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LESSONS TO GROW BY

Plant Needs

In this unit of Lessons to Grow By, we are exploring plant needs. For healthy growth and development, plants must obtain just the right amounts of light, water, air, and nutrients and they also need space to grow. These five requirements are the basic needs for all plant life. Fortunately for our world full of diverse environments, different plants need different amounts of each of these essentials so there are plants well adapted to grow in almost all environmental conditions. Through these activities, kids will investigate plant needs to better understand how to take care of their green friends while also gaining a deeper appreciation for how the living and nonliving elements in an ecosystem work together.

These houseplants are thriving under bright, full-spectrum LED grow lights.

Module 1: Light

Learning Objectives:

This module focuses on the plant need of light. Kids will:

- Learn about light and the different sources of light for plants.
- Investigate how the amount of light available to plants impacts their growth and health. Explore how plants are adapted to need different amounts of light.

Materials Needed:

Activity 1: Exploring Light

- Puzzled by Photosynthesis Worksheet
- Find the Light Worksheet
- Light meter or a light meter app (optional)
- Thermometer (optional)
- A prism or supplies to make your own prism (optional)

Activity 2: Light Experiments

- 4 to 5 potted plants of the same variety and approximately the same size (herbs in 4" pots work well) or
- Seed viewers (bean seeds, paper towels, clear plastic cups)
- Light Experiment Data Collection Worksheet

Activity 3: Sun versus Shade Plants

- Looking for Light Reading Page

Introduction

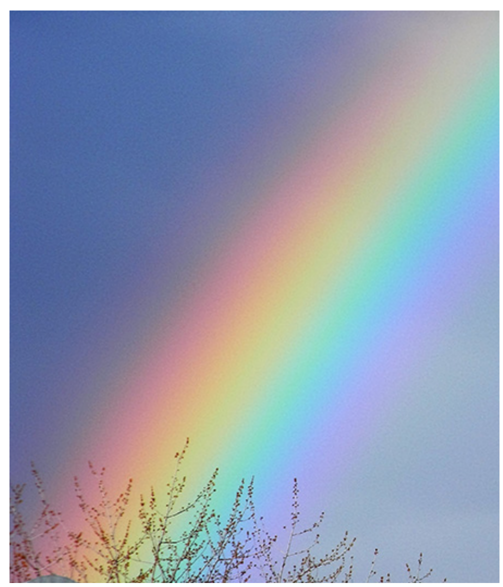
Light is among plants' most critical needs. Plants capture light energy and use this energy during photosynthesis to help them convert carbon dioxide and water into carbohydrates — the food they use to live. Without light, plants starve and die. Beyond plant life, the food energy made by plants is the foundation of every food chain for all animal life too. All life on earth depends upon plants' ability to photosynthesize and that process is dependent on the plant being able to capture light energy! For more background information about the process of photosynthesis, check out Photosynthesis 101 at: https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/.

Plants vary in their light requirements — and these requirements can even vary depending on the plants' stage of growth. It's up to gardeners to evaluate whether a plant is receiving adequate light based on research as well as on observations of its growth.

Plants can get light from two sources: the sun and artificial lighting. Although outdoor plants generally rely on sunlight, plants can also be grown successfully indoors by using a variety of fluorescent and LED bulbs. Regardless of its source, light is measured in two ways: light quality, and light quantity. Although this is a bit advanced for younger gardeners, below is a bit of background information about these two measurements and what they mean for plant growth.

Light Quality

Light energy radiates from a source in electromagnetic waves of different lengths and frequencies. Some of these waves aren't visible to humans, but those we can see are perceived as different colors. Visible light with the longest wavelength and lowest frequency is seen as red, and that with the shortest wavelength and highest frequency is seen as violet. Orange, yellow, green, and blue fall in between. When all visible wavelengths are combined, the light appears to be white or colorless, like sunlight. However, when you separate the light, as with a prism, you can see all the colors in the spectrum.



Water droplets in a rainbow act like prisms, revealing all the colors in the visible spectrum.

Light is either reflected or absorbed by objects. When you look at an object, the color you see is actually the color of light that the object reflects. If the object is white, it's reflecting all the waves and absorbing none; if it's black then it's reflecting none of the waves and absorbing them all. Thus, plants appear green because they are reflecting the green light waves and absorbing all the others.

Sunlight provides the full spectrum of light; however, artificial lights may offer a more limited spectrum. Here is a brief description of the quality of light provided by common grow light bulbs:

- **Cool white bulbs** emit wavelengths primarily from the blue/violent end of the spectrum.

- **Warm white bulbs** emit wavelengths primarily from the red end of the spectrum

- **Wide-spectrum and full-spectrum bulbs** emit wavelengths from all the colors of the spectrum; these lights come the closest to mimicking sunlight.

Red and blue light are the most important for plant growth, impacting photosynthesis and flowering. A mix of 90% red light and 10% blue light provides the balance of light colors needed for most plant growth.

Fun fact: In a controlled environment where lights only radiate red and blue wavelengths, plants appear purple.

Light Quantity

Light quantity is determined by both intensity and duration.

Light intensity is the measurement of the amount of light reaching a plant (or other object). Intensity is a combination of two factors: the brightness of the light and the distance between the light and the plant (or other site of measurement). With respect to a light of a specific brightness, the closer that light is to the plant, the higher the light intensity.

Light intensity is measured in terms of foot-candles or lux. One foot-candle is the amount of light produced in a totally dark space by one candle shining on a white surface measuring 1 square foot that is 1 foot from the candle. One lux is the amount of light that shining on a surface that is 1 meter away. To convert between the two measurements: 1 foot-candle = 10.764 lux.

To provide some perspective, average office light is 300-500 lux, or 30 to 50 foot-candles and the light at noon on a sunny day may be as bright as 10,000 foot-candles or over 100,000 lux. Although the duration and intensity of sunlight far exceeds the capacity of indoor lighting, there are many flowers, vegetables, and herbs that can grow well with the 1,000 to 1,500 foot-candles of light provided by grow lights, (To achieve this, most grow lights should be suspended just a few inches above the tops of the plants.)

Light duration can help compensate for less-than-ideal light intensity. Outdoors, many common garden plants need an average of 6 to 8 hours of sunlight per day. Under grow lights, since light is less intense, plants would need exposure to 14 to 16 hours per day to achieve adequate light quantity.

So, is more light always better? Longer light duration doesn't necessarily make plants produce more abundantly. Most plants actually require a daily period of darkness in order to complete respiration – the process whereby plants convert the products of photosynthesis into usable energy. Some plants even require a certain period of uninterrupted darkness to trigger flowering. Therefore, it is not beneficial to grow plants under lights left on 24 hours a day.

Activity 1: Exploring Light

1. Plants need light to grow. Explain to kids that plants use light to make food through a process called photosynthesis. Just like people need to eat food to grow and function, plants also need to make food to grow and function, but they don't need to go to the grocery store. They can make their own food in their leaves.

2. Use the Puzzled by Photosynthesis Worksheet to explain the process of photosynthesis from a broad perspective. In very basic terms, water is absorbed from the roots and transported to the leaves. At the same time, leaves take in carbon dioxide from the air. Inside the leaf, structures called chloroplasts absorb light energy from the sun (or another light source) and use this energy to

complete a chemical reaction between the water and carbon dioxide that results in the formation of sugars and oxygen. Using the worksheet, kids can cut out the puzzle pieces and glue them into the diagram.

3. Ask kids the question, Do you think plants must have light from the sun? What other sources of light are available?

4. Go on a light hunt and search for other sources of light, such as fluorescent and LED light bulbs. Share with kids that light bulbs give off light energy similar to the sun, although it is not as bright or intense as the light we get from the sun, and may not contain the full spectrum of colors.

   Next, encourage kids to use their senses to compare sunlight and artificial light. You can use the Find the Light Worksheet to record your observations. Ask them to describe if their eyes feel different when they are in sunlight versus indoor light? (Remind them to never look directly at the sun!) Next, ask them to close their eyes. Does the sunlight make their skin feel warm? Does light from artificial light sources give off heat? Which is warmer? If you have access to a light meter, you can use it to compare the light intensity of artificial lights versus sunlight measured in lux or foot-candles. If you do not have a light meter, there are also some apps that are designed to measure light intensity that you can try, or just use observation.

5. Next, compare variations of light available outdoors. Try standing in areas that are shaded and compare with spots in the full sun. Can you find different degrees of shade or light? How is shade under a tree different than shade under a roof? If you have a thermometer, see if you can record a difference in temperature in different locations.

6. Finally, ask kids to explore how sunlight availability changes throughout the day, both indoors and outdoors. Choose a few spots to monitor (such as near a couple of windows facing in different directions, areas near trees, areas out in the open) and visit a couple of times a day to see if the amount of sunlight and/or artificial light in each location receives changes. What does this mean for the plants located there? How much light do they actually get each day?

7. Extend the Activity. All of the above observations help kids explore light quantity, including intensity and duration. For more advanced students, you can also explore light quality. Introduce kids to the different wavelengths of light which we visually see as different colors of the rainbow. Try these activities using prisms to separate out the different wavelengths of light and compare sunlight with different types of artificial lighting:

NASA's Discovering Color With a Prism:
https://www.nasa.gov/pdf/350512main_Optics_Discovering_Color.pdf

The Lawrence Hall of Science's Make a Prism:
http://static.lawrencehallofscience.org/diy_sun_science/downloads/diy_ss_make_a_prism.pdf

Activity 2: Light Experiments

1. One of the best ways for kids to understand the impact of light on plant growth is to watch the same kind of plants grow in different locations with different amounts of light available.

   Challenge your kids to brainstorm ideas for creating a light experiment. Explain to them that since the goal is test the impact of light (quality and quantity) on plants, you need to limit the number of variables that might impact your results. Here are some tips for their experiment:

   - Use the same size containers
   - Grow the same kind of plants

- Try to find plants that are approximately the same size and health at the start of your experiment
- Make sure to maintain the same soil moisture levels. (Note that plants in shady locations may take up less water, so they may need less frequent watering).
- Try to control temperature levels, or if temperature does vary, make sure to record the variation.

If you do not have any potted plants readily available, you can also start some seed viewers of bean seeds to experiment with.

To make a seed viewer:

- Cut a piece of construction paper into a rectangular strip to fit inside the plastic cups. This is optional, but it helps with viewing.
- Ball up a few pieces of paper towels and place them inside the construction paper liner until the cup is full.
- Place 3 to 4 beans in the cup between the side of the cup and the paper towels or construction paper liner so the seeds are visible from the outside of the cup.
- Gently water the paper towels in the center until saturated.
- Place the cup (or cups if you would like to try multiples) on a shelf or windowsill and watch them grow. First you will notice the seed coat expanding (wrinkling) as the seed absorbs water. The root will start to grow in 2 to 3 days. Water as necessary to keep the paper towel and seeds continually moist.

Seed viewer

*Please note: Seeds in the viewers may not grow as well outside because they will dry out too quickly, so they may be best for testing different light availability indoors.

2. Once your locations are selected and plants are placed, track plant growth using the Light Experiment Data Collection Worksheet or your garden journal. You can either describe the light intensity of each location, or use a light meter to determine the intensity of each location.

3. Depending on the kind of plants you choose to grow, it may take a while to see the impact of the different light levels. If possible, continue to track your plants for 4 to 6 weeks.

4. Compare your results. Did you find any differences in plant growth based on the amount of light available? Do you think your plants tried to adapt to the different amounts of light? Did the plants change in appearance depending on the amount of light? Did leaves get bigger? Did stems get longer?

5. Extend the Activity. As interest and time allow, expand your experiment to observe the impact of varying light on different varieties plants.

Activity 3: Sun versus Shade Plants

1. Together or independently, read the Looking for Light Reading Page. Have your kids complete the reading comprehension questions and then discuss your answers together.

2. Fortunately for us, plants are adapted to need different amounts of light so they are capable of surviving in all kinds of environments. Plan a nature walk to look for plants growing well in the sun or

the shade in your area. Take pictures as you go and at the end of your trip, you can compare and contrast the characteristics of the plants you find.

3. Another great place to observe differences in sun- versus shade-loving plants is your local garden center. At the center, plants will typically be grouped by light requirements, and many times they may even labeled as sun-lovers or shade lovers, making it easy for you to compare the two groups of plants. As they walk through the aisle, have kids make a list of some of their favorite sun-loving and shade-loving plants they see.

Digging Deeper

You can use the following resources to dig deeper into this module's lessons:

Books and Additional Resources:

Seed School by Joan Holub

Jack's Garden by Henry Cole

Up in the Garden and Down in the Dirt by Kate Messner

Plantzilla by Jerdine Nolen

A Place to Grow by Stephanie Bloom

Videos:

Make a Plant Maze from the Potomac Valley Audubon Society:
https://www.youtube.com/watch?v=X-4vUXMMPTU

GPhase Time Lapse of Garden Cress Growing Towards Light:
https://www.youtube.com/watch?v=DhITXtENPrU

Phototropism Time Lapse of Radish Plants from Vito Pettito:
https://www.youtube.com/watch?v=G4Mo9-JAeok

Additional Related KidsGardening Lessons and Activities to Try:

Let There Be Light:
https://kidsgardening.org/resources/lesson-plan-let-there-be-light/

Photosynthesis Runs the World:
https://kidsgardening.org/resources/lesson-plan-photosynthesis/

Photosynthesis 101:
https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/

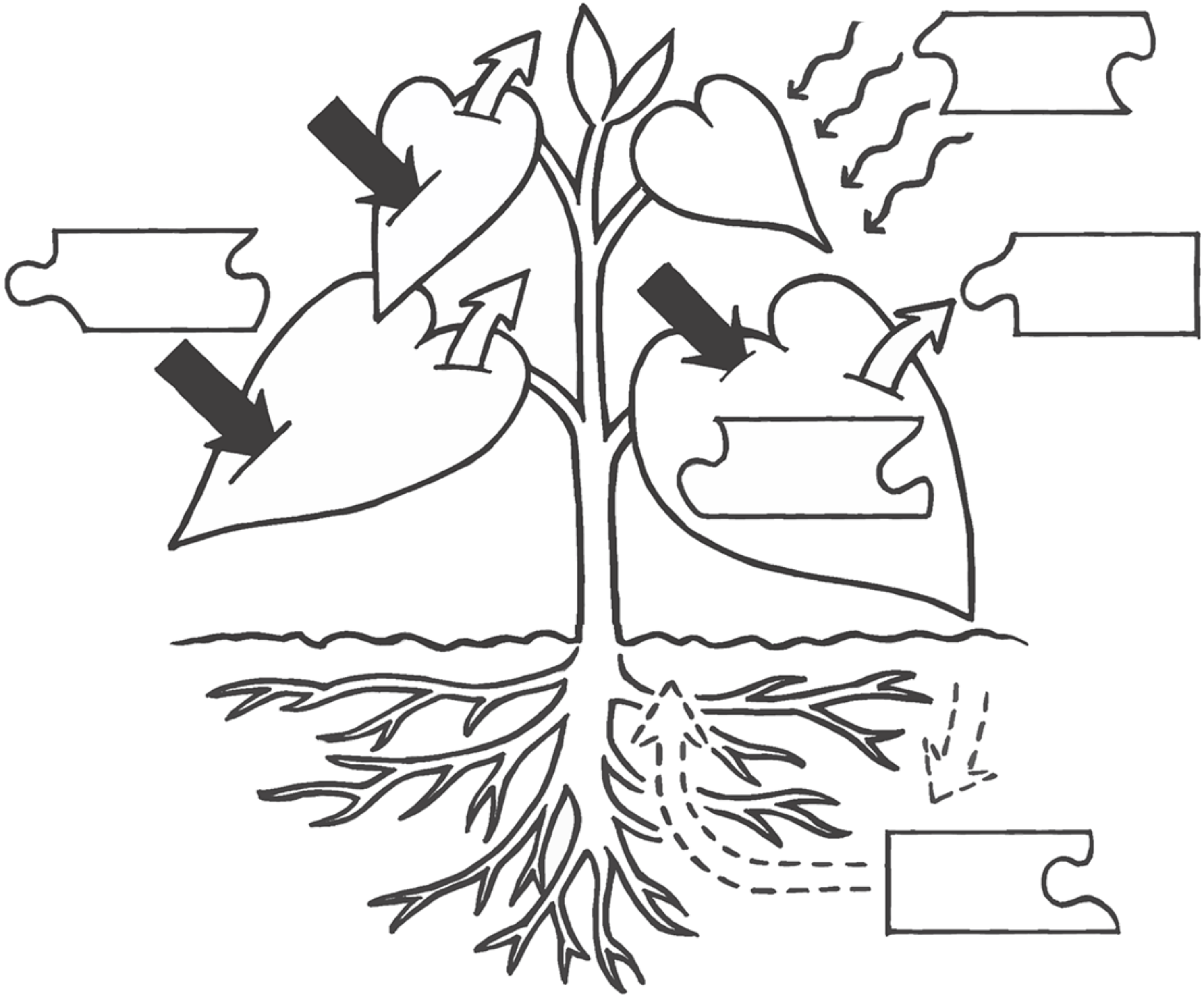
Tropical Rainforests:
https://kidsgardening.org/resources/lesson-plan-tropical-rainforests/

Plants in Space:
https://kidsgardening.org/resources/lesson-plans-plants-in-space/

Photoperiodism: Can Plants Tell Time
https://kidsgardening.org/resources/digging-deeper-photoperiodism-can-plants-tell-time/

Puzzled by Photosynthesis Worksheet

NOTES:



water + carbon dioxide —with light energy→ glucose (sugar) + oxygen

Find the Light Worksheet

Location	Source of Light	Time of Day	Describe what the light looks like. (If you have a light meter, record the intensity.)	Describe what the light feels like. (If you have a thermometer, record the temperature.)	Are there any plants growing here? Do they look healthy?

Light Experiment Data Collection Worksheet

Date	Location	Source of Light	Intensity* (brightness)	Hours of Light Per Day	Temp.	Plant Height	Appearance of Plant	Additional notes on treatment or observations:

*Rate the light intensity (how bright the light is) on a scale of 1 to 5, with 1=very bright, 5=very dark.

Looking for Light
Plant Needs - Reading Page - Light

Their name says it all! Sunflowers need lots of bright sunshine to produce their beautiful blooms.

Plants need light to live and grow. Plants have the special ability to make their own food through a process with a very long name: **photosynthesis** (foe-toe-SIN-the-sis). Through this process they catch light energy in their leaves and then use that energy to turn air and water into food. Not only do plants use this food for themselves, but all other living creatures rely on the food plants produce too.

Where does the light that plants need come from? Most plants growing outdoors gather the light they need from the sun. However, plants can also be grown indoors where they get light from different kinds of light bulbs. Some light bulbs are specifically designed to provide light for growing plants.

Do all plants need the same amount of light? Have you noticed how some plants grow out in the open in full sun, but others grow underneath other plants and spend a lot of time in the shade? Lucky for us, not all plants need the same amount of light.

Some plants need a lot of sunlight to meet their needs and we call these full-sun plants. Common examples of full-sun plants include tomato plants, roses, and fruit trees. Other plants need less light to grow and they need the protection of other plants or shade structures to be happy. Some examples of shade-loving plants include ferns, coleus, and many houseplants. Most plants are somewhere in between full sun and shade.

A tropical rainforest is a perfect example of how plants in the same ecosystem have special adaptations to survive with different amounts of light. A rainforest has 3 different layers of plants – the canopy, the understory and the forest floor.

These houseplants are thriving indoors under "grow lights" — light bulbs specifically designed for growing plants

- The **canopy** is made up of the large trees which need lots of light to be happy. This layer also includes vining plants that climb up the trees so they can get lots of sunlight too.
- The **understory** is made up of plants that are medium-sized in height. Understory plants can live in lower light levels — only 2 to 5 percent of the sunlight hitting the rainforest reaches this layer.

- Finally there is the **forest floor**. Very little light reaches the forest floor and plants like ferns grow in this layer.

A lot of our common houseplants were originally from the understory and floor of the rainforest because indoor lights are not as bright as sunlight.
What happens if plants do not get enough light? Since plants cannot get up and move if they are not getting enough light, they may make other changes in how they are growing. If plants are not getting enough light, you may notice the following:

- **Larger leaves**. Plants will start producing larger leaves to try and capture more sunlight.

- **Longer stems.** Plant stems may start to look long and skinny with fewer leaves as they try to put all their energy into stretching their stems to find more light.

- **Slower growth**. Remember that light is needed for plants to make food. So if plants are not getting enough light, they may not be making as much food and so they will not grow as fast.

- **Fewer flowers.** Plants may stop producing flowers and fruit when they do not get enough sunlight. They are using all their food to just stay alive.

Plants can also have problems if they get too much light! They can get sunburned just like people and if too much light is combined with warm temperatures and not enough rain, they dry out very quickly. It is important for gardeners to find out how much light their plants need so they can plant them in a spot where they will be happy and grow well.

Reading Comprehension Questions:

1. True or false: Plants need sunlight to grow.

2. Plants typically make food in:
   - ☐ Roots
   - ☐ Stems
   - ☐ Leaves
   - ☐ Flowers
   - ☐ Fruit

3. True or false: All plants need the same amount of light to grow well.

4. Match the layers of the rainforest with how much light the plants growing in that layer receive:

Canopy	A little bit of light
Understory	A lot of light
Forest Floor	Almost no light

5. Which of the following is not a sign that a plant is not getting enough light:
   - ☐ Long and skinny stems
   - ☐ Bigger leaves
   - ☐ Slower growth
   - ☐ Lots of flowers and fruit

Lessons to Grow By – Plant Needs

In this unit of Lessons to Grow By, we are exploring plant needs. For healthy growth and development, plants must obtain just the right amounts of light, water, air, and nutrients and they also need space to grow. These five requirements are the basic needs for all plant life.

Fortunately for our world full of diverse environments, different plants need different amounts of each of these essentials so there are plants well adapted to grow in almost all environmental conditions.

Through these activities, kids will investigate plant needs to better understand how to take care of their green friends while also gaining a deeper appreciation for how the living and nonliving elements in an ecosystem work together.

Module 2: Water

Learning Objectives:

This module focuses on the plant need of water. Kids will:

- Learn about the water cycle and the role plants play in this important natural process.
- Investigate how much water plants need and what happens if they get too little or too much water.
- Compare the benefits and challenges of different kinds of watering methods.

Materials Needed:

Activity 1: Round and Round: The Water Cycle

- Round and Round Reading Page
- USGS Water Cycle Diagram, available at: https://www.usgs.gov/special-topic/water-science-school/science/water-cycle
- Indoor or outdoor plant(s)
- Plastic sandwich bag(s)

- Rubber band or twist tie or string(s)
- Terrarium supplies (optional)

Activity 2: Water Experiments

- 4 to 5 potted plants of the same variety and approximately the same size (herbs in 4" pots work well) or
- Seed viewers (bean seeds, paper towels, clear plastic cups)
- Water Experiment Data Collection Worksheet

Activity 3: Fulfilling Plants' Water Needs

- Irrigation Comparison Worksheet

Introduction

Water is a critical component of all living things, including plants, and it plays an important role in basic functions and structure. It is also an element that is continually lost by organisms and therefore must also be constantly replaced.

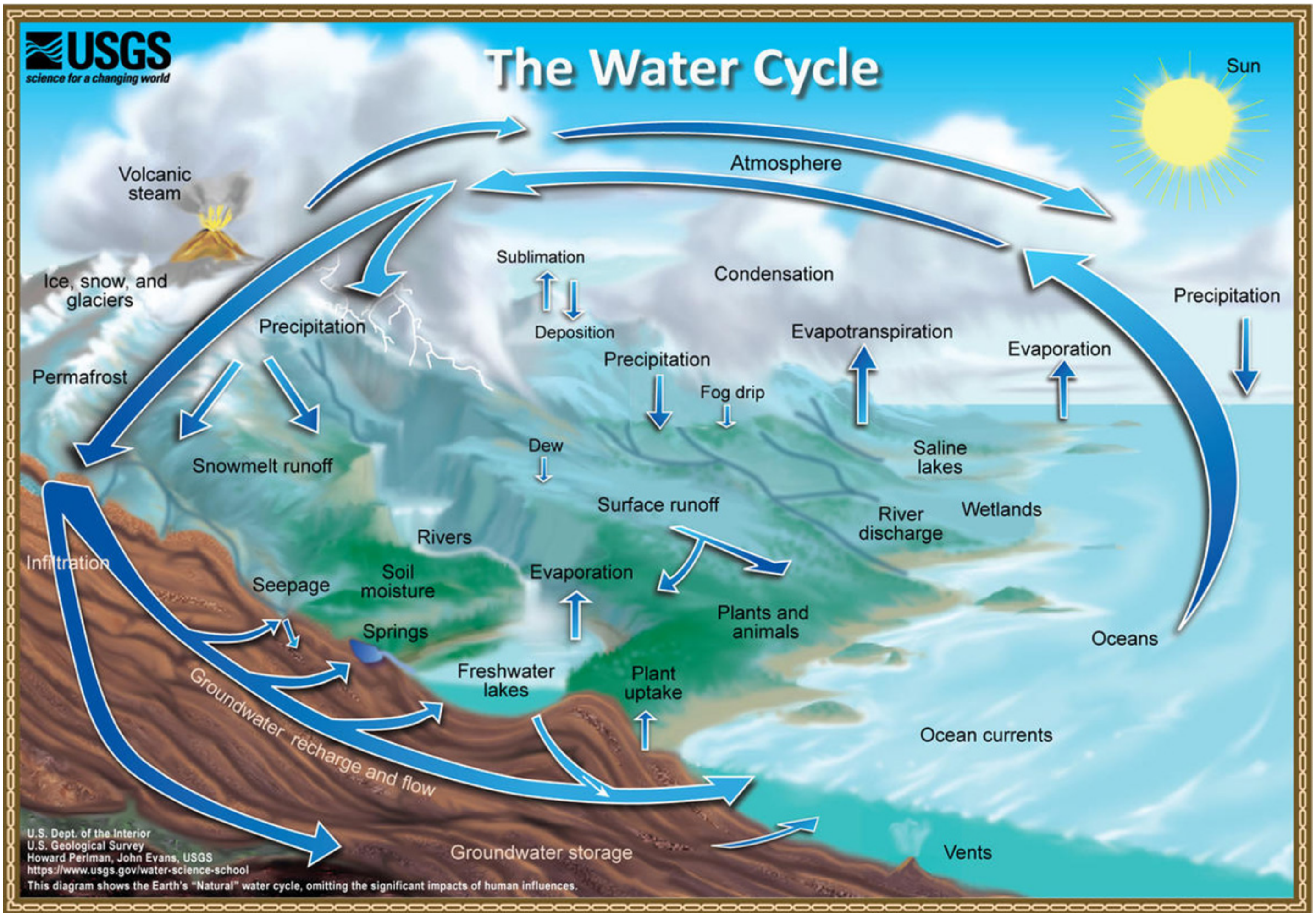
Most of the water used by plants comes from the soil. Water is absorbed by plant roots, moves up the stems and then into leaves. On this journey, it is used in plant cells as needed, and then some of it exits the leaves through small openings called stomata. This process is called transpiration, which is much like sweating in humans. The movement of water provides support for the plant and helps it adapt to varying conditions in its environment. Water is also a key component needed for photosynthesis which is how the plant makes food. There are some plants that are able to take in water through their leaves, but the vast majority of water used by plants enters through roots.

The Water Cycle

The cycling of water through the plant is also part of a bigger phenomenon known as the water cycle. In the water cycle, water vapor condenses in the air and then falls to land in the form of rain. When water hits land's surface, it follows one of two main pathways — either it infiltrates into the soil or it runs off into local streams, lakes, and rivers.

Infiltration of water into the soil provides many environmental benefits. Healthy soil works like a sponge, soaking up water and allowing it to be processed slowly into the environment while impurities are removed. The presence of plant roots in the soil is very important for creating healthy soil and aiding in this infiltration process.

Plants then take up the water in the soil and use it to sustain their basic functions, including making the food energy for all life through photosynthesis. The plants also release water vapor into the air through transpiration — and then water cycle begins again.



The Water Cycle. Credit: Howard Perlman, USGS. [*https://usgs.gov/media/images/water-cycle-natural-water-cycle*](https://usgs.gov/media/images/water-cycle-natural-water-cycle)

Water Use and Plant Adaptations

The speed at which a plant takes in and uses water depends on a number of factors, including the size of the plant and the environmental conditions the plant is living in. Smaller plants generally use less water, while larger plants usually need larger quantities. Temperature and sun exposure — which can vary by season and location — are also critically important. Plants in hot, dry climates will lose water more quickly. Plants in cold climates will lose water more slowly. During the winter, many plants drop their leaves and enter a dormant state where they hardly use any water at all.

Because the amount of water available varies greatly in different environments, plants have developed different adaptations to help them survive the conditions they live in. Plants like cacti that live in deserts where water is scarce have modified leaves that decrease the rate of transpiration and stems that have a special ability to store extra water. Tropical plants in a rainforest where water is plentiful have pointy tips (drip tips) and waxy surfaces that help water slide off quickly. These help prevent water buildup that could lead to decay and mold.

Water: A Precious — and Endangered — Resource

Water is one of our most valuable resources. Unfortunately, it's rapidly becoming one of the most endangered. Water shortages loom as growing cities and suburbs bring increased demands in concentrated areas, and droughts threaten various regions every year. Adopting efficient watering practices that provide just the right amount of water plants need should be a priority for all gardeners because it conserves water and boosts plant health.

When we are lucky, Mother Nature provides most of the water our plants need through rain. However, for indoor plants, and for many outdoor plants too, gardeners frequently need to provide supplemental water. Here are some wise watering techniques to teach kids to make sure they know how to efficiently use water in their gardens:

When to water. Irrigate during early morning hours. Much water applied in the heat of the day is lost through evaporation. Evening watering can contribute to disease problems because plant leaves stay wet longer. Avoid watering during windy periods because wind increases water loss.

Where to apply water. Since plants absorb moisture through their roots, it makes most sense to apply water to the soil. Watering leaves is inefficient and can lead to disease problems. Soaker hoses and drip irrigation, which apply water directly to the soil, conserve water compared to overhead sprinklers (More on this below.) If your garden is in a dusty area, however, rinse plants occasionally if dust builds up on leaves.

Watch the weather. As best you can, adapt your watering schedule to weather and changing seasons. Although watering every Monday and Wednesday might be convenient for you, it may not be the right schedule for your plants.

How much to water. It is better to water thoroughly a few times a week rather than a little bit every day. For most plants, you want the soil to absorb water to a depth of 6 to 8 inches to encourage deep, strong root growth. For large plants like trees and shrubs, water until soil is moist to a depth of 8 to 12 inches. For all but new seedlings and fast-growing, shallow-rooted plants, allow soil to dry to a depth of 1 inch before watering again.

Avoid runoff. Avoid letting your irrigation water run off onto paved areas or down storm drains. If you notice runoff, apply water more slowly in cycles, taking small breaks between applications to allow the soil time to soak up moisture.

Know your soil. How fast your soil absorbs water will vary by soil type and amount of organic matter in the soil. Clay soils are slow to absorb water but tend to hold moisture longer, so they need less frequent watering. Sandy soils drain quickly and do not hold water well, so they dry out faster. Adding compost and other organic matter to your soil will improve water penetration in clay soil and water retention in sandy soil.

Keep moisture in the soil. Mulch beds and around the base of trees (but don't pile mulch up against tree trunks) to decrease water loss from evaporation. Mulch also helps regulate soil temperature and decrease weed growth.

What to plant. Choose plants adapted to your weather, climate, and soils. Native plants adapted to the conditions in your garden are often a good choice because their moisture needs have evolved within regional weather patterns. Group plants with similar water needs. It's better for the plants and makes your job easier.

Choosing an Irrigation Method

There are many different ways to deliver water to plants. Below is background information about the most common watering techniques that you can use to help kids complete Activity #3.

Hand Watering

This method is usually the cheapest in terms of equipment costs. By using proper techniques, it can also be an efficient use of water. As you use a hose or watering can to irrigate you can be selective, watering each plant or plot as it needs. You can monitor how far moisture penetrates into the soil and adjust your watering time as necessary. It's important to apply water directly to the soil beneath the plants and to avoid excessive runoff onto sidewalks and other paved surfaces.

If you choose to use watering cans, select models that are the right size for your gardeners to avoid spills and injury. Remember that a gallon of water weighs 8 pounds, so cans get heavy quickly! Fortunately, watering cans are available in many different sizes. Or you can save money by using half-gallon or gallon milk and juice jugs with handles.

If you prefer using hoses, choose adjustable spray nozzles that allow you to stop the flow without having to turn off the spigot, and that offer a range of volume and pressure options. This will ensure that you have the appropriate pressure for various kinds of plantings and reduce water waste.

The downside of hand watering is the time and energy needed. Plants need water when they need water, so you will need to work on their schedule, not yours. This can be challenging, especially during vacation breaks.

Sprinklers

Sprinklers decrease the time and effort needed for watering. You can purchase hose-end sprinklers or install a system of underground pipes with spray heads. Both types can be made even more efficient and flexible by attaching manual or automatic timers.

Hose-end sprinklers are the least expensive option and can be a good choice if you have lots of beds scattered around. Some produce a spray that moves in a circular motion, others cast a fan that can move back and forth, and still others that resemble mini-tractors “drive” through the garden guided by the hose! You can turn them off and on by hand or purchase a timer to do it for you. The first time you operate your sprinkler, observe the spray pattern to make sure it's applying water where you need it and not to paved surfaces.

Built-in sprinklers use underground pipes and spray heads. They tend to be more sophisticated to use and expensive to install, but they can be useful for permanent beds and lawns. There are many different types of spray heads available, including pop-ups, rotors, and bubblers that allow you to choose the direction and pressure of water delivery. Most built-in sprinklers are controlled by automatic timers you can program to water at the most appropriate time of day — even if you're away. A helpful feature available on some automatic timers is a moisture sensor that prevents sprinklers from activating during rain! It is important to check the system regularly to make sure broken sprinkler heads are not wasting water or delivering spray to paved areas, and that spray isn't overlapping and overwatering some plants.

The main benefit of sprinklers on automatic timers is convenience, and this is also what makes them the least efficient irrigation method. Once they're on schedule, we often forget to monitor them and end up with dried up or drowned plants and wasted water. You also have very limited control over the spray, so some plants get water whether they need it or not. Much of water sprayed into the air is lost to evaporation and wind drift, and since you don't have to be present to operate them, it might be weeks before you discover a broken sprinkler head that is wasting water or starving plants of moisture.

Drip Irrigation and Soaker Hoses

Drip irrigation and soaker hoses provide a happy medium between hand watering and sprinklers. They allow for more selective water application and can provide the convenience of automatic watering. The equipment is more costly on the front end than hand watering, but less expensive than installing underground sprinkler systems. Water savings and convenience can give you a rapid return on your initial investment.

Soaker hose

Soaker hoses have small pores throughout their surface that leak water directly to the soil at a slow rate, allowing for increased soil absorption and less water waste. Soaker hose is a good option for rows and beds of vegetables and annual plants.

Drip irrigation features emitter hoses with components that are calibrated to deliver a precise amount of water, such as 1/2 or 1 gallon per hour. There are a variety of types. One kind features pipes with built-in emitters; others allow you to attach small-diameter flexible tubes capped with emitters to a main feeder hose, allowing you to locate emitters right under individual plants or in pots. Emitter irrigation is a great system for watering landscape beds with permanent plantings.

Both options deliver water more efficiently than sprinklers with less chance for water loss due to wind and runoff, and can be attached to timers and moisture monitors to allow for increased flexibility in scheduling. By delivering water directly to the soil, they are more selective than a sprinkler, but not quite as targeted as hand watering.

For optimal operation, you may need to add a pressure regulator to reduce and equalize water flow through the system and a filter to prevent small particles in the water from clogging pores and emitters. In some areas, insects such as ants may enter emitters in search of water and may cause clogs.

Activity 1: Round and Round: The Water Cycle

1. Together or independently, read the Round and Round Reading Page. Have your kids complete the reading comprehension questions and then discuss your answers together.
2. Download one of the USGS Water Cycle diagrams to share this important process with your kids. There are two versions: one designed for younger students (shown below) and one for older students. Both are available at: https://www.usgs.gov/special-topic/water-science-school/science/water-cycle.) Talk about the role plants play in the water cycle.
3. Launch an experiment to see transpiration in action to demonstrate how plants add to the water vapor in the air. Place a plastic bag over the stem of a plant and use a twist tie, rubber band or string to close it snugly around the stem, being careful not to damage the plant. This experiment will work best with outdoor plants located in full sun and in warmer temperatures, but you can try it on any plant and use indoor plants instead during winter months. Make sure to check that the leaf (or leaves) that you place in the bag is/are dry at the start of the experiment.
4. Place the bag on your plant in the morning and return in the afternoon to see what happens. By the end of the day, you should find water vapor accumulating on the insides of the plastic bag. Explain transpiration and talk about why water is important to plants and all living creatures.

Water vapor has condensed into droplets on the inside of this plastic bag.

Extend the Lesson: You can extend this lesson by building your own terrarium. A terrarium is a miniature garden grown inside a covered glass or plastic container. It is a low-maintenance way to incorporate plants into your classroom or home and an excellent tool for teaching children about the water cycle as it demonstrates evaporation, condensation, and precipitation. Detailed instructions are available at: https://kidsgardening.org/resources/garden-activities-building-a-terrarium/.

Activity 2: Water Experiments

1. One of the best ways for kids to understand the impact of water on plant health is to watch the same kind of plants receive different water treatments and watch how they react by observing differences in their physical appearance and growth.

   Challenge your kids to brainstorm ideas for creating a water experiment. Explain to them that since the goal is test the impact of water availability on plants, you need to limit the number of variables that might impact your results and focus on only changing the amount of water you deliver. Here are some tips for their experiment:

   - Use the same size containers
   - Grow the same kind of plants
   - Try to find plants that are approximately the same size and health at the start of your experiment
   - Grow all the plants in the same environmental conditions (same light, temperature, and humidity)

   If you do not have any potted plants readily available, you can also start some seed viewers of bean seeds to experiment with.

To make a seed viewer:

- Cut a piece of construction paper into a rectangular strip to fit inside the plastic cups. This is optional, but it helps with viewing.
- Ball up a few pieces of paper towels and place them inside the construction paper liner until the cup is full.
- Place 3 to 4 beans in the cup between the side of the cup and the paper towels or construction paper liner so the seeds are visible from the outside of the cup.
- Gently water the paper towels in the center until saturated.
- Place the cup (or cups if you would like to try multiples) on a shelf or windowsill and watch them grow. First you will notice the seed coat expanding (wrinkling) as the seed absorbs water. The root will start to grow in 2 to 3 days. Water as necessary to keep the paper towel and seeds continually moist.

Seed viewer

*Please note: If using seed viewers, you can start testing the effects of varying water availability right from the start and also look at the impact on seed germination, or you can wait to begin your experiment after the first set of true leaves appears. Seeds viewers grown outside will dry out very quickly. This may help speed up your water experiments, but they may need to be watched more closely than indoor seed viewers.

2. Once your location and plants are selected, water all of your plants to the point of saturation. If you are using potted plants, add water until excess water is running out of the drainage holes. If you are using seed viewers, fill your cups with water and let the paper towels become thoroughly soaked and then drain the extra water. This is done to try to make sure all of the containers are all starting at the same point of water availability.

3. Create your water schedule. You want to water all of the plants at the same time, but just give them different amounts of water. Make sure to label each plant so you remember which treatment to give each one. For example, Plant A may get 1 cup of water every other day, Plant B may get half of cup of water every other day, Plant C may get 1 TBSP of water every day and Plant D may get 1 TSP of water every other day, etc.

4. Track your observations using the Water Experiment Data Collection Worksheet or your garden journal. If you are not seeing much variation in the appearance and growth of your plants, you may need to adjust your water schedule or the amount of water you are using.

5. Discuss your results. Did some of your plants grow better than others? What happened if your plants did not get enough water? What happened if your plants got too much water?

Extend the Activity: Different types of plants are adapted to need different amounts of water. If you want to extend this activity, try it again using a different type of plant for your observations and compare the results.

Activity 3: Fulfilling Plants' Water Needs

1. Water, especially clean water, is a very precious resource in our world. If you have older kids, you may want to research some of the water shortage crises that have occurred around the world in recent years. If you are looking for a historical perspective, check out the Dust Bowl of the 1930s in the United States. In nature, plants mostly rely on rain to fill their water needs. Ask kids, Where do our garden plants get their water from? If there is not enough rain, what do we do?

2. Introduce kids to some of the basic types of watering techniques used by gardeners listed in the Background Information. If possible, find ways to demonstrate these different methods in your schoolyard or look for examples in nearby landscapes. The Digging Deeper below has links to some watering-related video that can supplement if you do not have access to live demonstrations.

3. Use the Irrigation Comparison Worksheet to evaluate the pros and cons of each of the main types of watering techniques. After making your lists ask, Is there one best technique? Or do different techniques work better in some garden situations than others? What would be best for our school or home garden?

   Here are some possible responses for the Irrigation Comparison Worksheet:

Irrigation Method	Benefits	Challenges
Hand watering	• inexpensive • allows targeted water delivery • allows you to monitor soil conditions as you water	• time consuming • labor intensive
Sprinklers	• can be inexpensive • save time	• often waste water • built-in systems can be costly and complex to design/install
Soaker hoses & drip irrigation	• efficient water delivery • saves time	• may not be as targeted as hand watering • more expensive initially than hand watering and many sprinklers

4. Conclude by talking about how important it is for us to conserve water and protect our water resources. You can extend the lesson by having kids create ads to encourage others to use water wisely.

Digging Deeper

You can use the following resources to dig deeper into this module's lessons:

Books and Additional Resources:

Seed School by Joan Holub

Jack's Garden by Henry Cole

Up in the Garden and Down in the Dirt by Kate Messner

Plantzilla by Jerdine Nolen

A Place to Grow by Stephanie Bloom

The United States Geological Survey Water Science School:
https://water.usgs.gov/edu/

Videos:
National Science Foundation: The Water Cycle:
https://www.youtube.com/watch?v=al-do-HGuIk

How to Water Your Plant Right from Proven Winners:
https://www.youtube.com/watch?v=7faaR8SoYDs

10 Ways to Water Your Garden Better from Epic Gardening:
https://www.youtube.com/watch?v=ueQCiSD5AdM

5 Watering Mistakes You're Probably Making from Epic Gardening:
https://www.youtube.com/watch?v=VaTkzYv8sMo&t=118s

GrowOrganic Peaceful Valley's Drip Irrigation Series:
https://www.youtube.com/watch?v=SNZ5xOVO_SM

Fine Gardening: Drip Irrigation Basics:
https://www.youtube.com/watch?v=tmEj3MQPITY

HortTube with Jim Putnam: How to Install Drip Irrigation:
https://www.youtube.com/watch?v=PetfxgFeOkM

Additional Related KidsGardening Lessons and Activities to Try:
Building a Terrarium:
https://kidsgardening.org/resources/garden-activities-building-a-terrarium/

Catching Water:
https://kidsgardening.org/resources/garden-activities-catching-water/

Wise Watering:
https://kidsgardening.org/resources/gardening-basics-wise-watering/

Rain Gardens:
https://kidsgardening.org/resources/lesson-plans-rain-gardens/

Weather -Tracking Tools:
https://kidsgardening.org/resources/lesson-plans-weather-tracking-tools/

Digging into Soil:
https://kidsgardening.org/digging-into-soil/

Photosynthesis Runs the World:
https://kidsgardening.org/resources/lesson-plan-photosynthesis/

Photosynthesis 101:
https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/

Tropical Rainforests:
https://kidsgardening.org/resources/lesson-plan-tropical-rainforests/

Round and Round: The Water Cycle

Lessons to Grow By – Reading Page - Plant Needs - Water

Have you ever heard someone tell you that we are drinking the same water that the dinosaurs drank? They can say that because of the water cycle.

What is the water cycle? On our planet, water moves round and round in a constant way. Water from the Earth's surface heats up in the sun and turns from a liquid into a gas. This water vapor then floats into the air. This part of the cycle is called evaporation.

When it gets high enough up into the sky, it gets colder and all of the water vapor gathers together to make clouds. This stage is called condensation.

When enough water gets together, it gets heavy and comes back down to earth in the form of rain or snow. This final part of the cycle is called precipitation.

Once back on land, water then follows one of two main pathways:

- It can go into the soil and get stored in the soil or in special places called aquifers (ACK-wiff-ers) below the soil.
- It can run off into local streams, lakes, and rivers.

It is in these two locations (from in or under the soil, and from bodies of water) that plants and animals can find the water they need to drink to live. Water then evaporates again (from bodies of water and also from liquid released by living creatures who have consumed it) and it all begins again.

The water cycle is a very important process in our world. Water is a basic need for all living creatures — from the little lady bugs eating aphids on your plants to the giant redwoods in California. We all need water to keep our cells alive, to grow, and to keep all of our systems working right.

Through the process of changing from liquid to gas back to liquid again (and sometimes to solid in the case of snow and ice) in the air and also through the process of soaking down into soil, another very important thing happens: Water is cleaned. Contaminants that have become mixed in the water are removed in a few different ways as water travels on this journey. Living things need clean water to be healthy.

Plants get most of the water they use from the soil. Water is absorbed by plant roots, moves up the stems and then into leaves. On this journey, it is used in plant cells as needed. It also exits the leaves through small openings called stomata (stow MAH tah) as a result of a process called transpiration, which is much like sweating in humans.

The movement of water through the plant provides support for the plant and helps it adapt to varying conditions in its environment. Water is also a key component needed for photosynthesis, which is how the plant makes food. The movement of water through plants is also an important part of the water cycle as plants move water stored in the soil back into the atmosphere again.

How much water do plants need? This depends on many different things. Some plants need lots of water to grow and others can get by with very little. For instance, cacti (word for more than one cactus) are adapted to desert conditions and need very little water, while water lilies live fully submerged in water. Smaller plants usually do not need as much water as big ones. Young plants with short roots need small amounts of water applied frequently because the soil near the surface dries quickly. Plants in cool, humid, and shady environments will lose water to transpiration more slowly than those exposed to sunny, warm, arid (dry), and windy conditions. Learning how much water to give garden plants is one of the most important skills gardeners need to learn. A well-watered garden — not too much and not too little — is a happy garden!

Reading Comprehension Questions:

1. True or false: All living things need water.

2. Which of the following is not a stage in the water cycle?
   - ☐ Precipitation
   - ☐ Condensation
   - ☐ Pollination
   - ☐ Evaporation

3. What two things can happen to rain when it hits land?

4. What part of the plant takes in the water the plant needs to live?

5. Based on question number 4, if the plants in our garden need water, where should we put it?

Water Experiment Data Collection Worksheet

Treatment Key:

Plant A gets ______________ water at each treatment.

Plant B gets ______________ water at each treatment.

Plant C gets ______________ water at each treatment.

Plant D gets ______________ water at each treatment.

Plant E gets ______________ water at each treatment.

Date	Plant A Observations	Plant B Observations	Plant C Observations	Plant D Observations	Plant E Observations

Irrigation Comparison Worksheet

Irrigation Method	Description	Potential Cost	Benefits of this Method	Challenges of this Method
Hand Watering				
Sprinklers				
Soaker Hoses & Drip Irrigation				

Plant Needs

In this unit of Lessons to Grow By, we are exploring plant needs. For healthy growth and development, plants must obtain just the right amounts of light, water, air, and nutrients and they also need space to grow. These five requirements are the basic needs for all plant life.

Fortunately for our world full of diverse environments, different plants need different amounts of each of these essentials so there are plants well adapted to grow in almost all environmental conditions.

Through these activities, kids will investigate plant needs to better understand how to take care of their green friends while also gaining a deeper appreciation for how the living and nonliving elements in an ecosystem work together.

Module 3: Air

Learning Objectives:

This module focuses on the plant need of air. Kids will:

- Learn that people and plants work together to keep the amounts of oxygen and carbon dioxide in our air relatively consistent.
- Explore how plants need air for their leaves and stems above ground and for their roots below ground.
- Discover that plants are an important part of the Earth's carbon cycle.

Materials Needed:

Activity 1: What is Air?

- The Air Around Us Reading Page
- Plastic bags in different colors or flagging tape
- A metal clothes hanger or a plastic loop
- String

Activity 2: Air Above and Below Ground

- Microscope (optional)
- Bucket or bowl of soil (no drainage holes)
- Tape
- Watering can
- 2 potted plants of the same variety and approximately the same size (herbs in 4" pots work well). One pot needs to have no (or blocked) drainage holes. The other pot needs drainage holes.
- Seed viewers (bean seeds, paper towels, clear plastic cups)
- Air Experiment Data Collection Worksheet

Activity 3: The Carbon Cycle

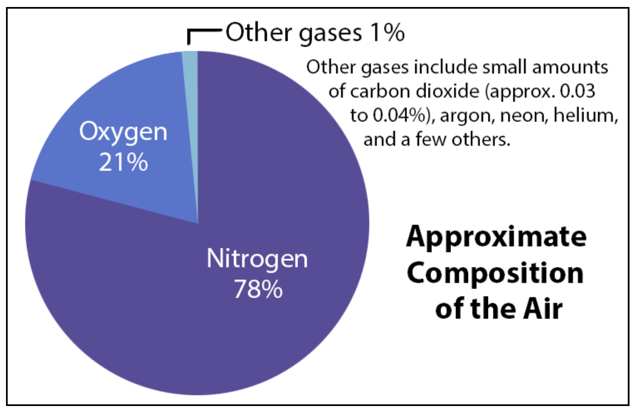
- Components of the Global Carbon Cycle Diagram from the US Department of Energy: https://public.ornl.gov/site/gallery/originals/CCycle_cover_image.jpg

- Terrestrial Photosynthetic Carbon Cycle Diagram from the US Department of Energy: https://public.ornl.gov/site/gallery/originals/Pg028_CCycle08.jpg

- Internet connection to watch the Kiss the Ground's The Soil Story

Introduction

Both animals and plants need air to live and grow. Our air is made up of many different kinds of gases including nitrogen (78%), oxygen (21%) and an assortment of others, including carbon dioxide, argon, neon, helium, and a few others (collectively 1%).



Animals need oxygen from the air for a process called respiration. Respiration is how we turn our food into energy that our body can use. Through this process oxygen is used and carbon dioxide is released. So, we breathe in air, use the oxygen, and breathe out air that has a higher concentration of carbon dioxide.

Plants also use oxygen for respiration to turn food into energy. However, unlike us, plants also need carbon dioxide from the air for photosynthesis. In the process of photosynthesis, they take the carbon dioxide out of the air and use it to make food in the form of carbohydrates. Not only do plants rely on this food — all living things rely on the food plants make! (For more details check out KidsGardening's Photosynthesis 101 at: https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/.)

Plants take in air, use some of the oxygen for respiration and carbon dioxide for photosynthesis, and then release the extra oxygen back into the air.

Photosynthesis:

carbon dioxide (carbon and oxygen) + water (hydrogen and oxygen) —with light energy→ food (carbon, hydrogen, oxygen) + extra oxygen

In a very simplified way of looking at our air composition, the net impact is that people/animals are removing oxygen and adding carbon dioxide into the air, and plants are removing carbon dioxide and adding oxygen into the air. Together we work to keep a balance so that the relative amounts of oxygen and carbon dioxide stay consistent.

That being said, there are a number of other factors that come into play and impact the elements found in our air. From gases and small particles that are released through human activity and considered pollutants, to actions and activities that release these naturally occurring elements in unnatural quantities, the balance of carbon dioxide and oxygen is a present-day concern. The vast removal of plants for human use or to make way for development has decreased the amount of oxygen being released into the air in a significant way. In addition, some of our inventions and agricultural practices have increased carbon in the air. This imbalance is causing a change in our climate.

Carbon is an essential element on our planet, and the Carbon Cycle is an important part of all life. In terms of the air, atmospheric carbon combines with oxygen to become carbon dioxide, which is a greenhouse gas. Greenhouse gases absorb and then re-emit energy back to the Earth. Therefore, the more carbon dioxide in the air, the warmer the temperatures both on land and in the oceans. The warmer temperatures also increase the amount of water vapor present in the atmosphere, increasing temperatures even more.

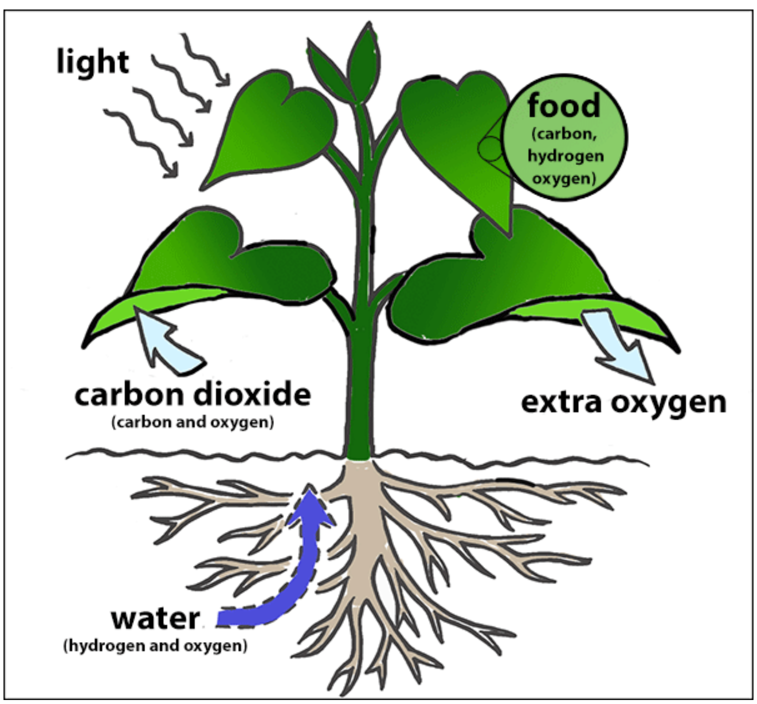
Plants' Role in the Carbon/Oxygen Balance in our Air

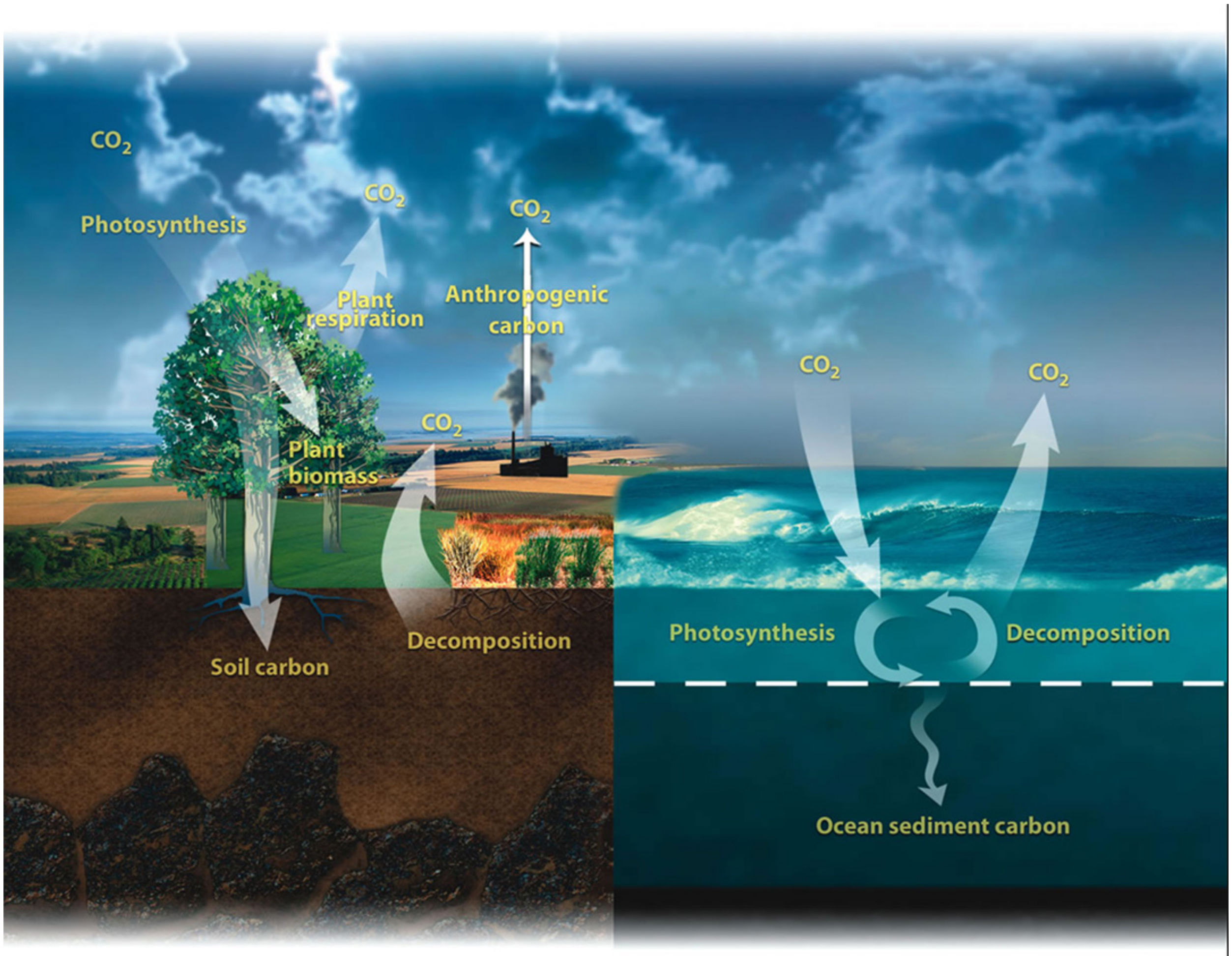
Plants are an important part of the solution for bringing balance back to our air:

- They take in carbon dioxide and use it to create food in the form of carbohydrates.
- They release oxygen back into the air.

And through this process, they not only capture carbon in their leaves, stems, and other structures, they also return carbon back to the soil and store it there in the form of living roots and decaying plant matter. Carbon that is "sequestered" in this way helps reduce the amount of carbon dioxide in the air.

Just another important job that plants do in our world! For more in-depth background information about the Carbon Cycle, check out The Carbon Cycle (shown below) from NASA's archives at: https://earthobservatory.nasa.gov/features/CarbonCycle.





Components of the Global Carbon Cycle
https://public.ornl.gov/site/gallery/originals/CCycle_cover_image.jpg
Source: Office of Biological and Environmental Research of the U.S. Department of Energy Office of Science. science.energy.gov/ber/

Activity 1: What is Air?

1. Read The Air Around Us Reading Page. This reading page may be best to read as a group with younger students (3rd through 4th grade) so you can pause for additional clarification if needed. For older students it can be an independent reading page. Together or independently, complete the reading comprehension questions and then discuss your answers as a group.

2. Understanding why people and plants need air can be especially complex for students to understand because it is not something we can see with our eyes. Take a nature walk in your schoolyard or local greenspace to "look" for air. Use all of your senses to explore air as mentioned in the reading page. What are some of the sensory signs that let us know air exists; e.g. touch (temperature and wind) and smell.

3. When air moves, we call it wind. We can feel the wind on our face and also see wind when it makes objects move.

4. Make a windsock for your garden so you can "see" air and watch as it moves through your garden:

- Cut plastic bags into strips or get a few rolls of flagging tape from a hardware store.

- Use an old metal hanger or a plastic ring to make the base for your windsock. There are many items you could repurpose to make a ring such as cutting a cross-section of a 2-liter water bottle, using an old pool toy, or if you want to go big, looking for an old hula hoop. You could also make your own hoop with a flexible piece of pipe or tubing that can be bent into a ring shape and taped.

- Securely tie the strips of plastic on your ring so that they hang down and flow easily in the wind. Make sure your ties are secure to avoid unnecessarily littering the environment with plastic.

5. Find a location to hang your new windsock that you can observe its movement regularly. You may want to experiment by tracking movement in different kinds of weather and hanging it in different places to see how plants and other objects impact wind movement.

Windsock

Activity 2: Air Above and Below Ground

Plants take in air through stomata in their leaves, and they also need air for their roots.

1. Use the background information to explain how plants take in air through the stomata on their leaves. If you have a microscope available to you, try to look for stomata on leaf samples.

   The stomata are typically found in greater numbers on the undersides of the leaves and on the outside layer of the leaf. To be able to see them under a microscope, you can fold the leaf in half and then tear it so that you can try to separate the bottom layer to get a thinner sample to look through.

   The California Academy of Sciences also offers suggestions for using clear nail polish and tape to try and separate the stomata off of your leaf for viewing. Instructions for this method can be found at: https://www.calacademy.org/educators/lesson-plans/stomata-printing-microscope-investigation.

   If you do not have a microscope, you can check out Travel Deep Inside a Leaf, also from the California Academy of Sciences: https://www.youtube.com/watch?v=Bf-RFPaZeAM.

2. Explain that plant roots need air to survive. Healthy soil is full of pore space — tiny open spaces between soil particles. These spaces contain water or air and make them available to plant roots. To demonstrate soil pore space, take a bucket or bowl with no holes in the bottom and fill it with soil. Spread the soil so it's level and place a piece of tape on the wall of the container to mark the soil line.

3. Slowly add water to the soil with a watering can. Look at the tape. Does the soil get higher? If the soil level does not rise, ask kids where the water is going? Keep adding water until your soil becomes completely saturated. Explain that the water is filling the air pockets or pores of air in your soil, displacing the air.

4. Plan an experiment to show that plant roots need these pockets of air for healthy growth. Gather two plants of the same kind that are approximately the same size. Plant them in pots that are also the same size, but one should have drainage holes and the other should either not have drainage holes or have the holes completely blocked. Add the same amount of water to each of them and place them in the same location.

5. Continue to water both plants at the same intervals and the same amount. Track the growth of each and compare. As you water, you will want to apply enough water so that your sample without holes is consistently waterlogged.

6. If you do not have any potted plants readily available (or none that you would like to sacrifice for the sake of experiment), you can also start some seed viewers of bean seeds to experiment with.

   To make a seed viewer:
   - Cut a piece of construction paper into a rectangular strip to fit inside the plastic cups. This is optional, but it helps with viewing.
   - Ball up a few pieces of paper towels and place them inside the construction paper liner until the cup is full.
   - Place 3 to 4 beans in the cup between the side of the cup and the paper towels or construction paper liner so the seeds are visible from the outside of the cup.
   - Gently water the paper towels in the center until saturated.
   - Place the cup (or cups if you would like to try multiples) on a shelf or windowsill and watch them grow. First you will notice the seed coat expanding (wrinkling) as the seed absorbs water. The root will start to grow in 2 to 3 days. Water as necessary to keep the paper towel and seeds continually moist.

Seed Viewer

   Once your seedlings have two true leaves, start your experiment. For half of your seed viewers, continue to only provide enough water to keep the paper towels moist. These samples will have air available to their roots. On the other half of the seed viewers, fill the cup completely with water so that the plants are kept in standing water which means they do not have any air available to them. Compare their growth.

   *Please note: If using seed viewers, you can start testing the effects of no air and varying water availability right from the start and also look at the impact on seed germination, or you can wait to begin your experiment after the first set of true leaves appears.

7. Track your observations using the Air Experiment Data Collection Worksheet or your garden journal. If you are not seeing much variation in the appearance and growth of your plants, you may need to adjust the amount of water you are using, which in this experiment is representing the amount of air availability.

8. Discuss your results. Did some of your plants grow better than others? What happened to the plants that did not have any air available to their roots? Does this show us that plant roots need air?

Extend the Activity: Testing the impact of air availability to leaves is very challenging. Because plants conduct both respiration (which gives off carbon dioxide) and photosynthesis (which gives off oxygen), plants grown in an enclosed space such as a terrarium can actually continue to provide for their own air-related needs for a very, very long time. You can try growing a plant in vacuum-sealed food container that comes with a pump to remove the air; however, you may or may not notice significant differences in growth.

Activity 3: The Carbon Cycle

1. Share with your kids the Components of the Global Carbon Cycle Diagram from the US Department of Energy available at: https://public.ornl.gov/site/gallery/originals/CCycle_cover_image.jpg

   Use the background information above to help you explain how carbon moves through the atmosphere and why that it is important. There is a fixed amount of carbon on our planet. It moves between being stored in the soil, the air, the water, and in living things. Keeping a set balance of carbon is important for keeping everything in our world working right. Share that if there is too much or too little carbon in our air, it can change our climate and environment.

2. Next, share the Terrestrial Photosynthetic Carbon Cycle Diagram from the US Department of Energy available at: https://public.ornl.gov/site/gallery/originals/Pg028_CCycle08.jpg.

   Explain that plants are a really important part of the carbon cycle and how they can take extra carbon from the air and then turn it plant food that can get stored in the plant and also returned to the soil.

3. The nonprofit organization Kiss the Ground has a short video called The Soil Story that helps explain this phenomenon in simple terms. There are 3 different versions of this video available to watch (and even more translated into different languages) at: https://kisstheground.com/playmedia/

The core message of this video is that the amount of carbon on our planet does not change, but it can be stored in different locations, including the atmosphere, oceans, biosphere, soil, and fossils. As we have released more carbon into the atmosphere, we have changed the balance in the storage location of carbon, negatively impacting our environment. Kiss the Ground presents different solutions for moving carbon back into the soil as a way to solve the problem of climate change.

Ask kids to consider the role of plants in bringing and keeping carbon in balance in our atmosphere. Are plants important for people?

Digging Deeper

You can use the following resources to dig deeper into this week's lessons:

Books and Additional Resources:

Seed School by Joan Holub

Jack's Garden by Henry Cole

Up in the Garden and Down in the Dirt by Kate Messner

A Place to Grow by Stephanie Bloom

10 Interesting Things About Air from NASA Climate Kids:
https://climatekids.nasa.gov/10-things-air/

Why Does Wind Blow? From NOAA SciJinks:
https://scijinks.gov/wind/

Why is Air Invisible? From Highlight Kids:
https://www.highlightskids.com/explore/science-questions/why-is-air-invisible

For Older Kids and Parents:
Understanding Food and Climate Change from The Center for Ecoliteracy:
https://www.ecoliteracy.org/download/understanding-food-and-climate-change-interactive-guide

Understanding Food and Climate Change uses video, photography, text, and interactive experiences to show how food and climate systems interact and how personal choices can make a difference. Ideal for grades 6–12 (and adults too), the guide provides connections to Next Generation Science Standards and the National Curriculum Standards for Social Studies themes. It also offers activities for student research and resources for further investigation.

Videos:
Travel Deep Inside a Leaf from the California Academy of Sciences:
https://www.youtube.com/watch?v=Bf-RFPaZeAM

Kiss the Ground's The Soil Story:
https://kisstheground.com/playmedia/

Photosynthesis — The Dr. Binocs Show By Peekaboo Kids
https://www.youtube.com/watch?v=D1Ymc311XS8

Additional Related KidsGardening Lessons and Activities to Try:

Photosynthesis Runs the World:
https://kidsgardening.org/resources/lesson-plan-photosynthesis/

Photosynthesis 101:
https://kidsgardening.org/resources/digging-deeper-photosynthesis-101/

Tropical Rainforests:
https://kidsgardening.org/resources/lesson-plan-tropical-rainforests/

The Soil-Air Connection:
https://kidsgardening.org/resources/lesson-plan-soil-air-connection/

Garden Basic: Carbon Cycle and Carbon Sequestration:
https://kidsgardening.org/resources/digging-deeper-carbon-cycle-and-carbon-sequestration/

Building a Terrarium:
https://kidsgardening.org/resources/garden-activities-building-a-terrarium/

Weather-Tracking Tools:
https://kidsgardening.org/resources/lesson-plans-weather-tracking-tools/

Digging into Soil:
https://kidsgardening.org/digging-into-soil/

The Air Around Us

Lessons to Grow By - Plant Needs – Air

Take a deep breath in. Take a deep breath out. Of all the things animals need to survive, constant access to air is the most important.

What is air?

Air on our planet is made up of lots of different components. We usually can't see the air around us because it is made up of gases which are elements in their tiniest forms. Because they are so small, they do not reflect light that our eyes can see.

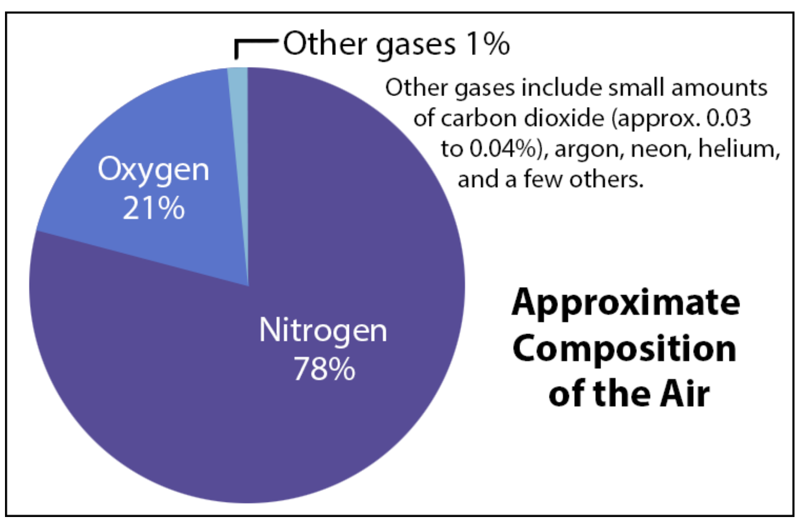
What about using our other senses? Have you ever been able to feel air? Air can change temperatures so sometimes it feels cold and other times it feels warm. Temperature changes can also cause the air particles to move and we feel wind. As the wind moves by objects it may produce a sound so that we can hear air, too!

Can you smell air?

Although normally the basic elements that make up air don't have a recognizable smell for people, sometimes, additional gases and other really small particles of matter can get into the air, and our sense of smell may notice an odor (sometimes good and sometimes yucky). Finally, can you taste air? Our sense of smell and sense of taste are connected so when things other than the normal gases are in the air around us, it can impact our sense of taste, too — but it is not exactly the same as doing a taste test.

What are these tiny components that make up air?

The elements present in the biggest amounts are nitrogen and oxygen. Under normal conditions, nitrogen makes up 78% of our air and oxygen makes up 21% of our air. Then there are components that just make up a small amount of the air, including things like carbon dioxide, argon, hydrogen, neon, and water vapor. All these other things usually make up 1% of the air.



Oxygen is the element in the air that is most important to animals. We breathe air into our bodies and use the oxygen to transform the food we eat into the energy our bodies need to stay alive and growing. After we take the oxygen out of the air, we breathe out the stuff we do not need. If animals all over the planet kept taking all the oxygen out of the air and just putting back the other stuff, it would seem like the amount of oxygen found in the air would decrease, right?

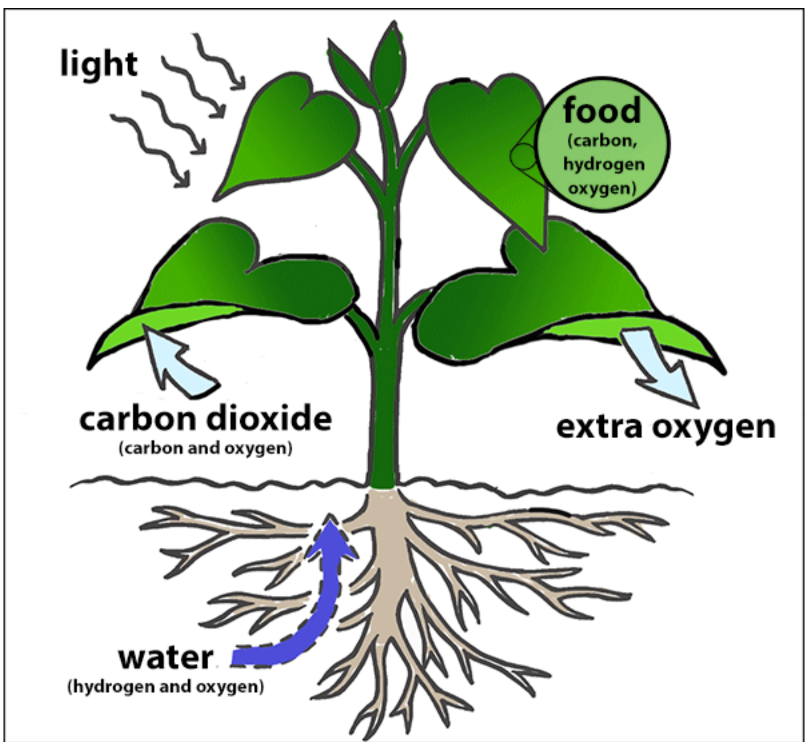
That is where our green plant friends come to the rescue! Plants also need air. Plants take in air through small openings in their leaves called stomata (stow-MAH-tuh). Like us they use the oxygen in it to transform their food into energy for them to live and grow.

However, unlike us, plants also use the carbon dioxide in the air. Carbon dioxide is made up of carbon and oxygen. Plants use the carbon dioxide they take into their leaves to make food through a process called photosynthesis (foe-toe-SIN-the-sis).

The process of photosynthesis also results in creating extra oxygen that the plants don't need. Plants release this extra oxygen back into the air.

Photosynthesis:

carbon dioxide (carbon and oxygen) + water (hydrogen and oxygen) —with light energy→ food (carbon, hydrogen, oxygen) + extra oxygen



Plants and animals are working like a team to keep the amount of oxygen and carbon dioxide in the air about the same.

So, what does all this mean for our air?

- People and animals take in air, use the oxygen in it, and then breathe out air that has more of the other elements like carbon dioxide in it.

- Plants take in air, use the carbon dioxide to make food, and then release the extra oxygen they don't need back into the air.

There are some other activities on the Earth that can also impact the types of gases in our air, but the way that people/animals and plants use air differently plays an important role in helping keep the amounts of all the elements in the air in balance. This amazing cycling of air is just another reminder of why plants are so important to us!

Reading Comprehension Questions:

1. True or false: Both plants and animals need air to live and grow.

2. What kind of particles is air usually made up of?
   A. Liquids
   B. Solids
   C. Gases
   D. None of the above

3. What element in the air is most important to animals?

4. What two elements in the air do plants need to survive?

5. Together people and plants help keep the amount of oxygen and carbon dioxide in the air about the same. What might happen to our air if we cut down too many trees and other plants on the Earth?

Air Experiment Data Collection Worksheet

Date and Treatment	Observations Plant(s) with Drainage Holes (Air Available)	Observations Plant(s) without Drainage Holes (No Air Available)
Date: Amount of Water Delivered:		
Date: Amount of Water Delivered:		
Date: Amount of Water Delivered:		
Date: Amount of Water Delivered:		
Date: Amount of Water Delivered:		
Date: Amount of Water Delivered:		

LESSONS TO GROW BY

Plant Needs

In this unit of Lessons to Grow By, we are exploring plant needs. For healthy growth and development, plants must obtain just the right amounts of light, water, air, and nutrients and they also need space to grow. These five requirements are the basic needs for all plant life.

Fortunately for our world full of diverse environments, different plants need different amounts of each of these essentials so there are plants well adapted to grow in almost all environmental conditions.

Through these activities, kids will investigate plant needs to better understand how to take care of their green friends while also gaining a deeper appreciation for how the living and nonliving elements in an ecosystem work together.

The bright green seedlings on the left received enough nutrients. The pale seedlings on the right did not.

Module 3: Nutrients

Learning Objectives:

This module focuses on the plant need of nutrients. Kids will:

- Learn what nutrients are and how plants obtain the nutrients they need to grow.
- Investigate how nutrient availability influences plant health and growth.
- Explore decomposition and the nutrient cycle.

Materials Needed:

Activity 1: What are Nutrients?

- The Plant Nutrient Cycle Reading Page
- Nutrient Matching Game

Activity 2: Nutrient Experiments

- Tomato seeds
- Potting soil (without added nutrients), peat moss, or coir (coconut fiber)
- Containers

- Nutrient Experiment Worksheet
- A variety of fertilizers (optional)

Activity 3: The Nutrient Cycle

- Food scraps
- Plastic bags (at least 2)
- Soil from an outdoor location
- Decomposition Bag Observation Worksheet

Introduction

Just as vitamins help people grow and stay healthy, mineral nutrients help plants grow and stay healthy. The nutrients that plants require in relatively large quantities are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. These are called macronutrients. Plants also need a number of other nutrients in much smaller quantities, including iron, copper, zinc, manganese, molybdenum, boron, nickel, and chlorine. These are called micronutrients. Though plants need just a tiny bit of these micronutrients (and many are relatively common in soils), a deficiency of any one of them can cause serious problems in plants.

Below are details about individual nutrients and how gardeners can supply some of these nutrients with fertilizers. But first, here's a closer look at the nutrient cycle in nature.

The Nutrient Cycle

In nature, plants obtain most of their needed nutrients from the soil. Nutrients occur naturally in the soil as a byproduct of the decomposition of organic matter, or in some cases they are released through the weathering process of parent rock. After being taken up by the roots, nutrients are then transported to the rest of the plant where they are needed. However, plants need help to access the nutrients.

Just like the living organisms above the ground, life underground also comprises a very intricate food web that includes both "producers" and "consumers" and results in the recycling of nutrients that plants need. In a simplified overview:

1. Plant roots give off substances called exudates that consist of carbohydrates produced by the plant through the process of photosynthesis.
2. These exudates become food for microscopic bacteria and fungi in the soil.
3. These tiny organisms are consumed by slightly larger life forms (although in most cases still too small to see with the naked eye), such as nematodes, protozoa, and some arthropods.
4. These organisms are eaten in turn by larger creatures that can be seen without a microscope, such as larger arthropods (like millipedes and sow bugs) and earthworms.
5. Finally, near the top of the web, small soil creatures become a buffet for even larger animals, such as moles.

In addition to eating each other, many of these underground dwellers also consume dead and decaying organic matter (both plant and animal) that has made its way down to the soil. As they digest the decaying organic matter and then deposit it back into soil through their waste, these organisms return nutrients to the soil, "recycling" them so they can then be absorbed by living plants.

Additionally, there are many bacteria and fungi that also facilitate the availability of the nutrients to plants. Nutrients as they naturally exist in the soil are not always in a form that plants can use. Plants depend on soil-dwelling microorganisms to convert certain nutrients into accessible forms that are available for uptake. Some microorganisms even play an active role in helping roots with the process of absorption.

Fertilizers 101

Sometimes gardeners step in to help plants they're growing meet their nutrient needs — especially if the existing soil is lacking any of them. Scientists spent many years conducting experiments to identify the specific nutrients needed for healthy plant growth. They used that information to create substances we call fertilizers. It is important to note that fertilizer is not the same thing as plant food. Plants make their own food (carbohydrates) through the process of photosynthesis. To put it into "people terms," fertilizer is more accurately compared to a multivitamin.

Nutrients: The Big Three

Although plants need all of the macronutrients and micronutrients listed above for optimum growth, scientists have identified three that are needed in larger quantities. These three are often limiting factors for plant growth and are more likely to be missing from soil, especially in a garden setting. The big three plant nutrients are nitrogen, potassium, and phosphorus. Here is a brief overview of why plants need these nutrients, as well as signs that might show plants aren't getting enough of them:

> Nitrogen is needed for the plant to make a number of essential compounds, including chlorophyll. A plant that does not have enough nitrogen will look weak and have light green to yellow older leaves.
>
> Phosphorus plays an important role in helping plants make flowers, fruits, and seeds. If a plant does not have enough phosphorus, it may have small, purple-tinged leaves, and will develop few fruits.
>
> Potassium impacts how well water can move around a plant and the opening and closing of the stomata. Common signs of potassium deficiency include stunted growth and yellowing or browning of leaf margins and weakened stems.

To help promote optimum plant growth, gardeners apply fertilizers containing missing nutrients to the soil around plants. Fertilizers are grouped into two major classifications: organic and synthetic.

Organic Fertilizers

These are derived from once-living ingredients. They include things like animal manure, composted plant matter, peat moss, and wood ash. Organic fertilizers more closely mimic the decomposition process that provides nutrients in nature.

- In addition to supplying nutrients to the plants, many organic fertilizers like compost improve the structure of the soil, thus improving the overall health of your plants.
- They are generally less concentrated and less likely to harm your plants if over-applied.
- They support the soil food web, which in turn supports plant life. There's an old saying, "Feed the soil, and the soil will feed the plants."
- They usually contain a multitude of other macronutrients and micronutrients, in addition to the N-P-K listed on the label, due to the variety of natural materials from which they're made.
- Note that some "certified organic" fertilizers, such as greensand and rock phosphate, are finely ground, naturally occurring rock.

Synthetic Fertilizers

Synthetic fertilizers are made up of chemicals that are usually derived from petroleum or rock. They are generally highly concentrated, offer quick results, and may be less expensive than organic fertilizers. Concerns about synthetic fertilizers include:

- They may have a negative impact on the naturally occurring organisms in the soil.
- They may wash away in heavy rains into the water system, leading to a form of water pollution.
- Because some types are in a concentrated form designed to be readily absorbed by plants, if too much synthetic fertilizer is applied it can harm and even kill plants.
- They contain only what's listed on the label — if a nutrient isn't listed, it's not in the fertilizer. Exclusive use of synthetic fertilizers can lead to deficiencies of other nutrients.

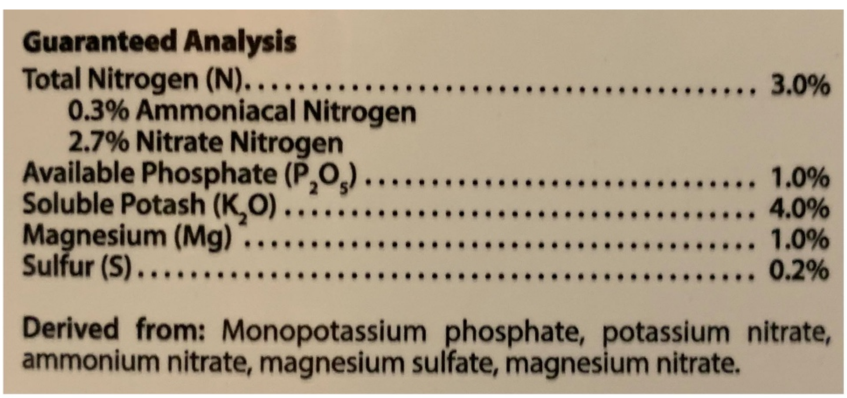
Note: To maintain plant health and reduce environmental impacts, always follow fertilizer label instructions and apply correctly.

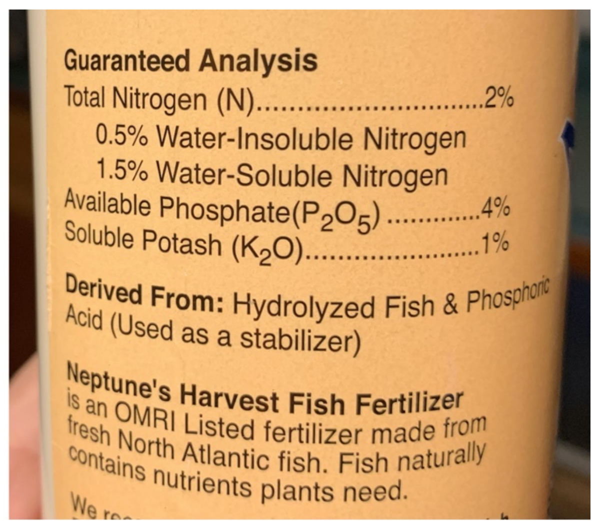
Deciphering Fertilizer Labels

No matter what kind of fertilizer you choose, most times you will notice three numbers listed on the packaging. These numbers represent the ratio of nitrogen, phosphorus, and potassium that is contained in the fertilizer.* An all-purpose fertilizer may list something like 5-5-5 which would mean that nitrogen, phosphorus, and potassium each represent 5% of the weight of the fertilizer. In a 5-5-5 synthetic fertilizer, the remaining 85% is made of some kind of filler, such as sand.

Note that organic fertilizers may have lower N-P-K numbers compared to synthetic fertilizers; at first glance it may seem that they offer less value. However, many organic fertilizers also contain a variety of important other nutrients, and the "filler" may be organic matter, humus, and other materials beneficial to soil life — as opposed to the inert material, such as sand, in synthetic options.

*Technically speaking, the three numbers represent the percentages of nitrogen (N), phosphate (P_2O_5, a source of phosphorus) and potash (K_2O, a source of potassium).





Labels from a synthetic fertilizer, above, and organic fish-based fertilizer, right.

Different Plants, Different Types and Amounts of Nutrients

Different N-P-K ratios are desirable for different types of plants. For example, flowering plants, bulbs, fruits, root crops, and vegetables require more phosphorus than potassium and nitrogen. For these crops, gardeners may choose an 8-12-4 formula.

In addition to needing different types of nutrients, different plants also need different quantities of nutrients. Some plants need a lot of nutrients for proper growth. Others are adapted to needing fewer nutrients. Tomatoes, for example require large amounts of nitrogen. From year to year, gardeners will rotate where tomato plants are grown in the garden to allow the soil to replenish its nitrogen supply. This rotation of crops is also beneficial in preventing diseases from ravaging the same food crop year after year. Flowers such as nasturtiums, on the other hand, prefer a “leaner” (less nutrient-rich) soil. Given too much nitrogen, they’ll produce loads of foliage but few blooms.

Looking Back to Nature

Although adding fertilizer is a handy trick for gardeners, imitating the nutrient cycle found in nature is much more beneficial over the long haul.

Unfortunately, a lack of understanding about the complexities and importance of the soil food web to the health of plants results in problems for many gardeners. The application of insecticides, herbicides, and synthetic fertilizers, along with horticultural practices such as repeated soil tilling, can impact underground organisms and destroy the balance of life within the soil system. For example, a fungicide applied to a lawn will not only kill the fungus that is attacking the lawn, it may also kill off the fungus that is working beneficially with the grass’s roots to make nutrients and water more available to them.

Supplementing soil with organic matter such as humus and compost is the best way to not only provide nutrients but also contribute to soil health. Other organic fertilizers that are friendly to soil microorganisms include liquid seaweed, fish emulsion, composted manures, and alfalfa meal.

Soil pH (acidity/alkalinity) also affects nutrient availability. A professional soil test can help you determine your soil’s pH and nutrient levels. Your state Cooperative Extension may offer soil test kits.

Activity 1: What are Nutrients?

1. Together or independently, read The Plant Nutrient Cycle Reading Page. Have your kids complete the reading comprehension questions and then discuss your answers together.

2. After getting the background information for the reading page, have kids use the Nutrient Matching Game Worksheet to further explore the Big 3 nutrients that plants need: nitrogen, phosphorus, and potassium.

3. Depending on the time of year, you can extend this lesson by going on a nature walk to look for signs of possible nutrient deficiencies in plants. Vegetable gardens are a good place to look. A lot of our common vegetable plants, especially those that bear fruit that we harvest (it takes the plant more energy to make flowers, fruit and seeds) require more nutrients than other landscape plants.

Also, because we disrupt the nutrient cycle when we harvest vegetables and remove spent plants (nutrients that in nature would be returned to the earth), the soil may become depleted in some of the essential nutrients.

If an outdoor garden is not available to explore due to season or availability, indoor plants can also be explored.

Activity 2: Nutrient Experiments

1. Tomato plants need a lot of nitrogen for healthy growth and so they make a great test subject for nutrient experiments. You can purchase tomato seeds from a seed company, or you can also collect seeds from the tomatoes you eat at the grocery store.

   If you collect seeds from tomatoes you purchased from grocery store, the plants you get may not end up looking exactly like the parent plant because a lot of tomato plants are hybrids. But for this experiment you only need to grow the plants for about a month, not necessarily to maturity.

To collect seeds from a tomato:

- Cut open and scoop out the seeds and pulp and placing them in a plastic or glass container. Add enough water to cover.

- Cover the top of the container with plastic wrap and let sit at room temperature for four days, stirring once daily. The viable seeds will sink to the bottom of the container, while the pulp and non-viable seeds will float to the top. Don't worry if you see mold forming on the floating material.

- After four days, pour off the water while retaining the viable seeds. Rinse the seeds in fresh water, and drain. You can plant these damp seeds immediately. However, if you plan to store the seeds, spread them out on a sheet of newspaper or a paper plate to dry for 7-10 days.

2. To see the impact of nutrient deficiency on plant growth most quickly, use potting soil with minimal or no nutrients already added. Another option is to sow seeds in pure peat moss or coir (coconut fiber), both of which are low in nutrients. Alternatively, depending on your budget, you can use different types of potting soil mixes and compare the growth of your plants.

3. Fill small pots or seed planting trays with moistened planting mix. Instead of purchasing pots, you can also use recycled plastic or carton food containers; be sure to clean thoroughly and put holes in the bottom for drainage. Plant your tomato seeds ¼" deep and place the containers in a warm, bright location.

4. Watch your tomato plants grow and water as needed. Track observations in your garden journal or use the Nutrient Experiment Worksheet.

Keep in mind that seeds are like a lunchbox for the new baby plant. They not only include plant food (carbohydrates), but also some nutrients to help the plant begin its new life. So, when the seeds first sprout they will have some food and nutrients available to them which will sustain them for a bit. However, tomato plants quickly use the nutrients provided in this initial store, which is why they make good subjects for a nutrient experiment.

Tomato seeds contain enough stored food and nutrients to allow the seed to begin growing. When those run out, it will need a source of nutrients.

5. About 3 to 4 weeks after sprouting (depending on the nutrients in your potting soil mix), most tomato plants will start to show signs of nitrogen deficiency, such as the yellowing of lower leaves. At this time, you can choose to end your experiment, or you can extend the learning by providing your plants with a selection of fertilizers and then watching to see what happens to the plant when additional nutrients are added.

If you decide to keep growing, there are a number of organic and synthetic fertilizers available from garden centers. All fertilizers should be applied under close supervision of an adult. Read the label and follow the directions carefully when using.

Activity 3: The Nutrient Cycle

1. Use the Background Information above and the Plant Nutrient Reading Page to help you explain the process of decomposition to your kids.

   The Natural Resources Conservation Service of the USDA has a soil food web poster that you may want to use in order to introduce some of the soil decomposers who help make this process possible available at: https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_049822.jpg

2. Next, make simple decomposition observation bags to help kids visualize the decomposition process. Place pieces of plant debris, old fruit, vegetables, and moist bread in clear gallon plastic bags (make at least 2 bags). If you are only making 2 bags, place approximately the same things in about the same percentages in each bag. If you are making more than 2, you can experiment with different combinations for further exploration.

3. In half of your bags, also add a scoop of soil (do not add any soil to the other half of the bags). Close the bags and place them in a warm location where you can make daily observations. You can use your garden journal or the Decomposition Bag Observation Worksheet.

4. What to expect: You will likely see some mold and other fungal growth within a week; however, timing is dependent on the materials chosen, moisture level, and temperature. Continue the observations until the contents of some of the bags begin to resemble soil. Compile the results and discuss. Did some of the bags decompose faster than others? What factors seemed to influence the timing? What do you think was different in the bags that also contained actual soil? What does this information tell us about the formation of soil and recycling of nutrients?

5. Depending on the age and interest of your students, you can look at other variables with your test, such as sunlight availability (offering a variety of light exposures), temperature (perhaps put some in a refrigerator), and moisture levels. You can also experiment with keeping the bags/containers tightly closed versus introducing air regularly, but make sure to warn kids not to inhale or ingest contents while examining. Some types of mold can be harmful.

Extension

You can extend this activity by starting a worm bin composter to make your own fertilizer from worm compost and worm compost tea. Worms provide a free and hassle-free source of rich, organic fertilizer. What's more, they engage kids' hands and minds and teach basic environmental concepts — and they're just plain fun! To start your own worm "farm," you'll need an aerated container, bedding (such as shredded newspaper), a moist and temperate environment, a small amount of soil, and red wigglers. You can find detailed instructions for starting your own worm bin at: https://kidsgardening.org/resources/garden-activities-worm-compost/

Digging Deeper

You can use the following resources to dig deeper into this module's lessons:

Books and Additional Resources:

Seed School by Joan Holub

Jack's Garden by Henry Cole

Up in the Garden and Down in the Dirt by Kate Messner

Diary of a Worm by Doreen Cronin

Compost Stew by Mary McKenna Siddals

Plantzilla by Jerdine Nolen

A Place to Grow by Stephanie Bloom

Videos:

Soil Nutrients from the Ground Up from University of Wyoming Extension:
https://www.youtube.com/watch?v=gBrhZKuG-HY

Green Our Planet's Virtual Academy – What Makes Good Garden Soil?
https://www.youtube.com/watch?v=jVXQ207D9gQ

Green Our Planet's Virtual Academy – How to Make Compost Using Worms:
https://www.youtube.com/watch?v=ZsXt1xbVwml

Nutrient Cycling Soil Food Web School:
https://www.youtube.com/watch?v=NVhY4ssMtbI

Big Green SEK Soil Investigation Video:
https://biggreen.org/edresources/video-library/

Additional Related KidsGardening Lessons and Activities to Try:

Garden Maintenance: Weeding, Mulching and Fertilizing:
https://kidsgardening.org/resources/gardening-basics-garden-maintenance-weeding-mulching-and-fertilizing/

All the Dirt on Soil:
https://kidsgardening.org/resources/gardening-basics-all-the-dirt-on-soil/

Soil is Alive:
https://kidsgardening.org/resources/lesson-plan-soil-is-alive/

Digging into Soil:
https://kidsgardening.org/digging-into-soil/

Worm Composting:
https://kidsgardening.org/resources/gardening-basics-worm-composting/

Make a Worm Composting Bin:
https://kidsgardening.org/resources/garden-activities-worm-compost/

Gardening Basics- Composting:
https://kidsgardening.org/resources/gardening-basics-composting/

Trouble Shooting Compost Problems:
https://kidsgardening.org/resources/gardening-basics-troubleshooting-compost-problems/

Borage and Other Compost Plants:
https://kidsgardening.org/growing-guide-borage-compost-plants/

The Plant Nutrient Cycle

Plant Needs - Reading Page - Nutrients

The bright green seedling on the left received enough nutrients. The pale seedling on the right did not.

Have you ever taken a vitamin? Was it crunchy or was it a gummy? Did it look like one of your favorite cartoon characters? Do you know what was inside of it?

People take vitamins to help our bodies grow and stay healthy. Vitamins are a type of nutrient. A nutrient is something that helps our bodies work properly. Some of the nutrients people take include things like vitamin C, vitamin D, iron, and calcium. These nutrients are also found in the food we eat. So don't worry if you do not take vitamins; you are probably getting all the nutrients you need from your food.

Guess what? Plants need nutrients to grow well too! Unlike people though, plants do not eat food, so where do you think they find the nutrients they need? Plant nutrients are found in the soil. Plants absorb them through their roots and then move them to their stems, leaves, flowers, fruits, and seeds.

Do you think plants and people need the same kind of nutrients? There are some things that both of us need to grow, but people and plants are pretty different so our lists are not exactly the same.

Plants have some nutrients they need a lot of. These are called macronutrients (macro means large). Other nutrients they need in small quantities. These are called micronutrients (micro means small). There are 3 main nutrients that are really important to plants: nitrogen, phosphorus, and potassium. What do these 3 substances do for the plant?

- Nitrogen is used by the plant to make important compounds inside of the plant, including chlorophyll. Chlorophyll is the green substance that plants use to help them make their food through photosynthesis. If a plant that does not have enough nitrogen, the older leaves at the bottom of the plant will turn yellow.

- Phosphorus is used by plants to help them make flowers, fruits, and seeds. If a plant does not have enough phosphorus, it may have small, purple-tinged leaves, and will develop few flowers and fruits.

- Potassium is important for helping water move around the plant. If a plant does not have enough potassium, it will stay short and the edges of the leaves will turn yellow and brown.

So how do these important nutrients get into the soil for plants to use? In nature, the main way nutrients get added to the soil is through a process called decomposition.

When leaves fall on the ground or when plants and animals die, there are little creatures in the soil called decomposers that eat the dead things. These creatures include earthworms, sow bugs, ants, and even smaller things we can't see, like bacteria and fungi. When they eat the dead things, they break them into smaller pieces and deposit those pieces in the soil through their waste (their poop).

Let's think about leaves that fall off the plant and collect on the ground. Those leaves used to be part of a bigger plant, so inside they will have stores of nitrogen, phosphorus, and potassium. But all those nutrients are locked up in the leaf and can't get out, even though the leaf fell off so the plant is not using them anymore.

Decomposers to the Rescue!

Decomposers will chomp on the leaf and break it down into little pieces — the components that include nutrients. The pieces will be returned to the soil through the decomposer's waste. So through this process, which is called decomposition, the nutrients that were locked up in the leaf will get free in the soil and be ready to be picked up and used by a new plant. (And when they die, the bodies of the decomposers themselves are broken down into nutrients, too!)

Snails (above) and earthworms (below) break down organic matter, helping to recycle the nutrients it contains.

The process where plants and animals use nutrients while they are alive and then pass them along to new plants and animals when they die is called the Nutrient Cycle. Nutrients go 'round and 'round from being available in the environment to being trapped in living things to being available again.

Gardeners can add nutrients to the soil for plants, too. Just like we have vitamins that we can take, sometimes gardeners help plants get the nutrients they need by adding something called fertilizer to the soil.

Fertilizer can be a solid or a liquid and there are lots of different kinds full of lots of different nutrients. Gardeners should always read the labels on fertilizers carefully to make sure they are giving their plants what they need. Too many nutrients or the wrong kind of nutrients can be just as bad for plants as not enough.

Reading Comprehension Questions:

1. What is a nutrient?

2. Where do plants get most of the nutrients they need for healthy growth:
   A. the grocery store
   B. rain water
   C. the soil
   D. food

3. True or false, macro means large.

4. What are the 3 nutrients that plants need in big quantities to grow well:

5. Sometimes gardeners provide nutrients to help plants grow. What do we call the nutrients people give to plants?

Nutrient Matching Game

Draw lines to match the nutrient on the left side of the page to the picture of the plant on the right side of the page that needs it.

Nitrogen **Job:** Helps the plant make things like chlorophyll which gives plants their green color	 **Problem:** This plant only has one small flower on it.
Phosphorus **Job:** Helps plants make flowers, fruits, and seeds	 **Problem:** The stem is bending and the edges of the leaves are turning brown.
Potassium **Job:** Helps move water around the plant and open/close stomata	 **Problem:** The bottom leaves on this plant are turning yellow.

Nutrient Experiment Observation Worksheet

Plant #	Date:		Date:		Date:		Date:	
	Height	Observations	Height	Observations	Height	Observations	Height	Observations

Potting Soil Used (note here if seeds were planted in different kinds of potting soil):

Treatment Notes (note here if fertilizer was applied to plants with date of application):

Date:

Decomposition Bag Observation Worksheet

Bag #: ____________

Contents: ____

____

Location: ____

Sunlight availability: ____

Average temperature: ____

Was soil added? ____

Moisture level rating at beginning of experiment:

☐ No moisture ☐ Low moisture ☐ High moisture

Was air added? ____

Observations: ____

____

____

____

____

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Plant Needs

In this unit of Lessons to Grow By, we are exploring plant needs. For healthy growth and development, plants must obtain just the right amounts of light, water, air, and nutrients and they also need space to grow. These five requirements are the basic needs for all plant life.

Fortunately for our world full of diverse environments, different plants need different amounts of each of these essentials so there are plants well adapted to grow in almost all environmental conditions.

Through these activities, kids will investigate plant needs to better understand how to take care of their green friends while also gaining a deeper appreciation for how the living and nonliving elements in an ecosystem work together.

Plants come in all shapes and sizes! Tiny duckweed plants, above, are less than 1/10" long, while the giant sequoia tree, below, is 275' tall.

Module 5: Space to Grow

Learning Objectives:

This module focuses on the plant need of space to grow. Kids will:

- Learn that in addition to the needs of light, air, water, and nutrients, plants must also have adequate space to grow and thrive.
- Investigate how the space available to a plant impacts its growth.
- Explore how plants can adapt to growing in different kinds of spaces as long as their other needs are met.

Materials Needed:

Activity: 1 A Place to Call Home

- A Place to Call Home Reading Page
- Flexible measuring tape or string and a ruler
- Plant Observation Worksheet
- Clipboard or piece of cardboard
- Pencil

Activity 2: Space to Grow Experiments

- Radish or lettuce seeds
- Potting soil
- 5 pots (or repurposed plastic containers) that are all the same size — at least 4” in diameter if using radish seeds and 6” in diameter if using lettuce seeds
- Space to Grow Experiment Data Collection Worksheet

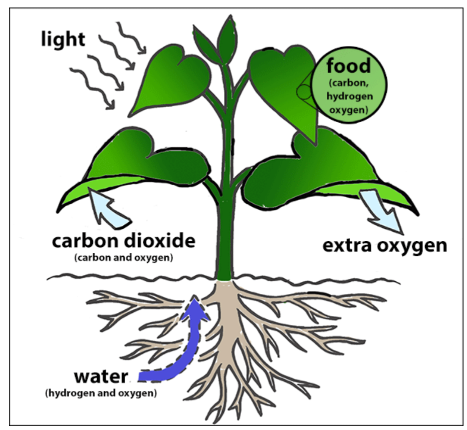
Activity 3: Straw Hydroponics

- Rockwool* or cotton ball
- Lettuce seeds
- Plastic container with lid
- Hydroponic nutrient solution (optional)*
- Drinking straw

*Rockwool is made from molten rock that is spun into fibers and then compressed into mats or cubes. Both rockwool and hydroponic nutrient solutions are available from hydroponics suppliers and on Amazon.

Introduction

All plants need water, air, light, nutrients, and a place to grow. Here is a brief review of the needs discussed in the previous Lessons to Grow By:



Light. Energy from light is captured to use during photosynthesis. Photosynthesis is the process by which plants make their food.

Air. Plants take in carbon dioxide to use during photosynthesis. The also take in lesser amounts of oxygen to help fuel their metabolic processes.

Water. Plants need water for a number of important processes, including photosynthesis (production of food) and transpiration (evaporation of water from the leaves into air that cools the plant and creates pressure to move water from roots to leaves). Water also aids in the absorption of some nutrients.

Nutrients. Just as people need vitamins, plants need certain nutrients to help them grow properly and for their biological processes to function. Plants obtain most of their nutrients from the soil. Nutrients occur naturally in the soil as a byproduct of decomposition of organic matter and the weathering of rocks. They can also be added through man-made fertilizer applications.

The last need plants must fulfill if they are to survive is a place to grow. Unlike most animals, plants are rooted in place. They must have a spot where they can anchor their roots, grow their stems and leaves, and obtain all of the other needs listed above. In nature, roots are usually anchored in the soil; however, there are exceptions, such as plants with aerial roots that live in rainforests and some floating water plants.

Plants come in all different shapes and sizes, so there is no set amount of space every plant needs to be thrive. Additionally, plants are extremely good at adapting. They can find ways to grow despite limited space, as long as their other needs are met.

Gardeners often push the limits regarding the space plants need to grow. Sometimes our gardens are more about our own needs and desires, rather than the plants' optimal conditions. This can have unfortunate consequences. For example, have you ever seen a sidewalk that has been cracked or buckled by tree roots because the tree wasn't given enough space to grow? Or a tree whose canopy had to be cut back because it was planted too close to power lines?

In some cases, however, limiting a plant's space to less than it needs in its native environment can have favorable results, as long as the gardener meets the plant's other needs.

Bonsai artists prune the stems and roots of trees over many years to achieve miniature forms that can grow in small pots.

For example:

- In the Japanese art of bonsai, gardeners prune the roots and stems of trees and shrubs to create healthy plants in miniature form.
- In urban areas, we grow plants in containers, in vertical gardens, and on rooftops.

These approaches allow people with limited space to be surrounded by green. Another example of this is a growing technique called hydroponics.

Hydroponics, in its simplest form, is growing plants by supplying all necessary nutrients via the plants' water supply, rather than through the soil. The word derives from the Greek root words hydro, meaning water, and ponics, meaning working.

Growing plants hydroponically helps gardeners and farmers grow more food in smaller areas, such as classrooms, greenhouses, rooftops, and living rooms. It also allows them to produce food in parts of the world where space, good soil, and/or water are limited, such as in an urban warehouse, in a desert, in Antarctica, or even on the International Space Station!

Activity 1: A Place to Call Home

1. Together or independently, read the A Place to Call Home Reading Page. Have your kids complete the reading comprehension questions and then discuss your answers together.

2. Talk about how plants come in all shapes and sizes. Venture out on a nature walk and take time to observe all the different sizes of plants. You can use the Plant Observation Worksheet as a guide. Bring along a measuring tape so you can record various plants' height and width and the circumference of tree trunks.

   If you do not have a flexible measuring tape, use a long piece of string and a ruler. Wrap the string around the object and mark it to record the height or diameter of the plant. Then use the ruler to measure the length of the string.

   As you make observations, you may also want to mention to kids that the size and shape of a plant can be influenced by its age.

3. At the end of the walk, reflect on the diversity of plants you observed. Did you find many large plants on your walk? Were there more small plants? Were there some plants too big or too small to measure? Did you find any examples of plants whose size might have been influenced by the space available?

Activity 2: Space to Grow Experiments

By growing different numbers of the same plants in the same-sized containers, kids can see the impact of adequate space vs. crowding on plant growth. Lettuce and radish seeds make good test subjects.

The recommended spacing for radish and lettuce seeds planted in the garden is to sow them approximately 1" apart; then, when they're an inch or two tall, thin the radish seedlings to approximately 3" apart and lettuce seedlings to 5-6" apart. For this experiment, you'll plant one or two pots that demonstrate the recommended spacing (with just 1 or 2 plants per pot), and other pots that are overcrowded.

1. Obtain at least 5 pots of equal size. You can also repurpose plastic food containers, but be sure to punch holes in the bottom for drainage. Fill pots with moist soil.

2. Decide how many seeds to plant in each pot. Have at least one pot that has 1 plant and then choose different numbers of seeds based on the sizes of your pots. For easy comparison, you could plant in multiples of 5 for example (1, and then 5, 10, 15, 20, 25, etc.). Have kids record how many seeds were planted on the Space to Grow Experiment Data Collection Worksheet. Then have them write down a hypothesis of what they expect to see as the plants grow.

3. Provide equal amounts of water and sunshine to all the pots. Have kids record the number of seeds that germinate in each pot on their worksheets.

4. Have kids measure and record the height of the plants each week. It may be hard to measure every plant; if so, they can record the height of the tallest plant in each pot.

5. After 4 weeks, remove the plants from each container and measure the length of the longest roots. If possible, weigh the biggest plant.

6. Ask the following questions to discuss the experiment:

    - Did the measurements of the radish/lettuce plants vary based on the amount of space they had to grow?
    - Did this data match your predictions?
    - Which plants looked the healthiest?
    - Can you make any conclusions about plant needs based on this experiment?

Activity 3: Straw Hydroponics

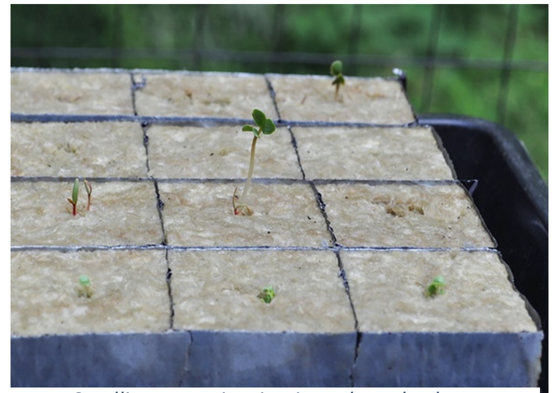
1. In nature, plants naturally adapt to the space they have to grow. In crowded conditions, many types of plants will grow taller to reach more light. When growing in nutrient-deficient soil, they will send their roots out further in search of nutrients to fill their needs. If they have lots of space available, they will spread out to their fullest.

    As gardeners, sometimes we try to grow plants in spaces that look very different than where they usually grow in nature. Share some of the examples listed in the Background Information or look for additional examples.

2. Try this simple straw hydroponic system to show kids how you can meet plant needs even in spaces that do not look like what we would find in nature. Kids are always amazed to see plants growing without soil. This kid-powered system gives them a chance to learn about hydroponic basics. Collect the materials:
    - Cotton balls or rockwool*
    - Lettuce seeds

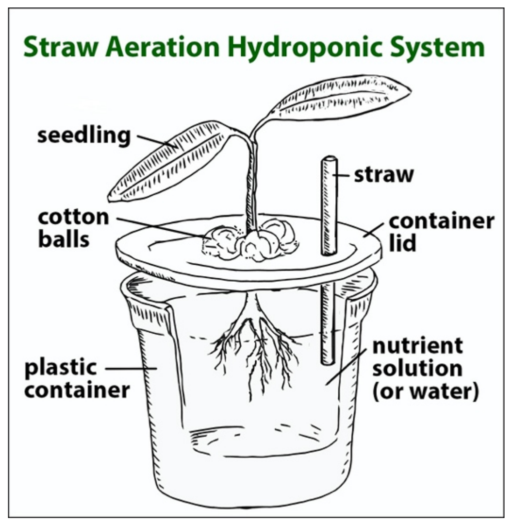
- Plastic container with lid
- Drinking straw
- Hydroponic nutrient solution (optional)**

*Rockwool is made from molten rock that is spun into fibers and then compressed into mats or cubes. Both rockwool and hydroponic nutrient solutions are available from hydroponics suppliers and on Amazon.
**Though it's fairly inexpensive and recommended for optimal growth, hydroponic nutrient solution is not essential for this activity. Like all seeds, lettuce seeds contain enough food and nutrients for the plants' initial growth. The seedlings will grow for several weeks without added nutrients.


Seedlings germinating in rockwool cubes.

3. Soak small squares of rockwool or cotton balls in a dilute hydroponic nutrient solution (or plain water if you're not using the nutrient solution). Plant two or three lettuce seeds in each one, and then place them on a waterproof tray or shallow container and keep moist until seeds germinate.

4. Find a small plastic container with a lid to repurpose, such as a margarine, cottage cheese, or yogurt container. Use a utility knife to carefully cut a 1" X shape in the center of the lid. Cut a second, smaller X shape in the lid, about 1" from the edge, large enough to insert a drinking straw.



5. Gently insert the rockwool or cotton ball with the seedlings halfway through the large X so that it is held securely in place in the lid.

6. Fill the container with dilute nutrient solution (or plain water) so that the very bottom of the cotton ball or rockwool square will touch the solution, then secure the lid.

7. Insert a drinking straw through the smaller hole into the solution. Twice a day, gently aerate the solution by blowing into the straw. *Depending on the age and maturity level of your kids, this may be a job for a supervising adult. Make sure you are blowing air in and not drinking the nutrient solution.

8. Change the nutrient solution (or water) every 1 to 2 weeks.

9. As the plants grow, talk to your kids about how they are delivering the plants needs of water and air (and nutrients, if using) in a unique way. Discuss the benefits of growing plants in hydroponic systems, such as:
   - They can be used in locations where quality soil is not available.
   - They can be used in urban locations close to population centers so that food does not need to travel far from harvest to market.
   - Plants can be grown year-round.
   - The systems use less water than traditional gardening.
   - Growers can control nutrient availability
   - There are no weeds and usually fewer insect and disease problems.

Digging Deeper

You can use the following resources to dig deeper into this module's lessons:

Books and Additional Resources:

Flower Garden by Eve Bunting

Errol's Garden by Gillian Hibbs

Seed School by Joan Holub

Jack's Garden by Henry Cole

Up in the Garden and Down in the Dirt by Kate Messner

Plantzilla by Jerdine Nolen

A Place to Grow by Stephanie Bloom

Videos:

San Diego Hydroponic Farm from CaBountiful:
https://www.youtube.com/watch?v=zod-246VCkg

NASA's Doug Ming on Technologies Required for Living on Mars:
https://www.youtube.com/watch?v=QCOlHrt6eTU

Exploratorium Subzero Water Works in McMurdo Station on Ross Island, Antarctica:
https://www.exploratorium.edu/video/subzero-water-works

Exploratorium Polar Paradise:
https://www.exploratorium.edu/video/polar-paradise?autoplay=true

Can living walls reduce air pollution? BBC News and Middlesex University:
https://www.youtube.com/watch?v=CcAAeGpLN4c

Virtual Tour of the US National Bonsai Collection from Mauro Stemberger:
https://www.youtube.com/watch?v=Qy6FlhRbVcl

Additional Related KidsGardening Lessons and Activities to Try:
Room to Grow:
https://kidsgardening.org/resources/lesson-plan-room-to-grow/

Square Foot Gardening:
https://kidsgardening.org/resources/gardening-basics-square-foot-gardening/

Plants in Space:
https://kidsgardening.org/resources/lesson-plans-plants-in-space/

Exploring Hydroponics:
https://kidsgardening.org/resources/gardening-basics-exploring-hydroponics/

Container Gardening for Kids:
https://kidsgardening.org/resources/garden-activities-container-gardening-for-kids/

A Place to Call Home

Plant Needs - Reading Page - Space

Plants need five main things to stay alive. They need air and light to make their food through photosynthesis. They need to take in water and nutrients through their roots so they can be used by all parts of the plant for healthy growth. And there is one more thing on their list — they also need space to grow.

Just like animals, plants come in all shapes and sizes. For example:

- The watermeal plant is about 1/42" long and 1/85" wide, which is about the size of a candy sprinkle or the salt on a soft pretzel. (Some people think the plant, which grows in water, looks like cornmeal, which is how it got its common name.)
- The tallest tree in the world is a giant sequoia in California that is 275' tall and has a trunk that is about 32' wide. It is just a little bit shorter than the Statue of Liberty.

That is a big difference in size!

So, if a plant is given all the space in the world, along with the perfect amounts of water, nutrients, light, and air, will it keep getting bigger? Nope! Each type of plant has a specific size and shape it will reach when it's all grown up, ranging from teeny tiny to humongous.

Do plants always grow to their full size? Unlike animals that can move around to find the space they need, plants are rooted into place. So, if they are planted in a spot with limited room to grow, they will adapt to the space they have and may be thinner or shorter than normal. Also, when plants are crowded in their space they are competing with the plants around them for their other needs (light, water, air, and nutrients), and this can also keep them smaller.

Floating on the surface of a pond, common duckweed plants are less than 1/10" long. Watermeal plants are even tinier!

Can you imagine a tree so big it would take 25 kids reaching hand-to-hand to form a circle around its trunk? The General Sherman sequoia tree stands 275' tall and is more than 36' in diameter at the base. If you wrapped a tape measure around the trunk it would measure more than 100'.

Have you ever seen a garden packed with lots of plants and noticed the plants are tall and skinny? They may be stretching to try to get more sunlight. How about a tree planted in a narrow strip of land between a sidewalk and a street that never seems to get any taller? The size of its roots may be limiting how much its trunk and leaves can grow.

This ability to adapt to the space available is a cool thing about plants.

Although each type of plant has an ideal environment and amount of space where it will grow best, individual plants can adjust to less-than-ideal spots and still thrive. This is a very good thing for gardeners who like to grow plants in places and in ways that are not necessarily found in nature.

One example of this is the Japanese art of bonsai. Gardeners prune the stems and roots of plants to make them grow much smaller than they would be in nature. Towering trees can become container plants that fit on a shelf.

An example of a growing method that provides plants with a place to grow that is much different than where they grow in nature is hydroponics. In hydroponics, gardeners grow plants with their roots getting nutrients from water, instead of soil. This growing technique can be useful in environments where good soil is not available. For example, it can be used to grow plants in the desert, in Antarctica, and even on the International Space Station!

A hydroponic garden looks very different than a regular outdoor garden, but as long as all of a plant's needs can be met, it will be happy to call it home.

many years to achieve miniature forms that can grow in small pots.

With enough light, water, and nutrients to meet their needs, plants can adapt to growing in small spaces.

These plants are growing in different types of hydroponic set-ups.

Reading Comprehension Questions:

1. List the 5 basic needs of plants:

2. True or false: All plants need the same amount of space to grow.

3. What does a plant do if it does not have enough space to grow:
   - ☐ Move to a new location
   - ☐ Adapt to its space by growing differently
   - ☐ Nothing
   - ☐ File a complaint

4. Hydroponics is a way to grow plants in:
   - ☐ Soil
   - ☐ Milk
   - ☐ Water
   - ☐ Quicksand

5. List one unusual place that you have seen a plant growing:

Plant Observation Worksheet

Plant # or Name	Height	Circumference	Does this plant look like it has enough room to grow? Why or why not?

Space to Grow Experiment Data Collection Worksheet

Pot #	# of seeds planted	# of plants growing	Height of tallest plant:				Length of longest root after 4 weeks	Weight of one plant after 4 weeks	Observations
			After 1 week	After 2 weeks	After 3 weeks	After 4 weeks			