy they need to grow.)*
- *Ask another student why genetics sometimes plays a role in how well trees survive a drought. (Some trees have adaptations that allow them to survive in dry conditions, so they are more likely to survive extended droughts.)*

2. Display *Tree Core Samples Visual*. Have a dialogue with students about how scientists can examine tree core samples to look for patterns about past disturbances.



- **Big Idea 9:** Coach students toward the idea that scientists study tree rings to learn about past conditions on Earth. For example:
    - *Ask one student why trees have tree rings. (As a tree grows, a new ring is added to its trunk each year. An* ***annual ring*** *refers to the light- and dark-patterned wood that forms as a tree grows in diameter over time.)*
    - *Ask another student how scientists can tell about past conditions from studying tree rings. (Thin rings mean the tree didn't grow as much as normal because of a lack of*

water. Thick rings mean the tree had plenty of water and so it grew a lot.)

- *Ask the first student to apply what they have learned about the importance of water in photosynthesis to explain why they think trees don't get as big when they don't get enough water. (When trees carry out photosynthesis, they produce glucose, which is a sugar that contains energy. This glucose is essential for plant growth.)*

Investigation: **Part 1**

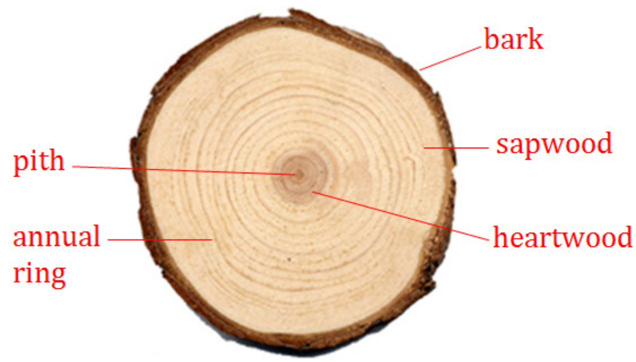
1. Divide students into teams of two. Stand by the materials stations to explain how the materials will be used and the amount each team can collect. Teams should go to stations to collect the materials they will use at their desks.

Pick-Up Station 1:

- "Tree Growth Investigation" – 1 per student (lab manual)
- rulers – 1 per student
- tree cross-section samples – 2 per team

Explain that each team will:

- ☐ Use the "**Tree Growth Investigation**" to explore the focus question of **Part 1** of the investigation: How can tree ring data be used to reveal patterns of growth in trees over time?
- ☐ Use the materials and procedures to analyze tree cross-sections and then answer the questions that follow.
- ☐ **Observations:** Record observations for each tree cross-section in Table 1.

Table 1: Tree Cross-Section Observations		
	Tree Type	**Diagram** (Label the pith, bark, sapwood, heartwood, and one annual ring.)
Tree Cross Section 1	red pine	

☐ **Analyze the Tree Cross-Sections**

1. Count the number of rings on your tree cross-section to determine the approximate age of the tree. Record this information in Table 2.
2. Count the number of wide growth rings you notice on the tree cross-section to determine how many years the tree experienced an increase in growth. Record this information in Table 2.
3. Count the number of narrow growth rings you notice on the tree cross-section to determine how many years the tree experienced a decrease in growth. Record this information in Table 2.
4. Repeat steps 1-3 with your second tree cross-section.

Table 2: Tree Cross-Section Growth Data		
	Tree Cross-Section 1	Tree Cross-Section 2
Approximate Tree Age (Years)	20	32
Number of Years with Increased Growth	11	18
Number of Years with Decreased Growth	9	14

NOTE: Data represent one possible outcome. Data will vary based on individual tree cross-section samples.

- ☐ **Analyze the Data:** Describe any growth patterns you noticed among the tree cross-section samples.

2. Teams collect materials from the pick-up stations to analyze the tree cross-sections. Circulate throughout the class to help troubleshoot or to ask questions that gauge student thinking as they analyze and compare the cross-sections. When students have completed Part 1 of the investigation, wrap up and debrief with the class before moving on to Part 2 of the investigation.

Part 1 Wrap-Up:

1. Review the results of the tree ring analysis. For example:

- Ask one student what growth patterns they noticed among the tree cross-section samples. [*Answers will vary depending on the individual tree cross-section samples. Some trees may have had more years with increased growth, while others will have had more years with decreased growth. This varies depending on the location of the tree and how able it was to access the resources it needed to survive.*]

- One at a time, provide multiple students with the chance to respond, presenting their own data analysis.
- Ask another student why wet and cool years produce wider rings than dry and hot years? [*In the years that are wet, there is plenty of water, which allows trees to carry out photosynthesis, which allows them to grow larger. This is why tree rings during these years are wider. In dry years, water is much scarcer, and so trees are not able to grow as much.*]

<u>Investigation</u>: Part 2

1. Divide the class into teams of two. Students collect their lab manuals and turn to the "Tree Growth Investigation." Explain that each team will:

- ☐ Use the "**Tree Growth Investigation**" to explore the focus question of **Part 2** of the investigation: "From 1985-1995, West Virginia experienced some times of increased precipitation and some times of decreased precipitation, including a drought from 1987-88. How did changes in precipitation during this time most likely affect the growth of yellow poplar trees in West Virginia?
- ☐ Use what you know about how environmental conditions can affect the growth of organisms to write a hypothesis for the question.

2. Teams discuss the question with their partner and form a hypothesis. Differences in team hypothesis are expected and encouraged. Even though this lesson follows an investigation format, students generate a hypothesis in the same way they would when developing a formal lab in their lab notebooks. Teams check in with the teacher to briefly review their hypotheses when complete before moving on to the next part of the investigation. The following sentences are example hypotheses for this lab:

- *Trees grow more during periods of increased precipitation compared to periods of decreased precipitation.*
- *Trees grow more during periods of decreased precipitation compared to periods of increased precipitation.*
- *There is no relationship between periods of increased or decreased precipitation and tree growth.*

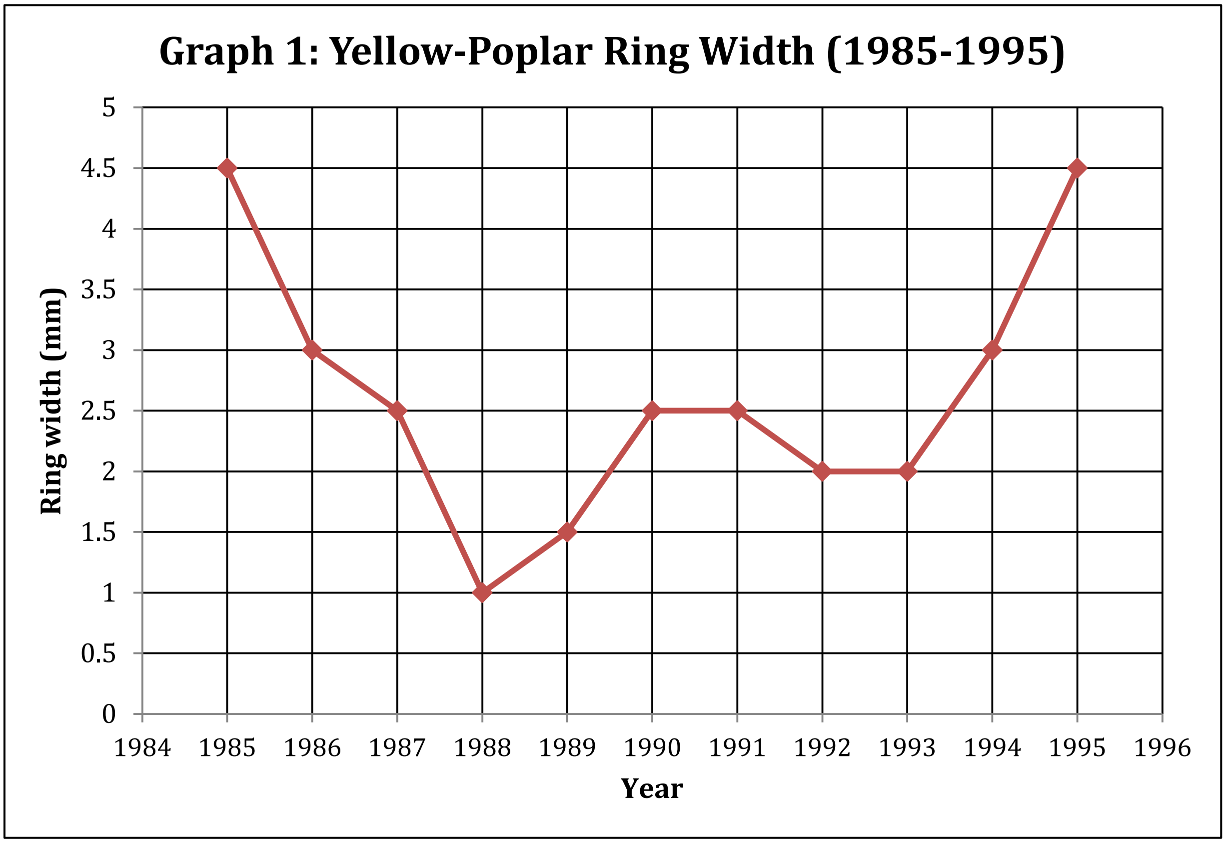
Each team will:

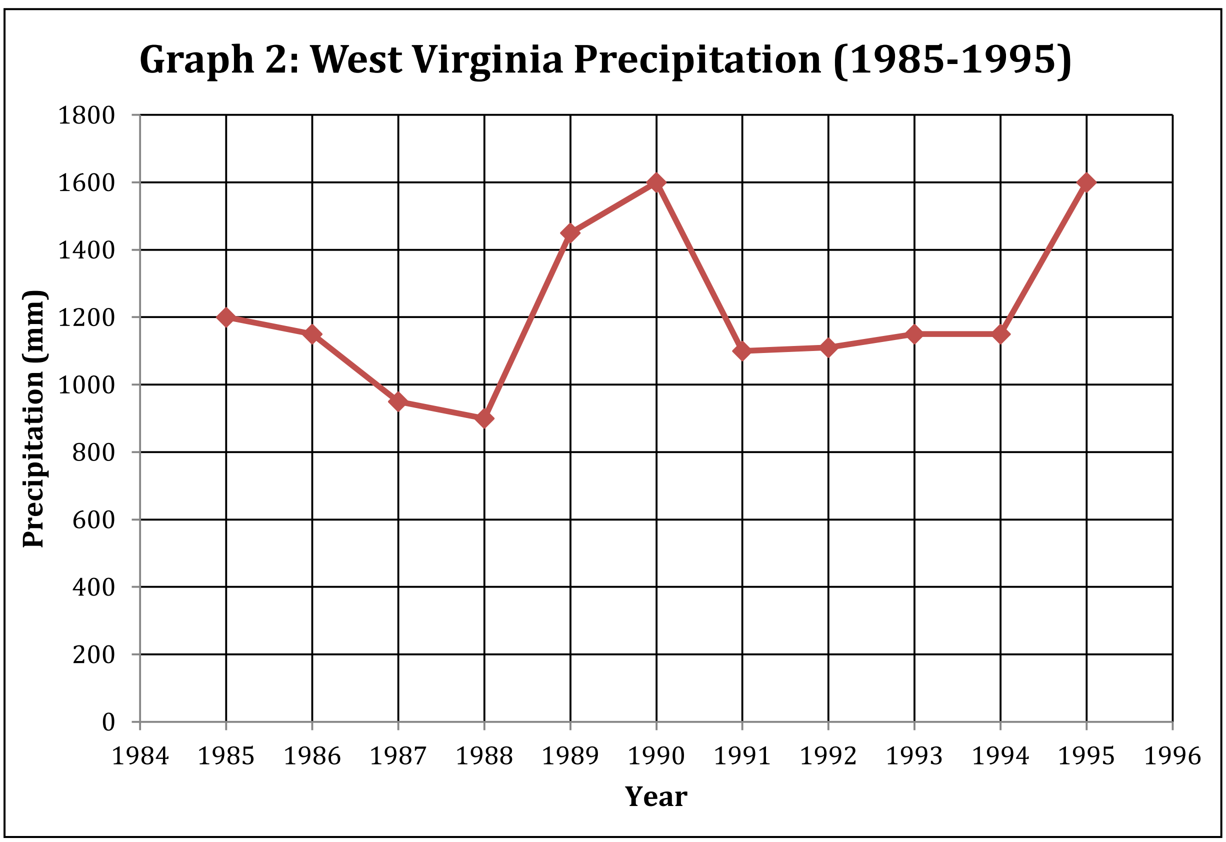
- ☐ **Graph the Data:** Analyze the West Virginia average yellow poplar tree ring width and precipitation data in the tables below. Graph the data in each table on the corresponding blank line graphs on the next page.

Table 1: Average Yellow Poplar Ring Width from 1985-1995	
Year	**Ring Width (mm)**
1985	4.5
1986	3
1987	2.5
1988	1
1989	1.5
1990	2.5
1991	2.5
1992	2
1993	2
1994	3
1995	4.5

Table 2: West Virginia Precipitation from 1985-1995	
Year	**Precipitation (mm)**
1985	1,200
1986	1,150
1987	950
1988	900
1989	1,450
1990	1,350
1991	1,100
1992	1,110
1993	1,150
1994	1,150
1995	1,600

**Climate data from www.ncdc.noaa.gov*


Graph 1: Yellow-Poplar Ring Width (1985-1995)
Ring width (mm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year


Graph 2: West Virginia Precipitation (1985-1995)
Precipitation (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year

☐ **Analysis and Conclusion**

1. Describe any patterns you notice in the ring growth and precipitation data in Graphs 1 and 2.
2. Explain how the data in the graphs do or do not support the hypothesis you wrote. Use specific evidence from the data to support your argument.

3. Move throughout the class as teams work through the investigation to ask questions to gauge student thinking and to help facilitate if needed. Student conclusions should follow the same format they use in a formal lab write-up. For example:

- *Our hypothesis, that trees grow more during periods of increased precipitation compared to periods of decreased precipitation is true. The data show that when precipitation decreased from 1985-1988 in West Virginia, the ring width of the yellow poplar trees also decreased. This pattern continues from 1988-1995, with the exception of 1990-91 when tree ring width data was the same for two years even though the precipitation decreased during that time. Given these data, we can conclude that the availability of water does affect the growth of trees over time.*

4. When students have finished with their conclusion and analysis, use the wrap-up to debrief with the class.

Wrap-Up:

1. Have a dialogue with the class to review their analysis of the relationship between tree growth and precipitation. For example:

- Ask one student to present their conclusion to the class, including the data they used to support their response. Did any teams have a different conclusion? Provide students with the chance to ask questions of one another or to clarify what other students have said as they seek consensus.

2. Continue the dialogue with students about their results, connecting their analysis back to the story presented in the lab manual to assess student understanding of the broader scientific concepts. For example:

- Ask one student how the investigation connects to the story presented in the lab manual about Christina Restaino and her work studying Douglas fir trees. [*Christina carried out a similar investigation to what students carried out. She went out into the field to collect tree ring samples, and then analyzed the samples for patterns that would tell her about past disturbances such as drought.*]
- Ask another student how Christina's results compared to their results. [*The results from both investigations should have shown that trees didn't grow as much during times of drought.*]
- Ask the first student what factors might influence how well a tree is able to survive a drought. [*There are several factors. One factor is how long the drought lasts. Another factor is how many trees are around that tree because the more trees there are, the more they will compete for scarce water. A third factor is genetic because some trees have adaptations that help them survive drought better than other trees.*]
- One at a time, provide multiple students with the chance to respond to this question so that students are making connections between the investigation and the reading.

Name: ______________________________ Date: ____________

Tree Growth Investigation

Part 1 Focus Question: How can tree ring data be used to reveal patterns of growth in trees over time?

Use the materials and procedures below to analyze tree cross-sections and then answer the questions that follow.

Materials

- 2 tree cross-sections
- 1 ruler

Observations

Record observations for each tree cross-section in Table 1.

Table 1: Tree Cross-Section Observations		
	Tree Type	**Diagram** (Label the pith, bark, sapwood, heartwood, and one annual ring.)
Tree Cross-Section 1		

	Tree Type	**Diagram** (Label the pith, bark, sapwood, heartwood, and one annual ring.)
Tree Cross-Section 2		

Analyze the Tree Cross-Sections

1. Count the number of rings on your tree cross-section to determine the approximate age of the tree. Record this information in Table 2.
2. Count the number of wide growth rings you notice on the tree cross-section to determine how many years the tree experienced an increase in growth. Record this information in Table 2.
3. Count the number of narrow growth rings you notice on the tree cross-section to determine how many years the tree experienced a decrease in growth. Record this information in Table 2.
4. Repeat steps 1-3 with your second tree cross-section.

Table 2: Tree Cross-Section Growth Data		
	Tree Cross-Section 1	Tree Cross-Section 2
Approximate Tree Age (Years)		
Number of Years with Increased Growth		
Number of Years with Decreased Growth		

Analyze the Data

1. Describe any growth patterns you noticed among the tree cross-section samples.

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Part 2 Focus Question: From 1985-1995, West Virginia experienced some times of increased precipitation and some times of decreased precipitation, including a drought from 1987-88. How did changes in precipitation during this time most likely affect the growth of yellow poplar trees in West Virginia?

Use what you know about how environmental conditions can affect the growth of organisms to write a hypothesis for the question.

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Graph the Data

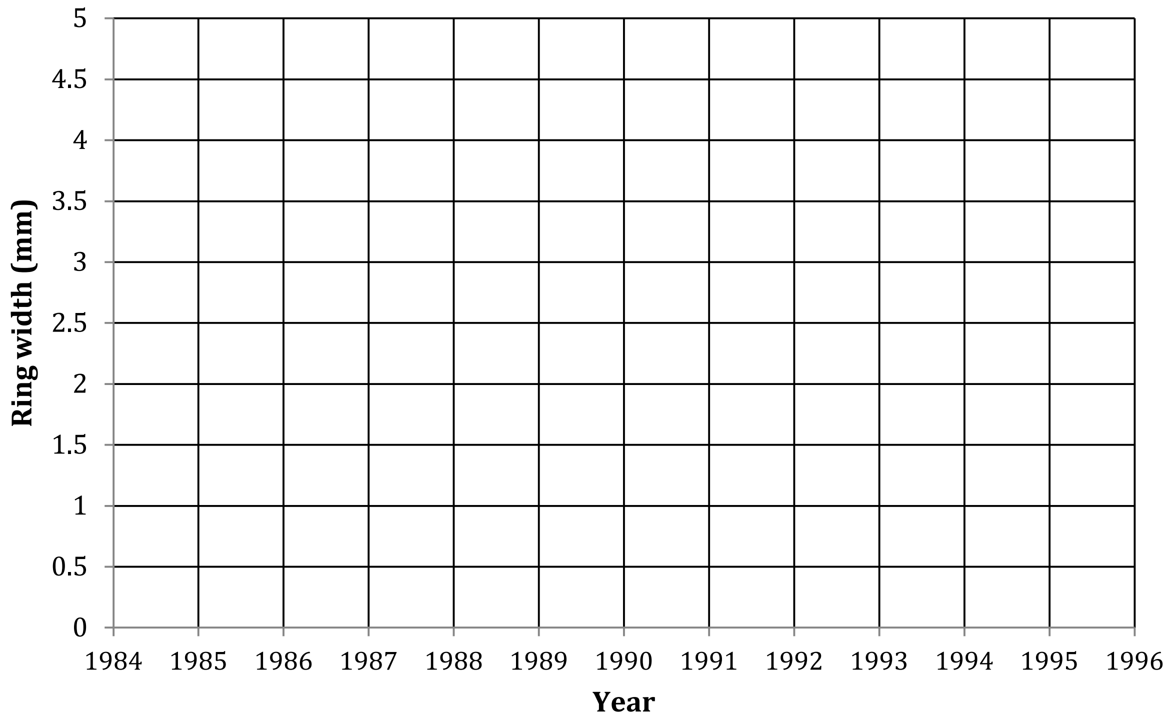
Analyze the West Virginia average yellow poplar tree ring width and precipitation data in the tables below. Graph the data in each table on the corresponding blank line graphs on the next page.

Table 1: Average Yellow Poplar Ring Width from 1985-1995	
Year	**Ring-Width (mm)**
1985	4.5
1986	3
1987	2.5
1988	1
1989	1.5
1990	2.5
1991	2.5
1992	2
1993	2
1994	3
1995	4.5

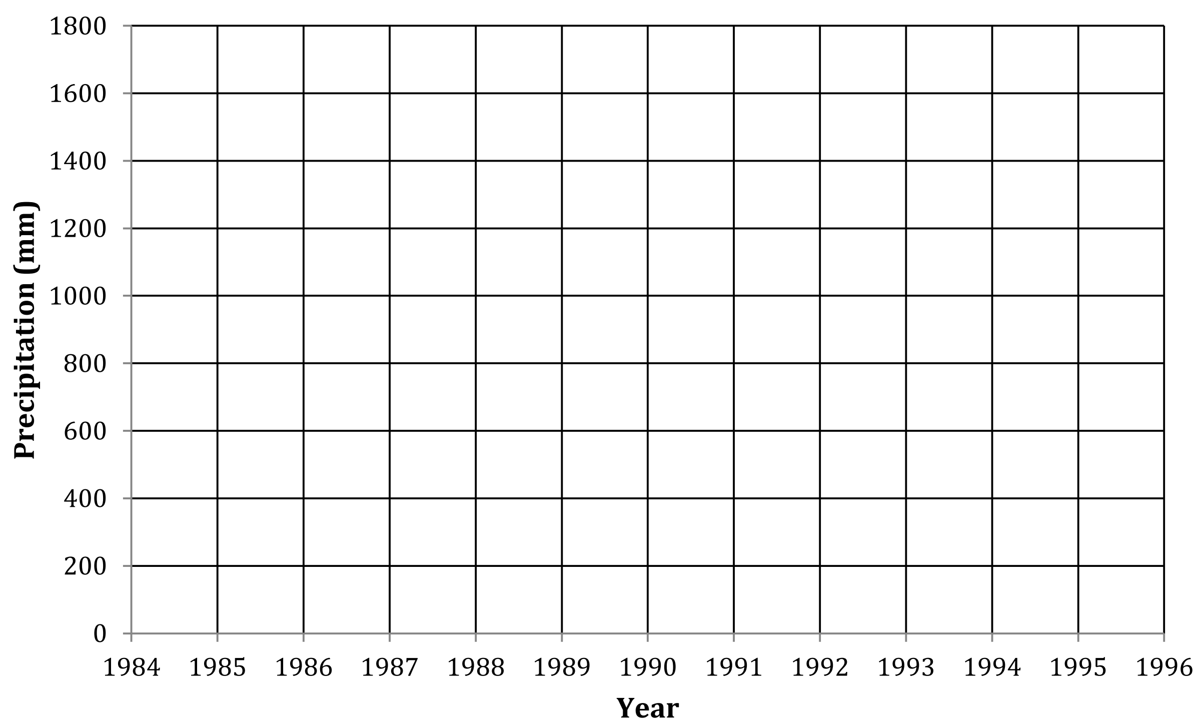
Table 2: West Virginia Precipitation from 1985-1995	
Year	**Precipitation (mm)**
1985	1,200
1986	1,150
1987	950
1988	900
1989	1,450
1990	1,350
1991	1,100
1992	1,110
1993	1,150
1994	1,150
1995	1,600

**Climate data from www.ncdc.noaa.gov*

Graph 1: Yellow Poplar Ring Width (1985-1995)



Graph 2: West Virginia Precipitation (1985-1995)



Analysis and Conclusion

1. Describe any patterns you notice in the tree ring growth and precipitation data in Graphs 1 and 2.

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2. Explain how the data in the graphs do or do not support the hypothesis you wrote. Use specific evidence from the data to support your argument.

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Name: ____ Date: _______________

Unit 8: Forests

Vocabulary Check

Part I: Circle the best answer for questions 1-5 below.

1. The ___________ refers to the back-and-forth exchange of oxygen and carbon dioxide between plants, animals, and the environment.

A. photosynthesis B. oxygen cycle
C. chloroplast D. life cycle

2. ___________________________ is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen.

A. Decomposition B. Competition
C. Predation D. Photosynthesis

3. An organism that breaks down organic waste and feeds on the nutrients is called a______________________________.

A. consumer B. predator
C. producer D. decomposer

4. A visual that shows the network of food chains in an ecosystem is called a ____________________________.

A. food web B. food chain
C. oxygen cycle D. nutrient cycle

5. A(n) ______ is the light- and dark-patterned wood that forms as a tree grows in diameter over time.

A. bark B. pith
C. sapwood D. annual ring

Part II: Write the answers to questions 6-9 below.

6. Why does **photosynthesis** depend on sunlight?

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7. Why is a **forest** an example of an **ecosystem**?

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8. Why do **droughts** affect the living things in an ecosystem?

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Name: ______________________________________ Date: ____________

Unit 8: Forests

Concept Check

Part I: Circle the best answer to each question.

1. A desert ecosystem is very dry. It doesn't rain much. Cactus plants have adaptations that help them survive. Their roots spread out just below the surface of the soil to collect water. All of the cactus plants in a certain area need some of this water. What kind of relationship do the cactus plants have with each other?

A. competitive
B. predatory
C. mutually beneficial
D. none of the above

2. The Amazon is a rainforest ecosystem. Toucans live in the Amazon. They eat large palm seeds for food. They then eliminate the seeds as waste. The seeds can grow to become new trees. What behavior of the toucan helps palm trees reproduce?

A. flying around the Amazon where the palm trees grow
B. perching on the branches of the palm trees where the seeds are created
C. eating the palm seeds and then eliminating the seeds
D. all of the above

Part II: Use the space below each question for your answer.

3. Plants do not need to eat other living things for food. How does the structure of some plant cells make this possible?

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4. How does an animal get the energy it needs to survive when it eats a plant?

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5. Jessie is starting an outdoor garden. She wants to grow tomatoes and cucumbers in one part of her garden. She wants to grow roses in another part of her garden.

a. Jessie wonders how her garden plants will get the food they need to grow and thrive. Her friend thinks the plants will absorb food from the soil. Is her friend right? Use evidence to support your answer.

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b. Time passes. Jessie's plants grow. She carefully waters them when it doesn't rain. Then Jessie goes out of town for a month. When she comes back, her plants don't look as healthy. The leaves have begun to shrivel. Jessie reads that rainfall was much less than average when she was away. What environmental factor influenced the growth of her plants? Identify cause and effect in your response.

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Unit 8: Appendix 1
Answer Keys

Vocabulary Check

Part I

1. B. oxygen cycle [The oxygen cycle refers to the back-and-forth exchange of oxygen and carbon dioxide between plants, animals, and the environment. Photosynthesis is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen. Chloroplasts are organelles, found only in plant cells, that have chlorophyll, the pigment that absorbs sunlight to begin the process of photosynthesis. A life cycle is the series of developmental stages an organism passes through on its way from birth to death.]
2. D. Photosynthesis [Photosynthesis is the process of turning sunlight, carbon dioxide, and water into glucose and oxygen. The glucose is food for the plants and it provides them with the energy they need to grow and develop. Decomposition is the breakdown of organic waste materials into usable nutrients. Competition refers to interactions between organisms that occur whenever two or more organisms require the same limited resource. Predation refers to interactions between two organisms that occur when one organism (a predator) eats another organism (prey).]
3. D. decomposer [An organism that breaks down organic waste and feeds on the nutrients is called a decomposer. Consumers are organisms that eat other organisms for energy. Producers make their own food using light energy from the sun. A predator is an organism that eats other organisms, called prey. All consumers are predators.]
4. A. food web [A visual that shows the network of food chains in an ecosystem is called a food web. A food chain is the path that energy travels as one organism eats another. The oxygen cycle is the back-and-forth exchange of oxygen and carbon dioxide between plants, animals, and the environment.]
5. D. annual ring [An annual ring is the light- and dark-patterned wood that forms as a tree grows in diameter over time. The bark protects the tree from insects, disease, storms, and extreme temperatures. Inside the bark is the pith, which is a pipeline of living tissue. The pith carries water and nutrients throughout the tree. The pith is surrounded by dense, hard, inner wood called heartwood. Sapwood is the softer wood between the heartwood and the bark.]

Part II

6. [Photosynthesis depends on sunlight because it is a chemical reaction, and like all chemical reactions, it requires an input of energy to rearrange the atoms of the original substances (water and carbon dioxide) into new substances with different properties (glucose and oxygen).]
7. [A forest is an example of an ecosystem because ecosystems are communities of different species that depend on interacting with each other and their physical environment for survival. In a forest, there are different species, including different kinds of plants and animals, that interact with one another and their environment for survival.]
8. [Droughts affect the living things in an ecosystem because droughts are prolonged periods of unusually low rainfall, resulting in water shortages. All living things depend on water for survival, so when there are water shortages, it negatively affects the living things in that ecosystem.]

Concept Check

Part I

1. A. competitive [Because all of the cactus plants in a certain area need water and there is a limited amount of water in a desert ecosystem, the cactus plants have a competitive relationship with one another. Competitive relationships occur whenever two or more organisms require the same limited resource. Predatory relationships occur whenever one organism (a predator) eats another organism (prey). Mutually beneficial relationships occur when two organisms get a survival advantage by working with the other.]
2. C. eating the palm seeds and then eliminating the seeds [When toucans eat palm seeds and then eliminate the seeds, it gives the palm seeds an opportunity to grow. This behavior of the toucans helps the palm trees survive by giving them a better chance of successfully reproducing. Perching on the branches of the palm trees where the seeds are created and flying around the Amazon where the palm trees grow don't increase the chances of the palm tree successfully reproducing.]

Part II

3. [Plants don't need to eat other living things for food because they have chloroplasts in their cells that allow them to collect sunlight to carry out the process of photosynthesis, in which they turn carbon dioxide and

water, along with sunlight, into glucose and oxygen. The glucose provides the plants with the energy they need to grow and develop.]

4. [When an animal eats a plant, it absorbs some of the plant's glucose that holds chemical potential energy. This is how the animal gets the energy it needs to survive.]

5. This question presents students with a scenario about Jessie, who is starting an outdoor garden and wants to grow tomatoes, cucumbers, and roses. It assesses whether students understand how plants obtain the energy and other resources they need to grow and survive.

5a. [Student answer should identify the source and mechanism of plants' food, specifically that plants don't absorb food from the soil because they carry out photosynthesis to produce their own food. Students could use the changes to matter that happen in photosynthesis to support their answer. For example, plants take in carbon dioxide and water, and through photosynthesis, use sunlight to change this matter into glucose and oxygen.]

5b. [Student answer should explore the relationship between a plant's growth and its ability to access water. When Jessie goes away, her plants don't look as healthy and the leaves have begun to shrivel because there wasn't much rainfall during the time Jessie was away. This decreasing amount of rainfall is what caused her plants to shrivel up.]

Lab Manual Answer Key

Section 1 Review

MC1. D. The atoms that make up the carbon dioxide and water are rearranged to form oxygen and glucose. [When plants absorb carbon dioxide and water from the environment, they then carry out photosynthesis, which is a chemical reaction. In all chemical reactions, the atoms that make up the original substances are rearranged to form new molecules with different properties. Matter is never destroyed.]

CT1. [Photosynthesis is important for plants because it the process in which they make their own food. All living things need food because food provides the energy necessary for growth and development. Unlike other organisms such as fungi and animals, plants don't eat other organisms for energy. Instead, they make their own food through photosynthesis.]

CT2. [Plants need sunlight, carbon dioxide, and water to successfully carry out photosynthesis. These are all resources plants get from the environment.]

CT3. [A plant's ability to survive would be harmed if it couldn't access sunlight because it wouldn't be able to carry out photosynthesis without sunlight. Sunlight provides the necessary input of energy to carry out photosynthesis.]

CT4. [According to Suzanne Simard's research, "mother trees" help their offspring plants by sending them extra carbon, which helps them survive because they send extra carbon to the seedlings growing in the understory. This helps the seedlings survive because plants use some carbon atoms to build and repair their different structures.]

Section 2 Review

MC2.B. mutually beneficial [The relationship between the algae and the fungus is mutually beneficial because both get a benefit from interacting with each other. Some algae form a partnership with a fungus to create a new organism called lichen. The algae make food for the lichen through photosynthesis, and in return, the fungus protects the algae and gets water and minerals for the lichen. In competitive interactions, two or more organisms require the same limited resources, and in predatory relationships, one organism (a predator) eats another organism (the prey).]

MC3. B. The number of sparrows will decrease because there are not enough worms for them to eat. [In a simple food chain consisting of worms, sparrows, and owls, if most of the worms are killed, the number of sparrows will most likely decrease as well because worms are the food source of the sparrows. It isn't true that the number of sparrows would increase because there are fewer worms to eat them, because worms don't eat sparrows. The arrow shows how energy flows, not which organisms eat each other. It also isn't true that the number of sparrows would stay the same because the worms were killed, not the sparrows. A common misconception is that the organisms in a food chain or food web are isolated and do not depend on other organisms for survival, but all of the organisms are connected, and so a change to one population will affect other populations as well.]

CT5. [The squirrel behavior of burying seeds helps the squirrels survive because the seeds are food for the squirrels. Squirrels need to eat all year, even in the winter when there are fewer seeds, so burying seeds provides the squirrels with food during the winter months.]

CT6. [The squirrel behavior of burying acorns increases the chances of oak trees successfully reproducing because acorns don't grow well if they are right beneath the parent tree. The branches of the parent tree will block the sun. If the squirrel doesn't make it back to its acorns, those acorns might grow into new trees.]

CT7. [Energy flows in one direction in a food web made up of fungi, squirrels, hawks, and oak trees. It begins with the sun and then moves to the oak trees. The chlorophyll in the chloroplasts of oak tree cells collects sunlight to begin the process of photosynthesis. Photosynthesis changes the sun's energy into chemical energy stored in molecules of glucose, which the plant uses to grow and develop. When the squirrel eats acorns from the oak tree, it absorbs some of this chemical energy, which it uses to grow and develop. When the hawk eats the squirrel, it absorbs some of the chemical energy. When the hawk dies, decomposers such as the fungi break down its body, absorbing its chemical energy and returning its nutrients to the soil.]

CT8. [Decomposers are an important part of all food webs because they allow for the cycling of matter to continue. As organic matter decomposes, the nutrients within it, including nitrogen and carbon, are recycled back into the environment. Plants can access these nutrients and use them as building blocks to help them grow.]

Section 3 Review

MC4. D. all of the above [All organisms need food, water, and air to survive in their environment. Students sometimes don't think about the nonliving parts of an ecosystem as being essential to survival, but living things cannot survive without both other living things and nonliving things such as water and air.]

MC5. D. Environmental conditions on Earth changed in the past, and they are changing now. [Students often think that healthy ecosystems don't change, and so ecosystems in the past didn't change but they are changing now because of humans, or that ecosystems today are unchanging but in the past, they changed a lot. In reality, ecosystems are dynamic, and they are constantly adjusting to remain balanced.]

CT9. [The answer should explain that Christina Restaino studies tree core samples for patterns about past disturbances, which is possible because trees keep a diary of disturbances in their trunks.]

CT10. [The evidence that Christina gathered about the Douglas fir trees was that the trees didn't grow as much during times of drought and increased temperatures. Thin rings mean the tree didn't grow as much as normal because of a lack of water. Thick rings mean the tree had plenty of water and so it grew a lot.]

CT11. [According to the text, some environmental factors that influence the growth and survival of trees are temperature and amount of rainfall. Specifically from the text: "The researchers found that rising temperatures caused the amount of water in the soil and atmosphere to decrease. This meant the trees took in less water. In response, the trees closed their stomata to try to reduce water loss through their pores. This meant the trees weren't collecting carbon dioxide for photosynthesis, so they weren't getting the energy they needed to grow."]

CT12. [According to the text, one genetic factor that influences the growth and survival of trees is how it pulled in water from the soil. When there is less water in the soil, a tree's roots have to pull harder to pull in water. Some tree species, such as junipers, are better adapted to dry conditions. They can pull in more water without harming themselves.]

Unit 8: Appendix 2
Common Core Connections

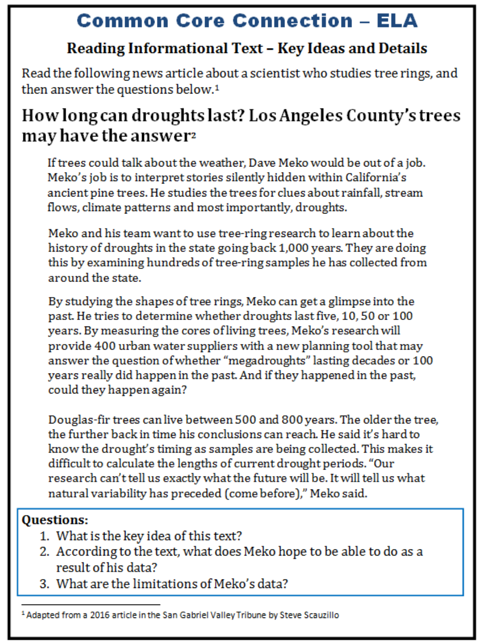
KnowAtom units generally cover many Common Core ELA standards for reading informational texts in hands-on activities. The lab manual is designed to further connect science content to other disciplines with assignments that can be used as homework or in-class. This unit highlights the following standards:

ELA (page 22 of lab manual)

Reading Information Text
Key Ideas and Details

- ELA-Literacy.RI.6.3: Analyze in detail how a key individual, event, or idea is introduced, illustrated, and elaborated in a text (e.g., through examples or anecdotes).

Students read a news account of a scientist in California who studies tree core samples to try to determine how long past droughts lasted in an effort to help inform current best practices.



Common Core Connection – ELA

Reading Informational Text – Key Ideas and Details

Read the following news article about a scientist who studies tree rings, and then answer the questions below.[1]

How long can droughts last? Los Angeles County's trees may have the answer[2]

If trees could talk about the weather, Dave Meko would be out of a job. Meko's job is to interpret stories silently hidden within California's ancient pine trees. He studies the trees for clues about rainfall, stream flows, climate patterns and most importantly, droughts.

Meko and his team want to use tree-ring research to learn about the history of droughts in the state going back 1,000 years. They are doing this by examining hundreds of tree-ring samples he has collected from around the state.

By studying the shapes of tree rings, Meko can get a glimpse into the past. He tries to determine whether droughts last five, 10, 50 or 100 years. By measuring the cores of living trees, Meko's research will provide 400 urban water suppliers with a new planning tool that may answer the question of whether "megadroughts" lasting decades or 100 years really did happen in the past. And if they happened in the past, could they happen again?

Douglas-fir trees can live between 500 and 800 years. The older the tree, the further back in time his conclusions can reach. He said it's hard to know the drought's timing as samples are being collected. This makes it difficult to calculate the lengths of current drought periods. "Our research can't tell us exactly what the future will be. It will tell us what natural variability has preceded (come before)," Meko said.

Questions:
1. What is the key idea of this text?
2. According to the text, what does Meko hope to be able to do as a result of his data?
3. What are the limitations of Meko's data?

[1] Adapted from a 2016 article in the San Gabriel Valley Tribune by Steve Scauzillo

Example Answer Key:
1. [*The key idea of this text is that Dave Meko studies the shapes of tree rings looking for clues about past rainfall, stream flows, climate patterns, and most important, droughts.*]
2. [*According to the text, Meko hopes to provide 400 urban water suppliers with a new planning tool that may answer the question of whether megadroughts lasting decades or 100 years happened in the past and whether they can happen again.*]
3. [*The limitations of Meko's data are that the research cannot tell the researchers exactly what the future will be. It will tell us what natural variability has come before.*]

Students use the following Common Core standards in this unit.

ELA Standards	Applying ELA Connections to the Unit
Writing	
W.6.1. Write arguments to support claims with clear reasons and relevant evidence.	• In Lesson 1, students write a conclusion (argument) to summarize their results from the photosynthesis experiment, analyzing whether or not their data (evidence) supported their claim (hypothesis). • In Lessons 2 and 3, students use evidence from their investigations to support their written claims.
W.6.2. Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.	• In Lesson 1, students develop and write out the process they follow to conduct the photosynthesis experiment in their lab notebooks, including the question, research, hypothesis, experiment summary, materials, test procedure, scientific diagram, data charts, graphs, and conclusion.
W.6.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	• In Lesson 1, students produce clear and coherent writing as they use their lab notebooks to work through the photosynthesis experiment. The lab notebooks must be clear, concise, and specific enough that someone else could replicate the experiment.
W.6.9. Draw evidence from literary or informational texts to support analysis, reflection, and research.	• In Lessons 1, 2, and 3, students use the nonfiction reading from their lab manuals to support their analysis, reflection, and research during the lesson.

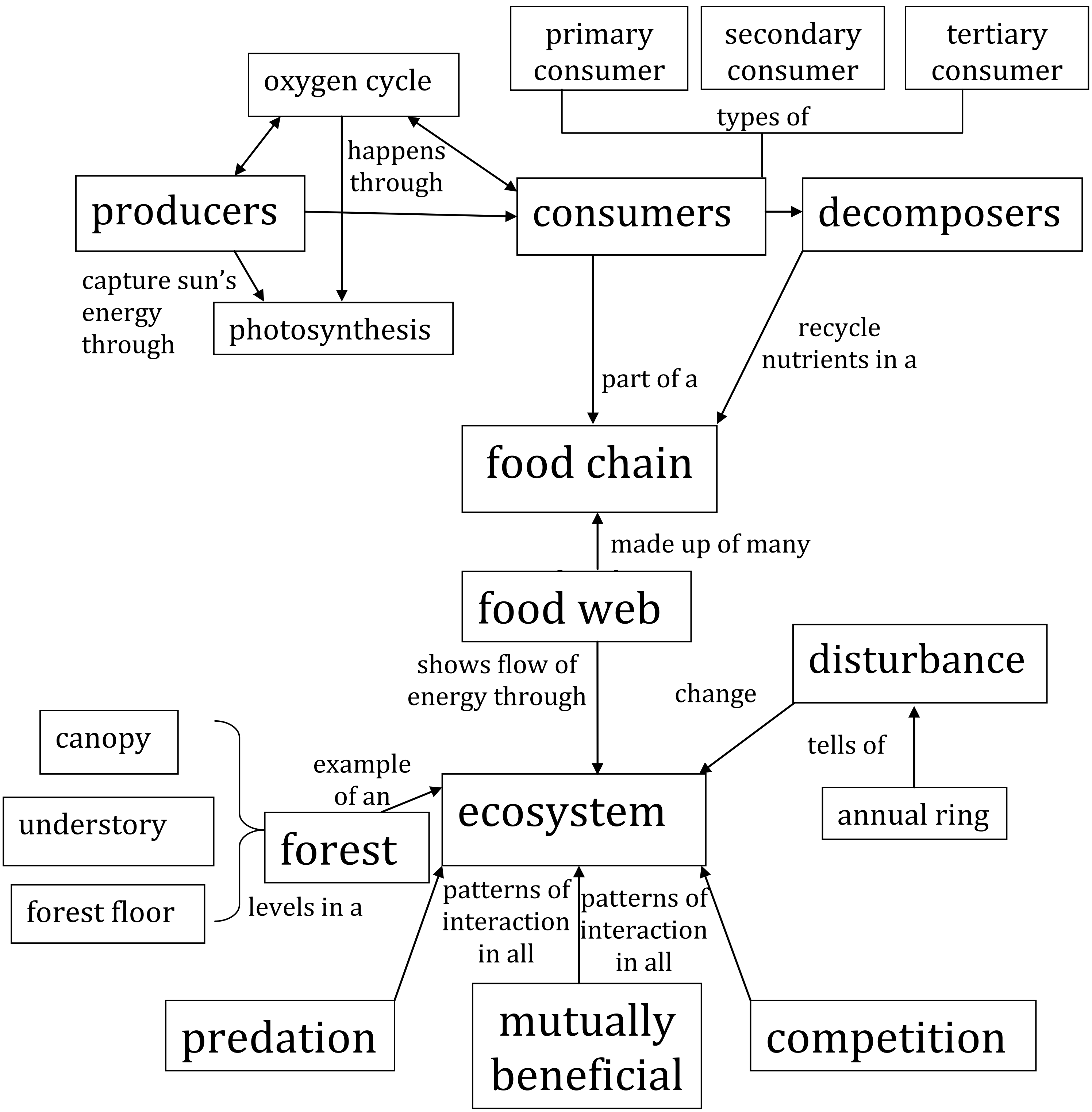
Speaking and Listening	
SL.6.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.	• In Lessons 1, 2, and 3, students engage in Socratic dialogue before beginning the experiment and investigations. Students apply what they have read in their lab manual, as well as any personal experiences or observations, to the dialogue. Students then work collaboratively in teams, discussing how they will proceed. At the end of the lesson, students come back to analyze each team's results as a class.
SL.6.4. Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.	• In Lessons 1, 2, and 3, students analyze what they have learned in the lesson in the wrap-up portion of class, coming together as a class to discuss their results. Student teams compare results, using their data and background knowledge to support their claims and evaluate other teams' claims.
Science and Technical Subjects	
RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.	• In Lessons 1, 2, and 3, students use the information from their lab manuals to support their understanding of the hands-on portion of the lesson.
RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	• In Lessons 1, 2, and 3, students read their lab manuals, determining the main ideas and conclusions of the text. They use this reading to inform and support the Socratic dialogue portion of the lesson.

RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	• In Lesson 1, students develop and follow a multistep procedure to determine the effect of sunlight on a plant's ability to carry out photosynthesis, as measured by the amount of carbon dioxide in water. • In Lesson 2, students follow a procedure for developing a forest food web model that shows the flow of energy in a temperate deciduous forest in Massachusetts. • In Lesson 3, students follow a multistep procedure for analyzing tree ring data, looking for patterns that indicate a relationship between tree growth and precipitation.
RST.6-8.10. By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.	• In Lessons 1, 2, and 3, students work on developing their understanding of science/technical texts, using the unit vocabulary, context from the lab manual, and Socratic dialogue to support their comprehension of the nonfiction reading.

Math Standards	Applying Math Connections to the Unit
The Number System	
6.NSB.3. Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.	• In Lesson 1, students calculate the change in pH over 24 hours in each of their test conditions.

Unit 8: Appendix 3

Sample Concept Map



Unit 8: Appendix 4
Support for Differentiated Instruction

Core Expectation	Assessment Strategies	Possible Primary Evidence
MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.	Low Entry Point • Recognize that cells make up all living things, and cells themselves are made up of smaller parts. • Identify different parts of the cell and their basic functions. At Grade-Level Entry Point • Construct an explanation for how each part of the cell helps the cell carry out its essential life functions. • Explain how the structure of plant cells allows them to make their own food.	• photosynthesis lab notebook entry completed by student • student diagram of a plant cell to show where photosynthesis occurs • student flow chart explaining how photosynthesis allows plant cells to obtain food and energy
MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.	Low Entry Point • Describe how organisms have structures that help them carry out essential life functions, which helps them survive. • Identify some of the structures that organisms have to help them survive. At Grade-Level Entry Point • Explain the relationship between a particular structure and how it allows the organism to survive.	• photosynthesis lab notebook entry completed by student • written explanation by student of different behaviors that help an animal survive, and how some of those behaviors help certain plants survive

Core Expectation	Assessment Strategies	Possible Primary Evidence
MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.	<u>Low Entry Point</u> • Recognize that both genes and the environment affect an organism's ability to survive and grow. • Identify different ways that the environment can influence the growth of organisms. <u>At Grade-Level Entry Point</u> • Identify evidence that would support the argument that both genes and the environment influence the growth of organisms. • Use the evidence in an argument about how genes and the environment influence the growth of organisms.	• "Tree Growth Investigation" completed by student • video of student analyzing how both genetic and environmental factors affect the growth of trees

Unit 8: Appendix 5
Materials Chart

	Lesson	Quantity	Notes	Used Again
Unit Kit Consumable				
Goggles	all	1 per student	safety	✓
Aquatic plants (LIVE MATERIAL)	1	class set	for photosynthesis lab	
pH indicator (bromothymol blue)	1	shared bottle(s)	for measuring water pH	
Straws	1	1 per student	for dissolving CO_2 in water	
Aluminum foil	1	1 sheet per team of 2	for blocking light	
Graduated cups (30 mL)	1	1 per team of 2	for measuring water	
Plastic cups (10 oz)	1	1 per team of 2	for holding water	
BTB pH color charts	1	1 per team of 2	for matching water pH	
Disposable gloves	1	1 pair per student	safety	
Test tubes with covers	1	3 per team of 2	for aquatic plants	
Red cellophane	1	shared roll	for blocking light	
Forest Organisms templates	2	1 set per team of 2	for forest organisms	
Poster paper	2	1 per team of 2	for food web models	
Yellow paper	2	1 per team of 2	for food web sun	
Non-Consumable				
Plastic bin	1	shared	for holding test tubes	
Graduated measuring container(s)	1	teacher use	for holding water	
Grow light	1	shared	for photosynthesis	
Tree cross-section samples	3	2 per team of 2	for observing tree rings	
Teacher Tool Kit				
Scissors	1, 2, 3	1 per student	for cutting materials	✓
Masking tape	1	shared	for labeling test tubes	✓
Rulers	1, 3	1 per team/2	for food web poster	✓
Markers	2	shared	for food web poster	✓
Glue sticks	2	1 per student	for food web poster	✓
Hand-outs				
Laboratory notebooks	1	1 per student	for "Lab 8"	✓
Lab manuals	2, 3	1 per student	for "Forest Food Web Investigation," "Forest Field Guide," and "Tree Growth Investigation"	
Visuals	Download			
Lesson 1	Photosynthesis Visual, Forest Layers and Sunlight Visual			
Lesson 2	Drought Investigation Visual, Forest Ecosystems Visual, Food Web Visual, Ecosystem Disturbances Visual			
Lesson 3	Tree Core Samples Visual			

