Back to the Roots Garden Toolkit

Unit 3: Garden-in-a-Can

OVERVIEW

Back to the Roots is on a mission to help every family experience the magic of growing their own food. We're bringing this mission into your classroom with the Garden Toolkit – including the organic Mushroom Grow Kit, Water Garden, and Garden-in-a-Can – all designed to help kids explore how their food grows!

In Unit 3 we will use the Garden-in-a-Can to learn about plants and what makes them so important to their ecosystems. We take a closer look at two types of herbs you'll be growing – organic basil and cilantro – and study the plant life cycle as you observe it in action while your classroom Gardens-in-a-Can grow. By the end of this unit, you will be able to answer the questions below and be well on your way to becoming an expert botanist (someone who studies plant life)!

Chapter 1: What are plants?
Exploration of the plant cell, the evolution of plants, and how herbs fit into the Kingdom Plantae.

Chapter 2: How do plants grow?
A closer look at the life cycle of flowering plants and the process of photosynthesis.

Chapter 3: How does biochar help plants grow?
How biochar is made, how it is used in your Garden-in-a-Can and in big agriculture, and its role in sustainable food production.

Chapter 4: Why are plants awesome?
The big picture – how plants benefit their ecosystems and make up the most diverse phylum on the planet!

WORD BANK

Keep an eye out for vocabulary words in blue throughout each chapter, and visit the Mushroom Glossary at the end to find each definition.

plant	evolution
cell	adaptation
organism	vascular plant
membrane	seed plant
organelle	angiosperm
chloroplast	herb
photosynthesis	phototropism
vacuoles	tissue

Thinking Cap
When you see the brain icon put on your thinking cap and write down your answers to our challenge questions!

ACTIVITIES

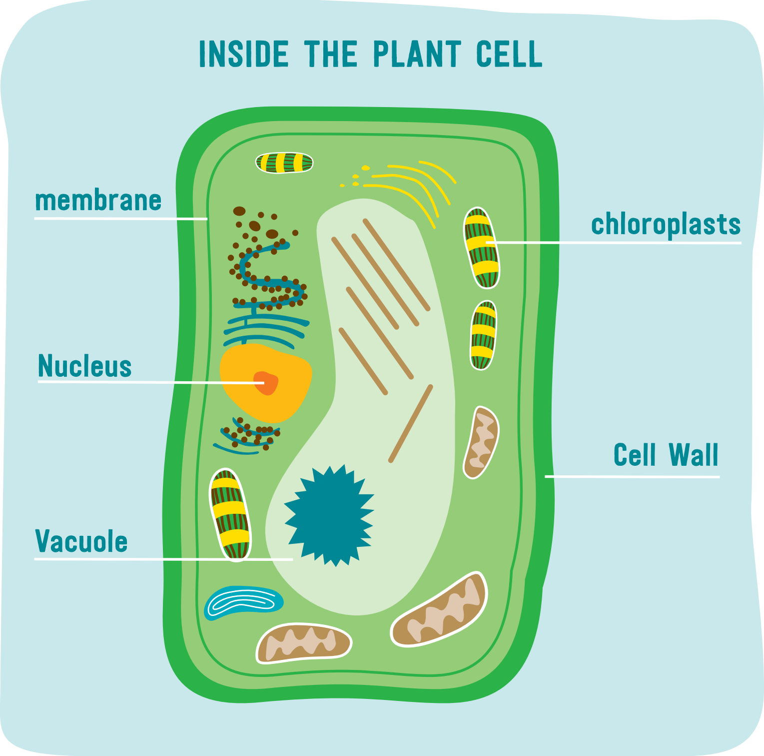
Garden-in-a-Can Growth Log

Thinking Cap: Unit Review

Chapter 1: What are plants?

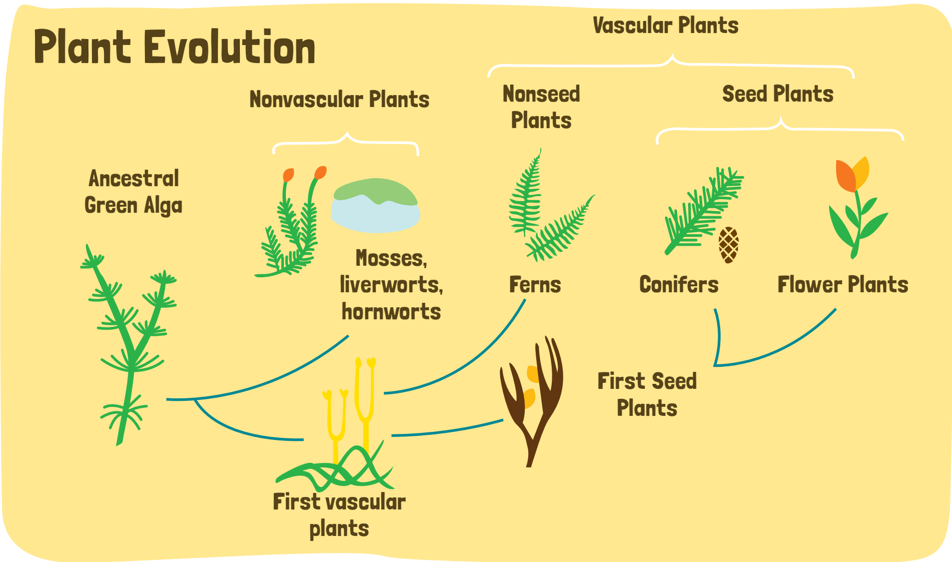
Plants are all around us – you've probably seen hundreds of different kinds of them! Plants are organisms, or living things, which make up one of the most interesting and diverse kingdoms, the Kingdom Plantae! Like all living things, plants are made up of cells. Cells are the smallest unit of an organism – they are so small that they can usually only be seen under a microscope! Most cells have a membrane, or barrier, that holds cells together.

Contained within the membrane are organelles, or parts which perform specific functions. Some organisms, like bacteria, are only made up of one cell. Plants, on the other hand, are very complex and are made up of many types of cells. Plant cells are unique in that they have a cell wall that keeps them rigid, chloroplasts that absorb sunlight for photosynthesis so they can feed themselves (more on this in Chapter 2), and large vacuoles which hold water and nutrients.



Evolution of plants

Evolution is the theory that species slowly change over time as individuals develop adaptations, or changes, to make them better suited to compete in their environment. Adaptations occur to help a species better reproduce, eat, and avoid being eaten. The plants that you see on land evolved from an ancient green algae in the water, well over a billion years ago.



Plants likely spread onto land to avoid being eaten by other organisms in the water, and to get closer to the sun, which they need to make food. To survive in new environments, plants had to evolve a waxy coating to avoid losing all of their water. They started to grow taller to avoid feeders on the ground and get more sunlight, which also required them to develop a piping system to help move water higher up their structure. Plants with this piping system are are known as vascular plants.

At the same time seed plants, or plants which produce a protected seed, were evolving . Eventually, the seed plants divided as flowering plants emerged. Flowering plants developed a different way to protect their offspring and reproduce, which we'll explore in Chapter 2.

Chapter 1: What are plants?

The **angiosperms**, or flowering plants, are the youngest phylum of plants. It's not entirely known how or when exactly the flowering plants came about (scientists believe around 300-100 million years ago!), but since their arrival on the planet they have evolved and divided into the most diverse phylum in the Kingdom Plantae. Angiosperms make up most of the vegetation on Earth,including the herbs in your Garden-in-a-Can!

Herbs, or "**herbaceous plants**" are seed-bearing plants with a fleshy stem that die after flowering (one type of angiosperm). The Gardens-in-a-Can include seed packets to grow different types of herbs - including organic basil and cilantro.

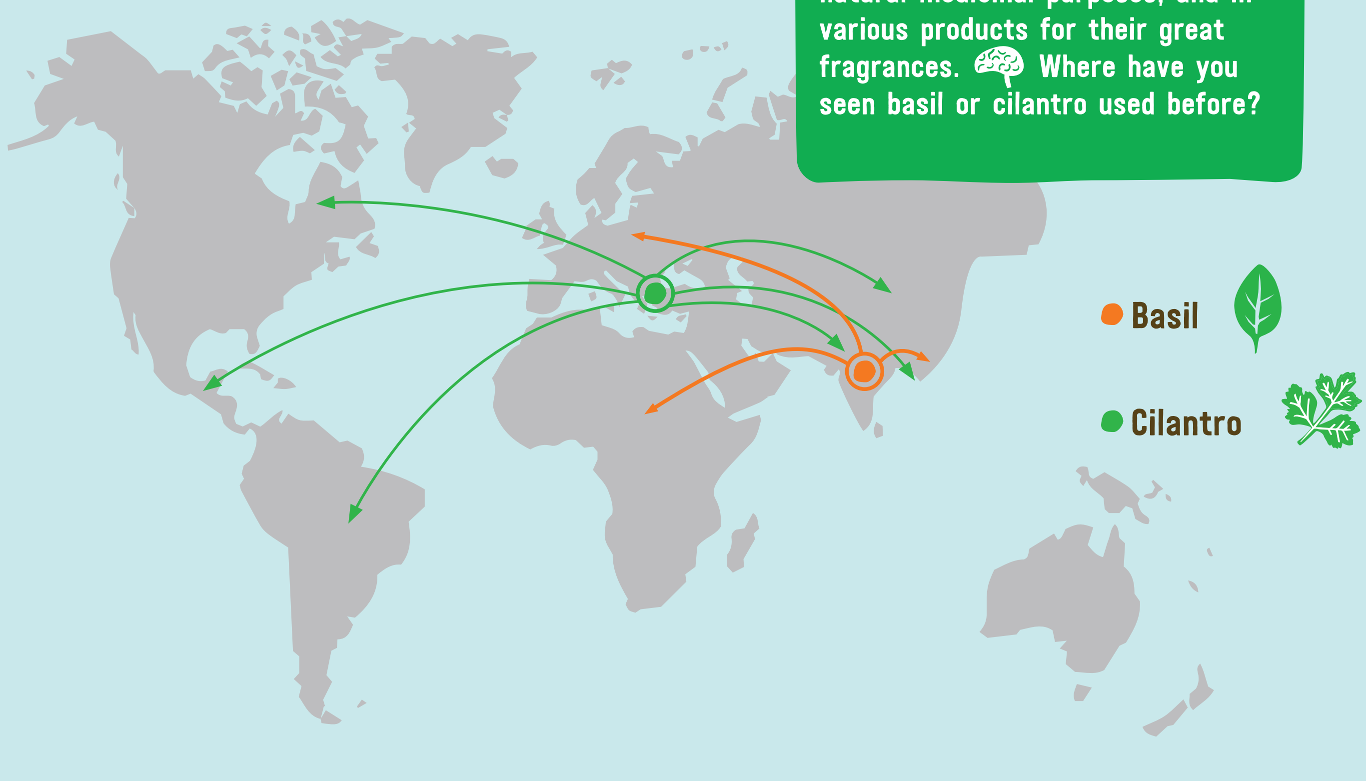
Basil & Cilantro Origins

Basil is quite diverse. There are many different species but the one in your Garden-in-a-Can is called Large Leaf Basil. It is a variety of sweet basil which is believed to have originated in India. In ancient times, spices and herbs were of great value and were traded from kingdom to kingdom all over the world. Basil traveled from India into parts of Asia and to the Mediterranean via trade routes.

Cilantro, also know as the coriander plant, originated in the Mediterranean area, but also ended up being traded all over the world!

How do we use herbs?

Throughout history herbs have been used by people to add flavor and spice to cooking and also as medicines for a wide range of illnesses and ailments. Nowadays, people still use herbs for cooking, natural medicinal purposes, and in various products for their great fragrances. Where have you seen basil or cilantro used before?

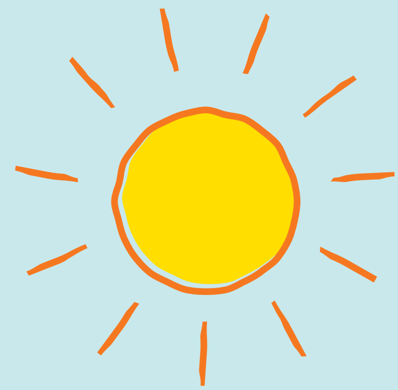


Chapter 2: How do plants grow?

As we learned in Units 1 and 2, all living things eat, reproduce, and excrete outputs. In order to do this, plants need four things: 1) water, 2) sunlight, 3) nutrients, and 4) air. Let's take a closer look at how plants use each of these to grow:

SUNLIGHT

The sun is constantly emitting energy through its rays. The plants' leaves absorb the sunlight and convert its energy into sugars through a process called photosynthesis. These sugars feed the plant as it grows. Sunlight also serves as a compass for the plant, allowing it to orient itself towards or away from the light. The sunlight tells the stem to grow towards the sun and tells the roots to grow away from the sun—this is called phototropism).

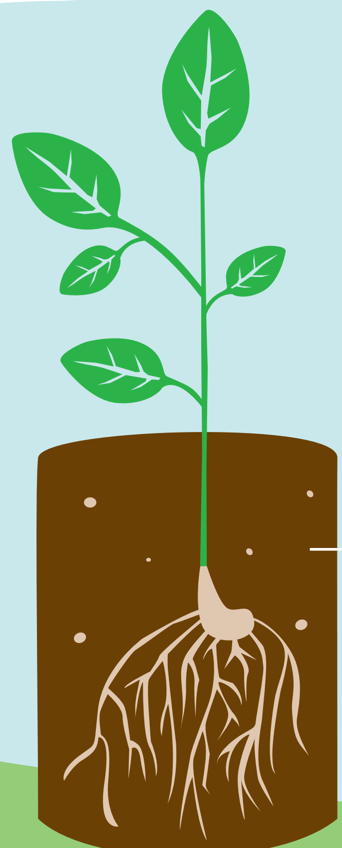


AIR (CO_2)

Air is all around us and is made up of multiple gases that we normally cannot see. Plants breathe in air (CO_2) through their leaves and use it to conduct photosynthesis.

PHOTOSYNTHESIS

$$\underset{(6CO_2)}{\text{AIR}} + \underset{(6H_2O)}{\text{WATER}} \xrightarrow{\text{sunlight}} \underset{(C_6H_{12}O_6)}{\text{SUGAR}} + \underset{(6O_2)}{\text{OXYGEN}}$$



WATer (H_2O)

The plant sucks up water through its roots and absorbs the nutrients from the soil along with it. Water then moves the nutrients through the vascular system of the plant up to the leaves, where it contributes to photosynthesis.

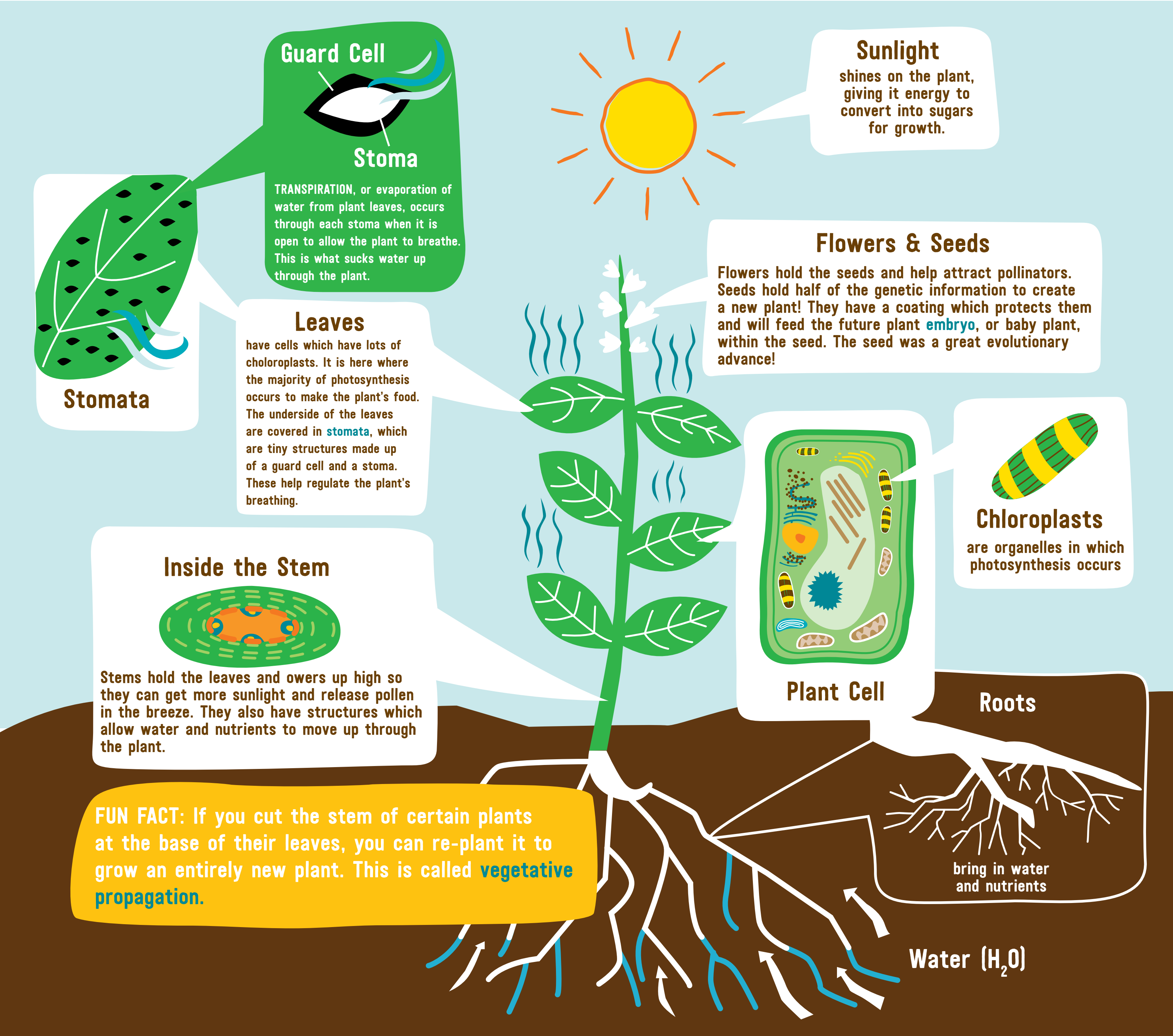
NUTRIENTS

Nutrients are minerals that the plant absorbs from the soil. Plants use nutrients to create many important structures inside the plant like DNA, and regulates processes like growth and reproduction.

Chapter 2: How do plants grow?

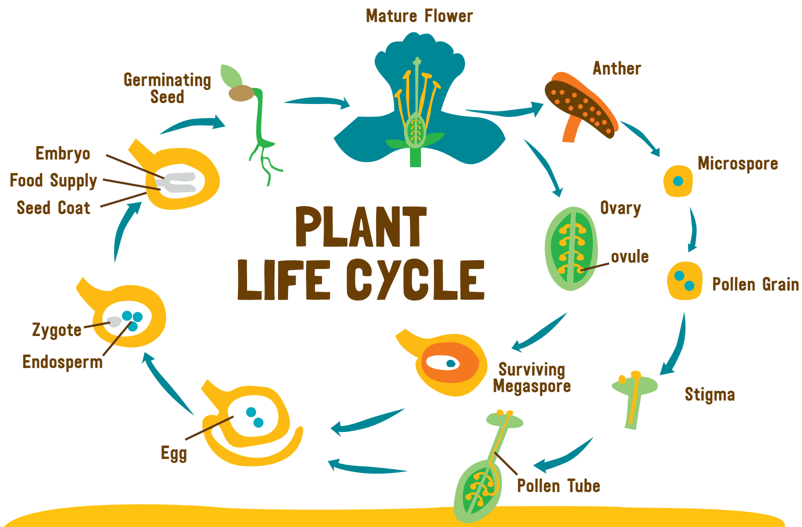
As we've learned, cells make up all living things. Inside more complex organisms, like plants and animals, similar cells group together to make up tissues. These tissues combine to form larger units called organs that perform specific functions. Plant cells make up tissues that become their three organs: the roots, the stems, and the leaves. Other parts of plants we are familiar with are variations which came about over the evolution of plants (flowers are modified leaves!). Plants have evolved in many ways which is why their parts look so different.

One of the most incredible things about plant cells, is that new cells in an area are totipotent, which means they can develop into any organ as the plant grows – roots, stem, or leaves! As they age, the cells lose this ability and become specialized to one organ. Let's take a closer look at each of the organs:



Chapter 2: How do plants grow?

The Life Cycle of Flowering Plants



One of the reasons the flowering plants have thrived is because they have evolved a very effective means of reproducing. They have all of the reproductive parts on one structure: the flower! Pollen, or the yellow dusty grains you see in the center of the flower, produce the male reproductive part of the plant, or gamete, which holds half of the information needed to create a new plant. The other half of the information comes from the female gamete, the ovule, produced in the ovary.

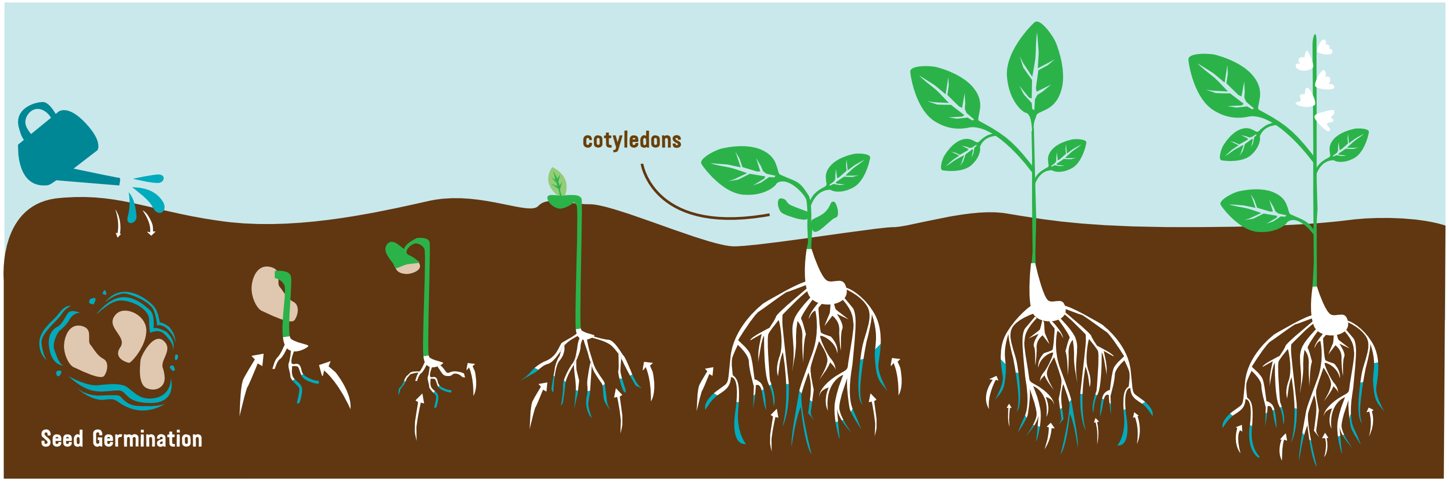
FUN FACT: In fruit, the ovary is the fleshy part of the fruit you eat – for instance, the yummy part of the apple, peach, or blueberry!

Pollen is held out from the flower on the anther as seen in the diagram. The ovules are held within the ovary at the bottom of the pollen tube with a sticky landing pad at the top called the stigma. When pollen reaches the ovule they combine in a process called fertilization, resulting in an embryo, or fertilized egg. The embryo contains all of the information needed to grow a new plant!

What sets flowering plants apart from other plants is double fertilization. In this process, two pollen grains travel down the pollen tube—the first fertilizes the female part of the ovule to make the seed, and the second fertilizes the neutral part to make the seed coat. The seed coat feeds the seed and protects it from environmental conditions. Often, the process of double fertilization is done with the help of a pollinator, or other organism which are attracted to the flower and knock pollen onto the stigma and down the pollen tube to the ovule. Can you think of an example of a pollinator?

Germination & Plant Growth

Most plants spend the majority of their life cycle in the growing phase. When the egg is fertilized, the stage is set for a process called germination, in which the tiny little plant within the seed sprouts. In order to germinate, the seed must first get wet so its hard outer shell softens and opens up, allowing for a little root and stem to emerge. From here, the roots grow down and the stem grows up and produces its first leaves, or cotyledons. The cotyledons fall off to make room for the true leaves, which facilitate photosynthesis so the plant can continue to grow. When it's at the end of its growth stage, an herb will flower and produce seeds before it dies to give way for the next generation.



Chapter 3: How does biochar help plants grow?

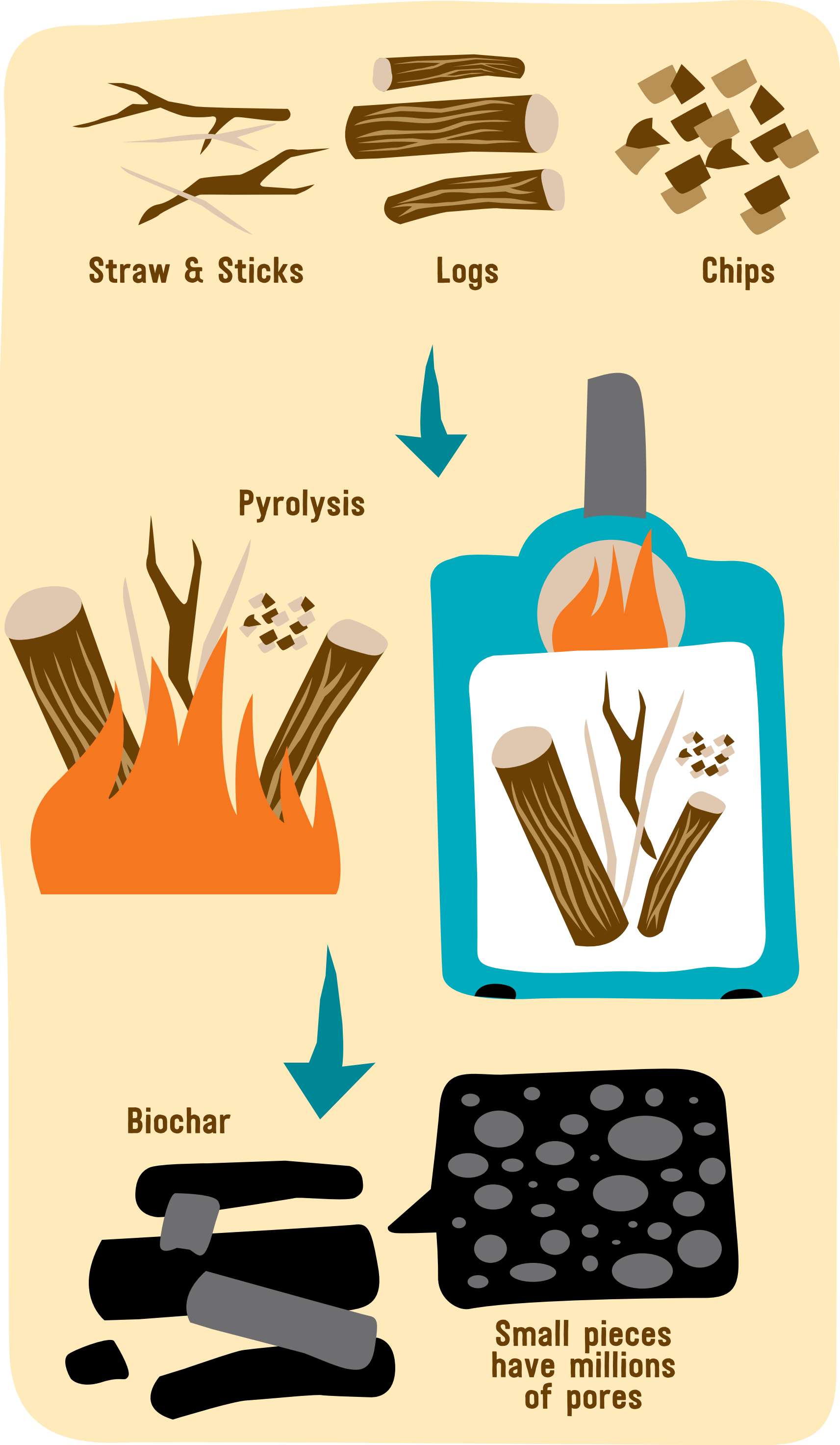
What is biochar?

Biochar is the charred remains of plant material that is created through a process called pyrolysis. The plant life is burned in a way such that little oxygen is allowed in, and the oils inside the plant separate out. The gases in the smoke are burned as fuel in the process. The result is a very dry piece of charcoal that is incredibly porous, meaning it has lots of small spaces and holes throughout it (like a sponge!). This feature becomes very important in the soil.

Biochar is used in farming and gardening as a type of soil amendment, or substance that is added to soil to help plants grow. In what ways would it be helpful to have something porous and hard in the soil around a plant you wanted to grow?

Origins

Many indigenous cultures, or native peoples, in the western hemishepre burned what was left of crops after a harvest and left the land alone to replenish nutrients. This practice was performed for centuries, and many people still do it today. In modern agriculture, biochar is produced on many scales. Some companies make biofuels, or fuels extracted from plants using pyrolysis (or other more complicated methods). These processes produce large volumes of high quality char which can be sold to farmers. On smaller scales, lots of creative people all over the world have designed their own biochar ovens to suit their own farming needs.

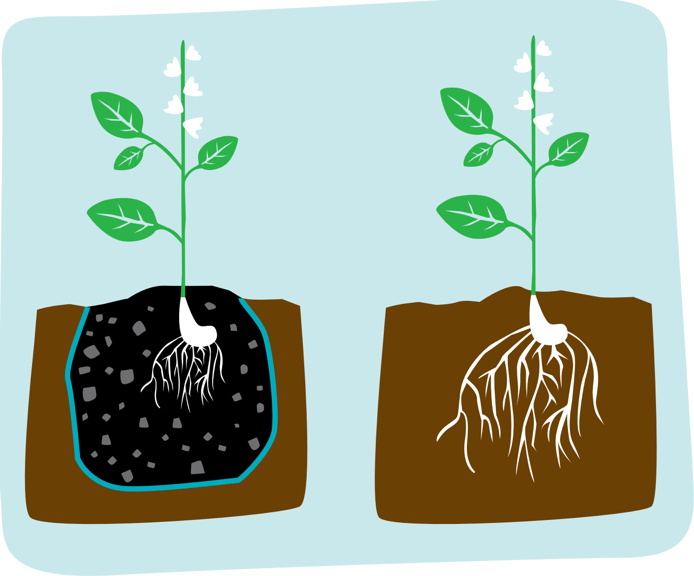


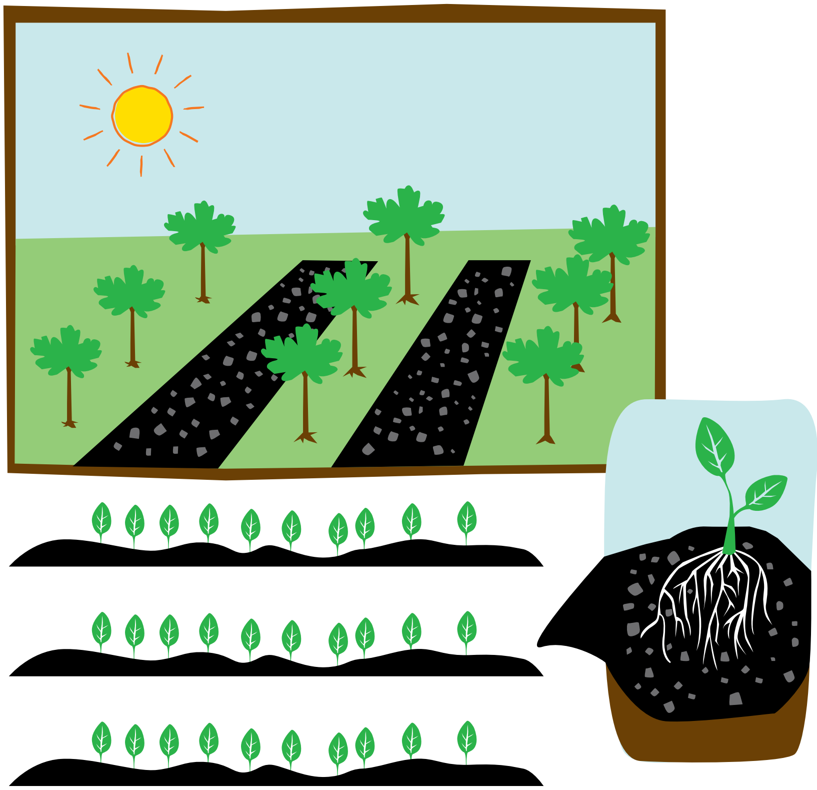
FUN FACT: The words "biochar" and "pyrolysis" might sound a little funny at first, but that's because they have Greek origins! They make a lot of sense when we break them down – the word "biochar" comes from"bio" which means life and "char" from charcoal. The word "pyrolysis" comes from "pyro" which means fire, and "lysis" which means to separate.

Chapter 3: How does biochar help plants grow?

How does biochar work?

As we just learned, each piece of biochar has many pores, or holes. These pores allow each piece to hold much more water than the soil could on its own. Keeping water close to the plant helps the roots so they don't have to grow as deep to search for water. This allows the plant to focus its energy on growing taller, producing more leaves and flowers, or whatever else it needs to do to grow! Biochar keeps water near the roots where nutrients move freely, making it easy for the plant to absorb water and suck up lots of nutrients along with it. Additionally, the pores provide areas for the bacteria to live. We learned in Unit II: Water Garden that some bacteria are beneficial, making nutrients available for the plants. We also learned that bacteria need places to live. The pores in biochar create many new homes for bacteria to live and multiply in the soil, where they convert more minerals into nutrients to help the plant grow.





Why is biochar beneficial in gardening and farming?

Biochar works great in your Garden-in-a-Can in helping the soil to retain moisture and nutrients for the herbs. On a larger scale, biochar is also very helpful for farmers in big agriculture. Nature wears on soil, often through rain, wind, and other conditions, to pack it down in a process called compaction. This can make it very difficult to maintain a soil structure suitable for farming: one with tiny spaces for bacteria, roots, and most importantly, air. Biochar keeps it shape and doesn't break down like soil does, so adding layers of it in farming helps to maintain the soil structure. Also, if loaded with beneficial bacteria and nutrients, it offers a great way to stimulate growth and plant health without using chemical pesticides or fertilizers. Allowing bacteria to multiply, biochar also helps strengthen the soil food web (more on this in Chapter 4!), creating more places for life to live!

Chapter 3: How does biochar help plants grow?

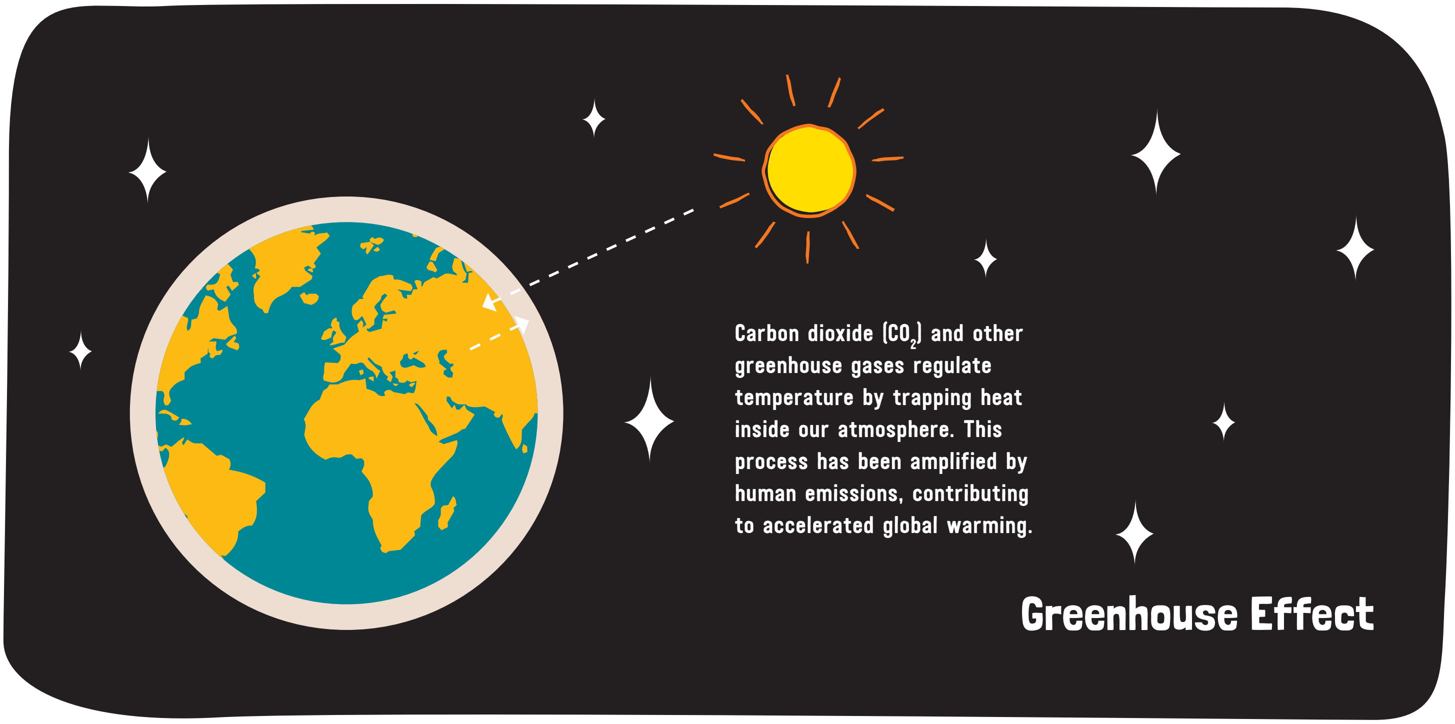
Why is biochar awesome for the environment?

You may have recognized a certain chemical – carbon dioxide (CO_2) – popping up throughout each unit. Plants breathe in CO_2 from the atmosphere, whereas mushrooms and people exhale CO_2. As we learned in Chapter 2, plants use CO_2 to create sugars through photosynthesis, and ultimately to build all of its parts. When they die, bacteria and other decomposers break them down until eventually the carbon trapped within them is released as part of the natural carbon cycle.

The carbon cycle is important because every living thing is made of carbon! CO_2 and other gases also help regulate global temperature. They do this by blocking the rays from the sun from bouncing freely back into space, instead trapping the heat in our atmosphere. This is a natural phenomonon called the greenhouse effect. Have you ever been inside of a greenhouse? What did you notice?

While this process has been occurring naturally throughout the history of the planet, in the last 200 years humans have burned an enormous amount of oil to fuel cars and machines, and coal to generate electricity. This has released an unnatural amount of CO_2 into the atmosphere, contributing to accelerated global warming. Rising temperatures pose many challenges to society, especially concerning the melting polar ice caps, which are causing sea levels to rise and threatening many coastal regions.

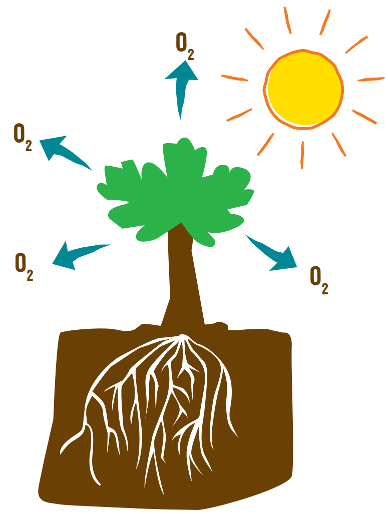
Biochar helps offset these CO_2 emmsions by trapping carbon in the charcoal instead of releasing it back into the atmosphere. It also serves as an awesome soil amendment to help crops (and your Garden-in-a-Can) grow!



Chapter 4: Why are plants awesome?

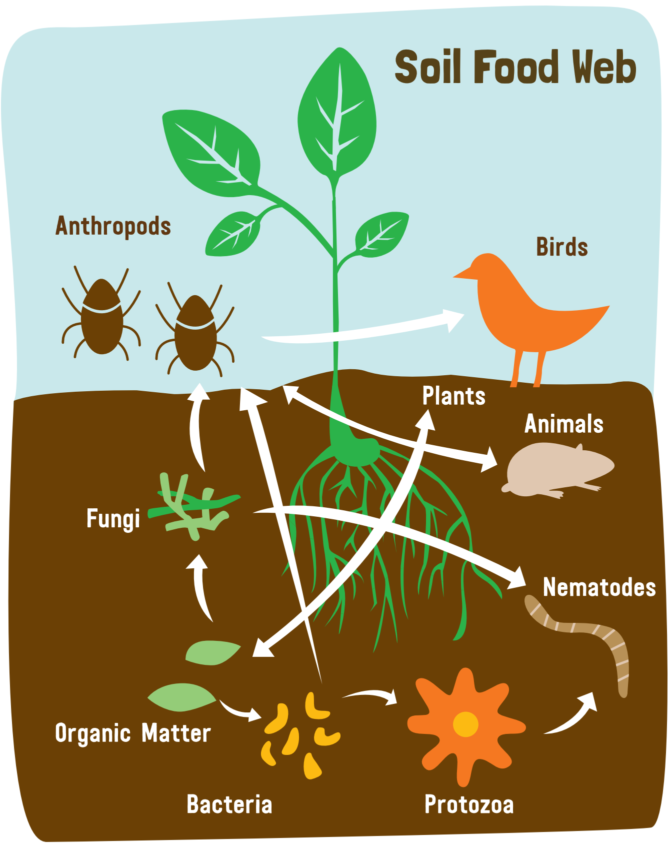
Foundation of Ecosystems

One of the most incredible things about plants is that they harness the power of the sun and use it to make their own food. As we've learned, this process is called photosynthesis. As part of the process, they also remove carbon dioxide from the atmosphere and put out oxygen. In doing this, they create the basis for almost all other life and serve as the foundation, or primary producers, of all ecosytems.



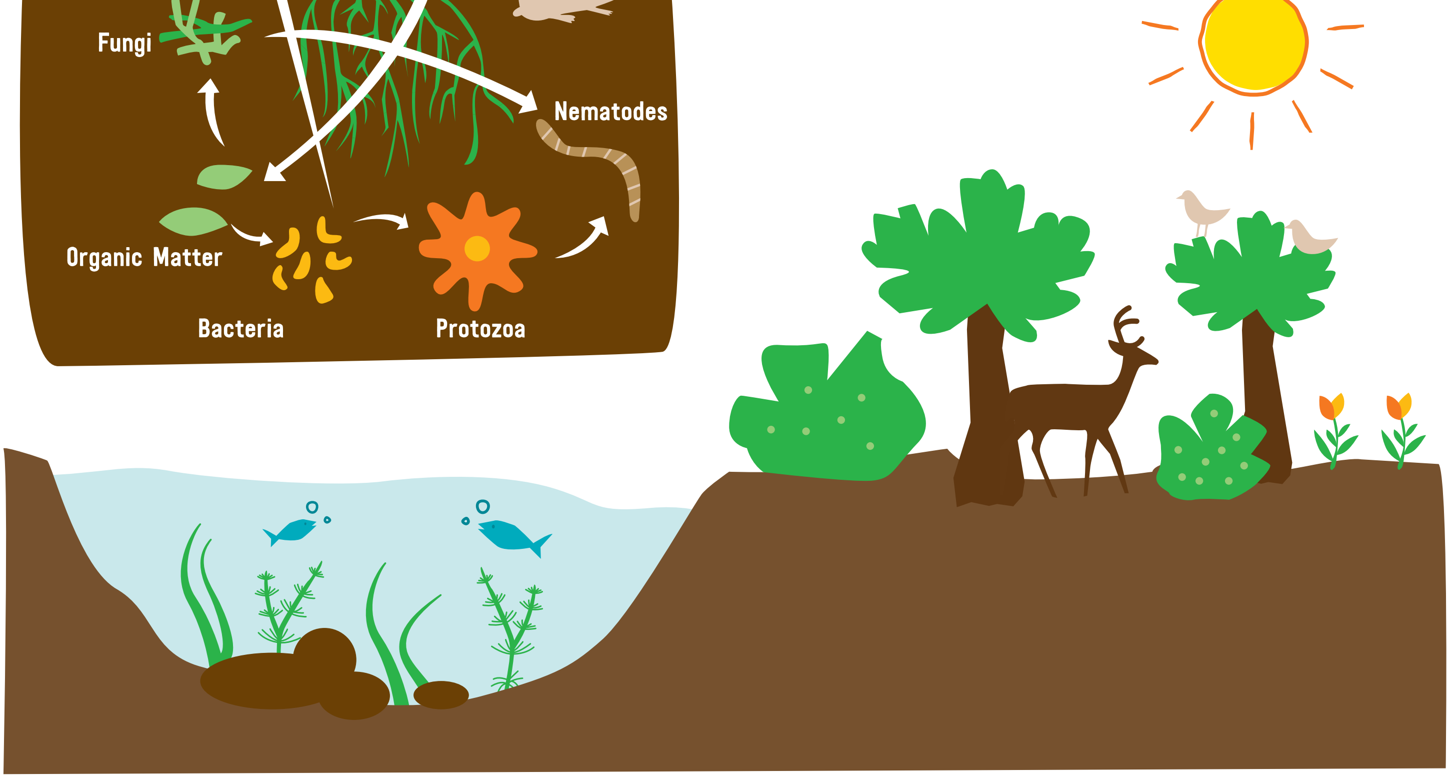
Soil Food Web

The soil food web is an ecosystem within the soil, centered around plants. Through photosynthesis, plants allow other organisms to feed off of them and provide shelter for many organisms, big and small. Plants also rely heavily on the other interactions happening around their roots in the soil to make nutrients available, fight pathogenic bacteria and fungi, and ultimately to decompose their dead structures to recycle the nutrients for the next generation of plants.



Diversity

The Kingdom Plantae is amazing in its incredible diversity and the way in which each phylum has uniquely evolved to eat and reproduce. As a result, plants are virtually everywhere on earth and include over a million species in a variety of environments and appearances! A bean, green algae, and a redwood tree are all exampls of plants. How do they differ? How are they the same?



Vocabulary

ADAPTATION (ad·uh·p·tey·shuh·n) A change in an organism

ANGIOSPERMS (an·jee·uh·spurm) Flowering plants

ANTHER (an·ther) The part of a flower that holds the pollen

BIOCHAR (bahy·oh·chahr) The charred remains of plant material that is created through the process of pyrolysis

BOTANIST (bot·n·ist) Someone who studies plant life

BIOFUEL (bahy·oh·fyoo·uh·l) Fuel extracted from plants

CELL (sel) The smallest unit of an organism

CELL WALL (sel wawl) The outer structure of a plant cell

CELL MEMBRANE (sel mem·breyn) A barrier that holds cells together

CHLOROPLASTS (klawr·uh·plast) Part of the plant cell that conducts photosynthesis

COMPACTION (kuhm·pak·shuh·n) The process by which nature wears on soil, often through rain, wind, and other conditions, to pack it down

COTYLEDON (kot·l·eed·n) The first leaves of a plant

DOUBLE FERTILIZATION (duhb·uh l fur·tl·uh·zey·shuh·n) A process unique to flowering plants where two pollen grains fertilize a female ovule and a neutral ovule to make the seed and seed coat

ECOSYSTEM (ee·koh·sis·tuh·m) All of the organisms in a given environment

Vocabulary

EMBRYO (em·bree·oh) A fertilized egg that makes a baby plant

EVOLUTION (ev·uh·loo·shuh) Theory that species slowly change over time to make them better suited to compete and survive in their environment

FERTILIZATION (fur·tl·uh·zey·shuh·n) The process in which the pollen and ovule combine to form an embryo

GAMETE (gam·eet) The male reproductive part of the plant that holds half of the information needed to create a new plant

GERMINATION (jur·muh·ney·shuh·n) The earliest stage of plant growth when the plant sprouts from the seed

GLOBAL WARMING (gloh·buh·l wawrm·ing) The rise of global temperatures that cause other global climate changes

GREENHOUSE EFFECT (green·hous ih·fekt) A natural phenomenon where heat is trapped within the earth's atmoshpere

HERBS/HERBACEOUS (urb / hur·bey·shuh·s plahnt) Seed-bearing plants with a fleshy stem that dies after flowering

ORGAN (awr·guh·n) A group of tissues in a structure with a specific function

ORGANELLE (awr·guh·nel) Part of a cell that performs a specific function

OVARY (oh·vuh·ree) The gland where ovules are produced

OVULE (ov·yool) The female reproductive part of the plant that holds half of the information needed to create a new plant

Vocabulary

PHOTOSYNTHESIS (foh·tuh·sin·thuh·sis) The process by which a plant's leaves absorb sunlight and convert its energy into sugar to feed the plant as it grows

PHOTOTROPISM (foh·to·truh·piz·uh·m) The growth and bending of plants towards or away from sunlight

PLANT (plahnt) Organisms of the Kingdom Plantae made up of many cells that produce their own food through photosynthesis

POLLEN (pol·uh·n) The yellow dusty grains in the center of a flower that produce the male gamete

POLLINATOR (pol·uh·neyt·ter) Organisms that move pollen down the pollen tube to enact fertilization

PORE/POROUS (pohr / pawr·uhs) A small hole / full of small holes

PYROLYSIS (pahy·rol·uh·sis) The burning of plant material at a very high heat

SEED COAT (seed koht) The layer surrounding a seed that protects it from outside conditions and feeds the seed

SEED PLANT (seed plahnt) Plants that produce a protected seed

SOIL AMENDMENT (soil uh·mend·muh·nt) A substance that is added to soil to help plants grow

SOIL FOOD WEB (soil food web) An ecosystem in the soil centered around plants

STIGMA (stig·muh) The sticky landing pad at the top of the pollen tube that receives the pollen

STOMATA (sto·ma·ta) Tiny structures on the underside of a leaf that allow the plant to breathe

Vocabulary

TISSUE (tis·sue) A group of similar cells

TOTIPOTENT (to·ti·po·tent) The ability of new cells to develop into any organ as the plant grows

TRANSPIRATION (tran·spuh·rey·shuh·n) Evaporation of water from plant leaves

VACUOLE (vak·yoo·ohl) Part of the plant cell that holds water and nutrients

VASCULAR PLANTS (vas·kyuh·ler plahnt) Plants with a piping mechanism to move water upward throughout its structure

VEGETATIVE PROPOGATION (veg·e·ta·tive prop·a·ga·tion) The ability of certain plants to produce an entirely new plant from a stem cutting