



Too Much? Too Little?

Grades 5-8

Editor
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Agriculture in the Classroom

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California Foundation for Agriculture in the Classroom

Vision: An appreciation of agriculture by all.

Mission: To increase awareness and understanding of agriculture among California's educators and students.



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Thank you for recognizing the importance of helping students understand and appreciate agriculture. We hope you find this resource useful in your teaching endeavors.



Unit Overview

Unit Length

Eleven lessons of varying length. Some lessons will require ongoing investigation and will extend over the course of one or two weeks.

Objectives

Students will:

- ▶ Identify soil components
- ▶ Analyze how plant growth is affected by soil type
- ▶ Determine plant nutrient deficiencies
- ▶ Demonstrate how various quantities of plant nutrients affect plant growth
- ▶ Analyze the contents of fertilizers
- ▶ Research different methods for maintaining and improving soil quality for plant growth
- ▶ Analyze how political decisions affect humans and the environment

The framework for California public schools emphasizes the need to make education meaningful to students so they can apply what they learn in the classroom to their daily lives. Since all students eat food and wear clothing, one natural connection between academic education and the real world is agriculture.

Agriculture is an important industry in the United States, especially in California. As more rural areas become urbanized, the ability to maintain existing farmland and feed the people of the world becomes a greater challenge. As such, it is important to educate students about their environment, science, and agricultural innovation.

Brief Description

Too Much? Too Little? is an eleven-lesson unit created to introduce fifth-through eighth-grade students to the connection between soil nutrients and the food they eat. The lessons consist of a series of demonstrations and hands-on experiments that show that plants require nutrients in certain quantities. Students will investigate soil properties, learn how to properly prepare fertilizer nutrient solutions, identify deficiencies in plant nutrients using a key, and much more. At the end of the unit, students will use their knowledge to vote on mock ballot propositions that relate to agricultural issues. Many lessons provide opportunities for cooperative learning by suggesting that students work in pairs or as teams.

California Standards

A concerted effort to improve student achievement in all subject areas has impacted education throughout California. California Foundation for Agriculture in the Classroom provides educators with numerous resource materials and lessons that can be used to teach and reinforce the current standards for California Public Schools, including Common Core State Standards, Next Generation Science Standards and Content Standards for Visual and Performing Arts. The lessons encourage students to think for themselves, ask questions, and learn problem solving skills while exploring information and scenarios needed to better understand the world in which they live.

This unit, *Too Much? Too Little?*, includes lessons that can be used to teach and reinforce many of the educational standards in grades five through eight. The lessons can be used separately or together and may be taught in any order. A matrix chart showing how the entire unit is aligned with the standards is included on pages 143-154.

Unit Overview

Evaluation

This unit incorporates numerous activities and questions that can be used as evaluation tools, many of which can be included in student portfolios. With an emphasis on student inquiry, few lessons have “right” or “wrong” answers, but rather engage students in thinking critically about their learning experience and applying what they learn to real-life experiences. Embedded assessment includes oral and written responses to open-ended questions, group presentations, and other knowledge-application projects.

Visual Display Ideas

- ▶ Create a Plant Nutrients chart that lists the necessary nutrients for healthy plant growth. Include a picture of a possible source of each nutrient.
- ▶ Create a living “KWL” chart that documents what students know (K), want to know (W), and learned (L).
- ▶ Make a unique display of new words your students learn. Create a word wall by matching up new vocabulary words with a photo or illustration as a visual definition.
- ▶ Create a bulletin board display titled “What is a Fertilizer?” Have students fill the board with examples as they learn about fertilizers and why they are important.

Before You Begin

1. Skim over the entire unit. Make appropriate changes to the lessons and student worksheets to meet the needs of your students and to match your personal teaching style.
2. The following resources may be helpful in learning about various plants and plant nutrients:
 - ▶ California Foundation for Agriculture in the Classroom’s *Teacher Resource Guide*. This guide provides recommendations for lessons, activities, field trips, information sources, and literature that relate to agriculture. The *Teacher Resource Guide* is available online at www.LearnAboutAg.org/trg.
 - ▶ California Department of Food and Agriculture’s website, www.cdfa.ca.gov. This site contains general and specific information on various aspects of agriculture.



Unit Overview

- ▶ California Farm Bureau Federation's website, www.cfbf.com. This site has articles on current issues in agriculture as well as agricultural information on each county.
 - ▶ The agricultural organizations listed on pages 129-138.
3. Read "Answers to Commonly Asked Questions" on pages 123-128 for information that will help you gain a thorough understanding of the goals, objectives, and content of the unit. Also review the glossary on pages 155-161. Use these definitions with your students as you see appropriate.
 4. Arrange classroom visits from people involved in the plant health industry. Guest speakers may include farmers, ranchers, soil scientists, compost specialists, and fertilizer specialists.
 5. Organize appropriate field trips. Possibilities include nurseries, farms, greenhouses, compost centers, and landfills.
 6. Obtain supplies shown in the "Materials" list included at the beginning of each unit.



Unit Overview

Key Vocabulary *(Glossary on page 155)*

Abiotic	Fungi	Pollen
Acidic	Germination	Pollination
Alkaline	Green manure	Potash
Amendment	Habitat	Potassium
Anther	Heterogeneous	Primary nutrients
Arable	Homogeneous	Producer
Assimilation	Humus	Reproduction
Bacteria	Hydroponics	Root
Biodegradable	Hypothesis	Root hairs
Biotic	Leaf	Saline
Carbon dioxide	Loam	Sand
Carpel	Legume	Secondary nutrients
Cell	Macronutrients	Seed
Chlorophyll	Manure	Sepal
Chloroplast	Mesocarp	Sidedress
Clay	Micronutrients	Silt
Compost	Mixture	Soil
Conservation	Monocot	Soil amendment
Consumer	Mutualism	Soil horizon
Control	Nitrogen	Soil porosity
Cotyledon	Nitrogen-fixation	Soil profile
Crop rotation	Nodule	Soil texture
Decomposer	N-P-K	Solution
Decomposition	Nutrients	Solute
Deficiency	Organelle	Solvent
Dicot	Organic matter	Stamen
Dilution	Organism	Stem
Embryo	Ovule	Stigma
Endocarp	Oxygen	Stomata
Exocarp	Parts per million (ppm)	Symbiosis
Fertilizer	Petal	Sustainable agriculture
Filament	Phloem	Transpiration
Flower	Phosphorus	Topsoil
Food chain	Photosynthesis	Xylem
Food web	Phototropism	Yield
Fruit	Plant	

Plant Parts and Functions

Purpose

In this lesson students will learn about plant parts and how they function in plant growth and reproduction.

Time

Teacher preparation:
45 minutes

Student activities:
Two 60-minute sessions

Materials

For teacher demonstration:

- ▶ Celery or white carnation flowers
- ▶ Red or blue food coloring
- ▶ Two glass jars filled with water
- ▶ Potted plant
- ▶ Clear plastic bag
- ▶ Twist tie

For each group:

- ▶ 2-3 different types of leaves
- ▶ Clear nail polish
- ▶ Clear tape
- ▶ Microscope
- ▶ Elodea leaves
- ▶ 4 slides and coverslips

Background Information

Plants are vital to life on Earth. Plants are known as producers because they use energy from the sun to make their own food and are the main source of energy entering food chains. Sunlight energy is transferred by plants into chemical energy through the process of photosynthesis. Consumers like deer, humans, and mice eat plants and that energy gets transferred from one organism to another through the food chain.

Plants come in all shapes and sizes and can be found on mountain tops, in valleys, deserts, fresh and salt water—almost everywhere on Earth. Some plants, like the Giant Sequoia tree, are enormous while other plants, like the weeds growing in between sidewalk cracks, are tiny. There are carnivorous plants that trap and digest insects and animals as large as rats. The largest flower in the world, the Corpse Flower, *Amorphophallus titanum*, is also one of the smelliest. This flower can grow up to 20 feet tall and 16 feet wide, and it attracts flies, which are its pollinators, with an aroma of rotting meat.

Plants provide us with food, clothing, medicine, shelter, and oxygen. Everything we eat comes directly or indirectly from plants. Each part of the plant plays a specific role. Plants hold soil in place with their roots, and roots anchor the plant in the soil and absorb nutrients. Leaves act as food factories by capturing sunlight energy and transforming it into food for the plant through photosynthesis. Flowers are involved in plant reproduction. This lesson provides activities for students to explore the structure and function of plant parts.

Procedure

1. Set up the following class demonstrations to introduce plant parts and functions.
 - a. Bring a potted plant to class and have the class observe the plant. Next, cover one branch and its leaves with a clear plastic bag and make a tight seal around the branch. Ask students to look at the branch, leaves, and plastic bag as soon as it has been attached. Water the plant as needed and observe the bag over the next couple of days. Condensation should develop inside the bag. Ask students to tell you why this is happening. This is an easy way to demonstrate transpiration from the leaves.
 - b. To demonstrate the function of xylem, put cut stalks of celery in clear jars with water. Add red or blue food coloring to one



Plant Parts and Functions

For each student:

- ▶ *Plant Parts and Functions* handout (pages 13-16)
- ▶ *Plant Parts and Functions Lab* handout (pages 17-19)

California Standards

5th Grade

Common Core English Language Arts

- RI.5.1
- RI.5.2
- W.5.2a
- SL.5.1

Next Generation Science Standards

- 5-PS3.D
- 5-LS1-1
- 5-LS1.C
- 5-LS2.A
- 5-LS2.B

6th - 8th Grade

Common Core English Language Arts

- SL.6-8.1
- RST.6-8.2
- RST.6-8.3
- RST.6-8.4
- WHST.6-8.1e
- WHST. 6-8.4
- WHST. 6-8.7

Next Generation Science Standards

- MS-PS3.D
- MS-LS1.A

jar. Have students observe the celery over the next day. Ask them why the leaves of one stalk of celery are turning the color of the food coloring. White carnation flowers may also be used for this demonstration.

- c. Both of these demonstrations lead into the student handout, *Plant Parts and Functions*. Go over this informational handout together as a class.

2. Review *Plant Parts and Functions Lab*.

- a. Lead students in a demonstration of set up for the Stomata Observation activity and facilitate a discussion of the questions to be answered in the activity.
- b. Lead students in a demonstration of set up for the Chloroplast Observation activity and facilitate a discussion of the questions to be answered in the activity.

Optional: Show students the labeled diagram of an Elodea cell.
www.exploratorium.edu/imaging-station/students/elodea.html

3. After students have completed the Stomata and Chloroplast Observations, have a class discussion about what students observed. Draw labeled diagrams on the board to reinforce specific plant structures and functions.

4. As a conclusion to your discussion, ask students the following riddles about plants they eat.

- a. My taproot gathers nutrients from the surrounding soil. I am orange and I have feathery green leaves with veins in a netted pattern. Rabbits and people like to eat me.
What am I? *carrot*
What plant part am I? *root*
- b. I transport water, nutrients, and food the plant makes for itself. I have tubes that act as roadways for water, nutrients, and the food I make. I have red stalks and have poisonous green leaves at the top. I am often mixed with strawberries to make a special pie.
What am I? *rhubarb*
What plant part am I? *stem*



Plant Parts and Functions

California Standards (cont.)

6th - 8th Grade (cont.)

Next Generation Science Standards (cont.)

MS-LS1.B
MS-LS1.C
MS-LS2.A
MS-LS2.B

Standards descriptions are listed
in the matrix on page 143.

- c. I attract insects so that I can become pollinated and produce seeds. I am white and a member of the cabbage family. Some people say I look like clouds.
What am I? *cauliflower*
What part of the plant am I? *flower*
- d. I have lots of iron. I use sunlight, carbon dioxide, nutrients, and water to make food for myself and the rest of my plant parts. I go well with salads. Popeye is a big fan.
What am I? *spinach*
What plant part am I? *leaf*
- e. If planted and the conditions are right, I will grow into a tree. I have a light tan shell that easily splits in two and greenish colored nut. I grow on trees and have become a popular nut to grow in California. I start with a "P."
What am I? *pistachio*
What plant part am I? *seed*
- f. I am the yellowish-orange fleshy substance around a large seed. I protect the seed and encourage insects or larger animals to eat me so that my seeds can be dispersed. I have fuzzy skin.
What am I? *peach*
What plant part am I? *fruit*

Variations

- ▶ If materials for Chloroplast Observation activity are not available, project the following website on the board and play the video clips of chloroplasts moving inside the Elodea leaf cells and have students answer the lab questions.
www.exploratorium.edu/imaging-station/students/elodea.html
- ▶ Have students draw their own plant, label the parts, and describe the functions of each plant part.
- ▶ Begin the lesson by making a KWL chart with your class. Have students copy the chart onto a piece of notebook paper. Conclude with a class exercise to complete the chart, filling in any of the blank spaces that were not filled in at the beginning of the lesson.

Plant Parts and Functions

Extensions

- ▶ Divide students into groups and assign each group to be experts on one plant part and function. Groups should research their plant part and make a short presentation with a slideshow presentation or poster board to provide the class with in-depth information about their assigned plant part. The group should also bring in several different examples of that plant part from different plants.
- ▶ Carefully dissect and observe various plant parts. Pull weeds and observe root systems. Observe a celery stock and learn about stems. Cut an apple in half and observe the fruit anatomy. Dissect a roasted peanut or soaked lima bean.
- ▶ Make an edible plant part salad. Discuss which of the parts the class is eating and the function of each part.

ELL Adaptations

- ▶ This lesson incorporates hands-on activities. Kinesthetic learning events provide an excellent learning environment for English language learners.
- ▶ Demonstrate all lab procedures to the class before they begin the lab.
- ▶ Add new vocabulary to a word wall and match photos to the new words.

Plant Parts and Functions

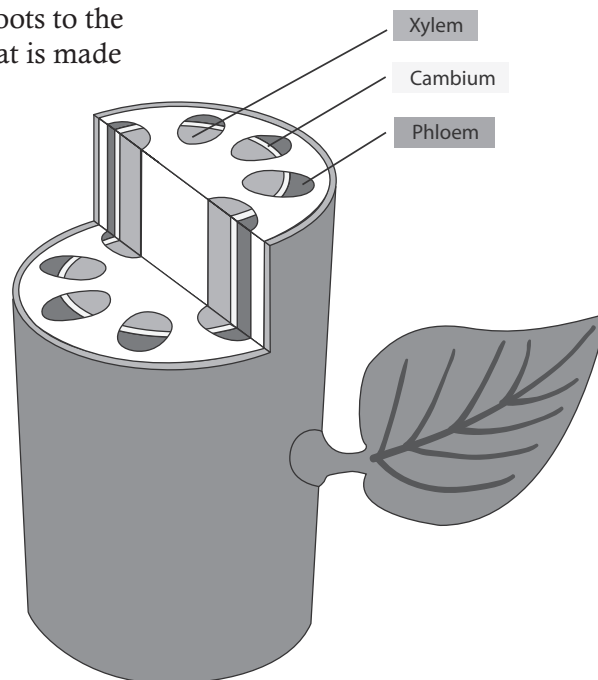
Roots anchor plants in soil, store food, and absorb nutrients and water. Different types of plants have different types of roots. If you pull up a tuft of grass you will see that it has fibrous roots. If you pull up a carrot you will see that it has a tap root. Root hairs are tiny roots that grow off the root tips and increase the area for water and nutrient absorption



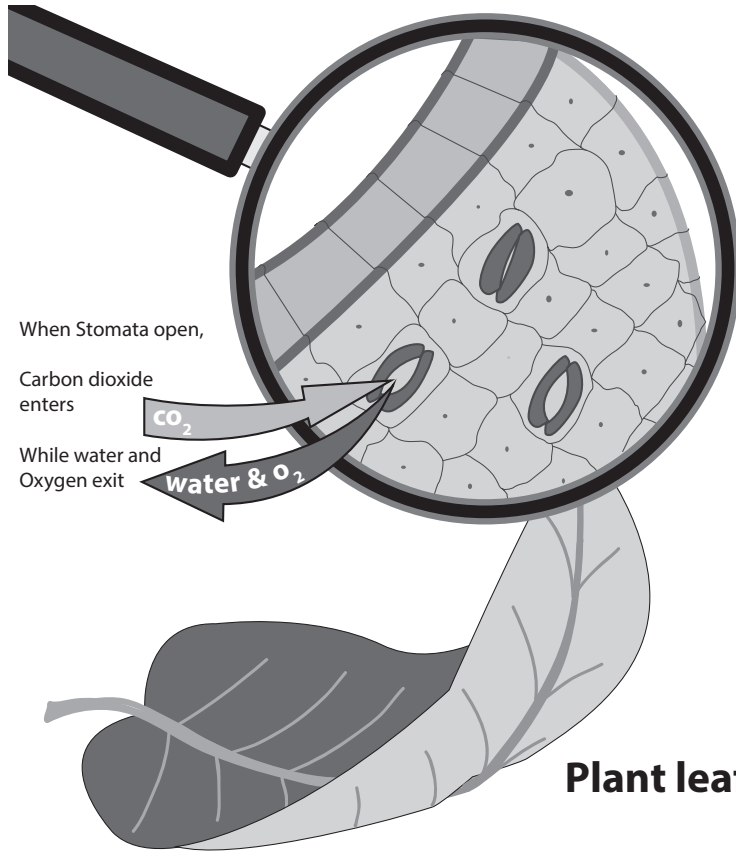
Stems support the upper part of the plant. The stem houses the xylem cells that transport water and dissolved nutrients from the roots to the rest of the plant and the phloem cells that transport food that is made in the leaves to the rest of the plant.

Leaves capture sunlight energy so the plant can make its own food through photosynthesis. **Chloroplasts** are the specific organelles within leaf cells that are responsible for photosynthesis. Green chlorophyll pigment captures sunlight energy for the chemical reactions that take place during photosynthesis to turn water and carbon dioxide into plant food and oxygen.

Stomata are tiny pores that regulate the passage of oxygen, carbon dioxide, and water vapor into and out of the cells. Stomata are invisible to the naked eye and are usually found on the underside of leaves, surrounded by two jelly bean-shaped guard cells that regulate the opening and closing of the stomata.



Plant Parts and Functions *(continued)*

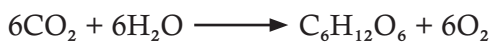


The illustration to the left shows a magnified view of stomata on the underside of a leaf. When the stomata are open, carbon dioxide can enter the leaf while water and oxygen can exit the leaf.

During hot, sunny days, stomata close in order to prevent water loss from the plant.

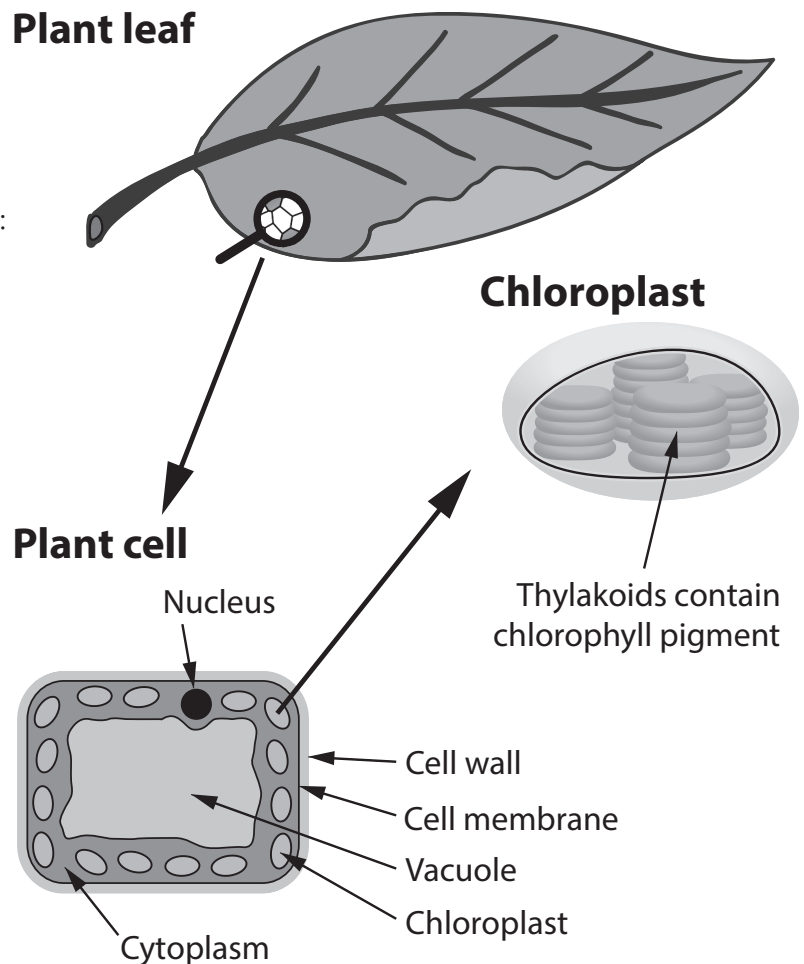
Plant leaf

The balanced equation for photosynthesis is:



The illustration to the right is a section of a plant leaf magnified to show an individual plant cell. Chloroplasts are the oval shaped organelles along the perimeter of the cell wall.

If you were to look inside a chloroplast, you would see stacks of disks called thylakoids which contain green chlorophyll pigment.



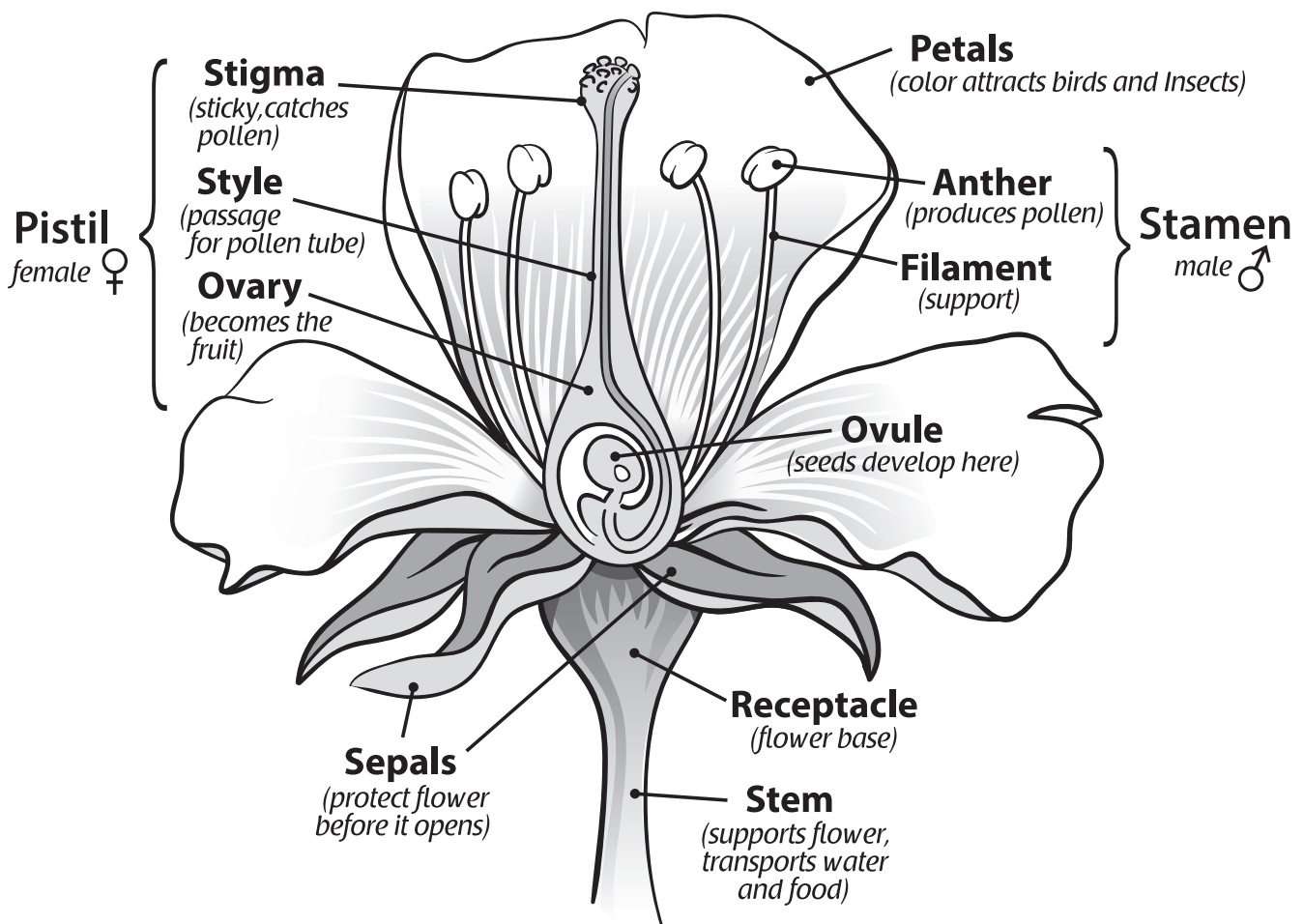
Chloroplast

Plant cell

Plant Parts and Functions *(continued)*

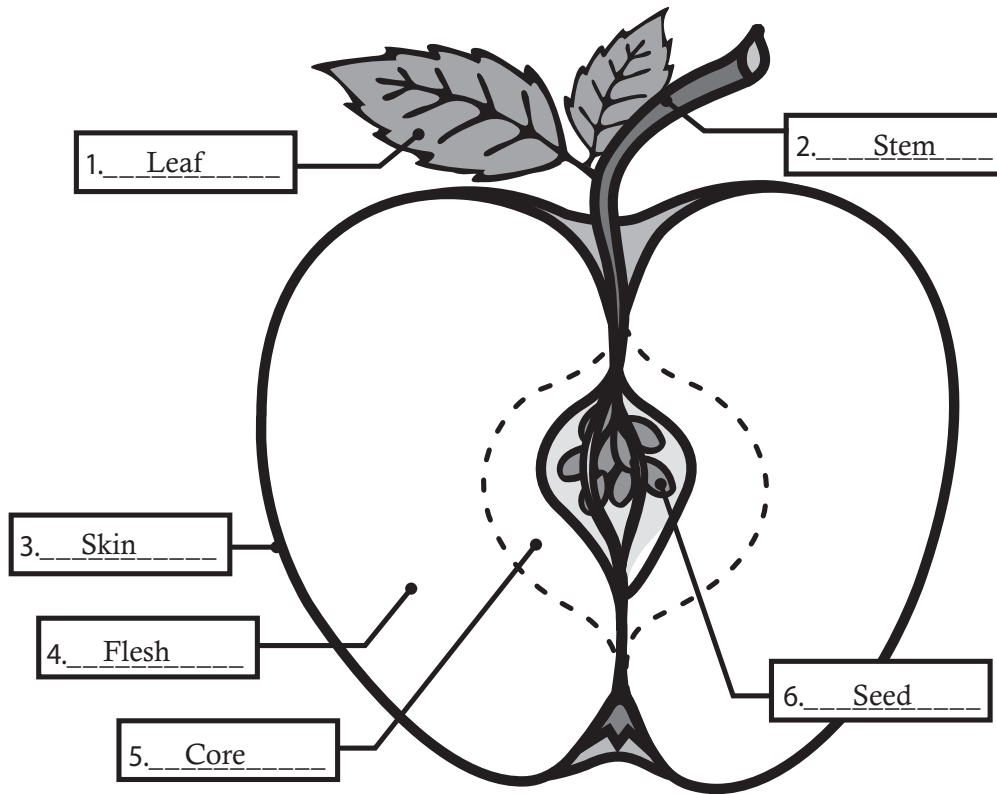
Flowers are the reproductive parts of plants. They often have showy petals and fragrances to attract pollinators such as birds, bees, and other insects. Most flowers have four main parts: petals, stamen (anther and filament), pistil (stigma, style, and ovary), and sepals. After flowers are pollinated and fertilized, they produce seeds in the ovary of the flower.

Parts of a flower

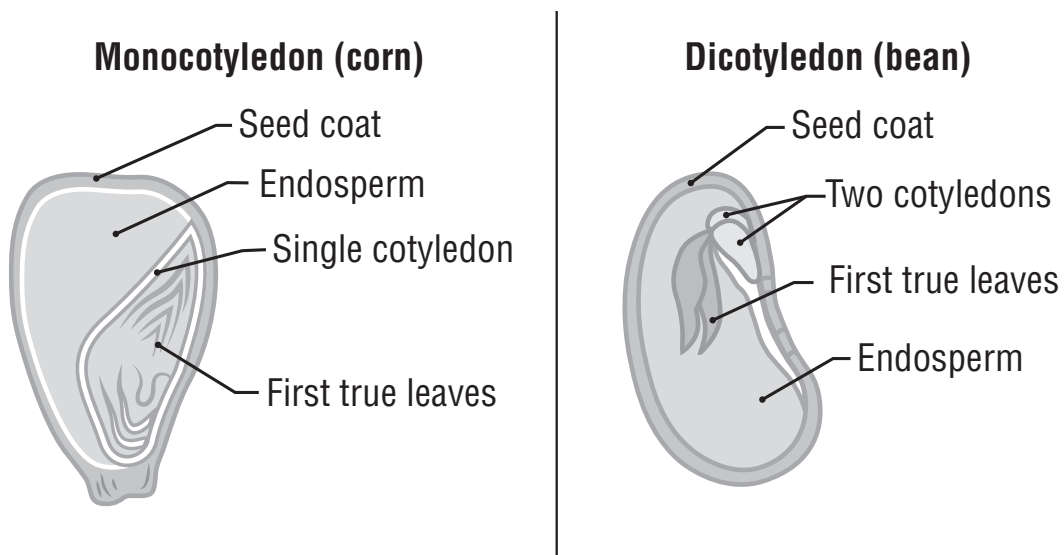


Plant Parts and Functions *(continued)*

Fruits are the fleshy substance that surrounds seeds. They protect the seeds and attract animals to eat them. This helps with seed dispersal.



Seeds contain plant material that can develop into another plant. This plant material is called an embryo. The endosperm provides food for the seed as it develops into a seedling plant. Seeds are covered with a protective seed coat and have one or two cotyledons. Cotyledons are part of the embryo and develop into the first leaves of the plant. Flowering plants are called angiosperms. The angiosperms are divided into two classes, the monocots, which have one cotyledon, or seed leaf, and the dicots, which have two cotyledons or seed leaves. Monocots have parallel leaf veins and fibrous roots, such as corn. Dicots have leaf veins that are in a netlike pattern and have taproots. Oak trees and dandelions are both dicots.



Plant Parts and Functions Lab

Name: _____

Stomata Observation

Stomata are tiny pores that allow carbon dioxide gas and water vapor to pass into and out of plant leaves. Most stomata are on the underside of the leaf. Guard cells that look like jelly beans line the sides of the stomata. These guard cells regulate the opening and closing of the stomata. On hot days, guard cells close the stomata to keep the plant from losing water and wilting. When plants lose water through evaporation from the stomata, this process is called transpiration.

Procedure

1. Obtain two to three different types of leaves.
2. Paint a thick patch of clear nail polish on the underside of each leaf and allow it to dry.
3. Put clear tape over the nail polish once it is dry and carefully peel back the clear fingernail polish. Tape this fingernail polish impression of your leaf to a clean microscope slide. Label the type of leaf that you used to make the impression.
4. Examine your slide under a microscope and search for stomata. Always begin with your microscope in the lowest magnification, focus and move up to the next magnification level if needed.
5. Sketch the leaf impression with stomata on your worksheet. Make note of the concentration of stomata. Do this for all three leaves.

Leaf 1	Leaf 2	Leaf 3

Plant Parts and Functions Lab *(continued)*

Stomata Observation

1. Compare the concentration or abundance of stomata on each leaf. Why might this be different for different types of plants?

2. What time of day would stomata likely be closed? Why?

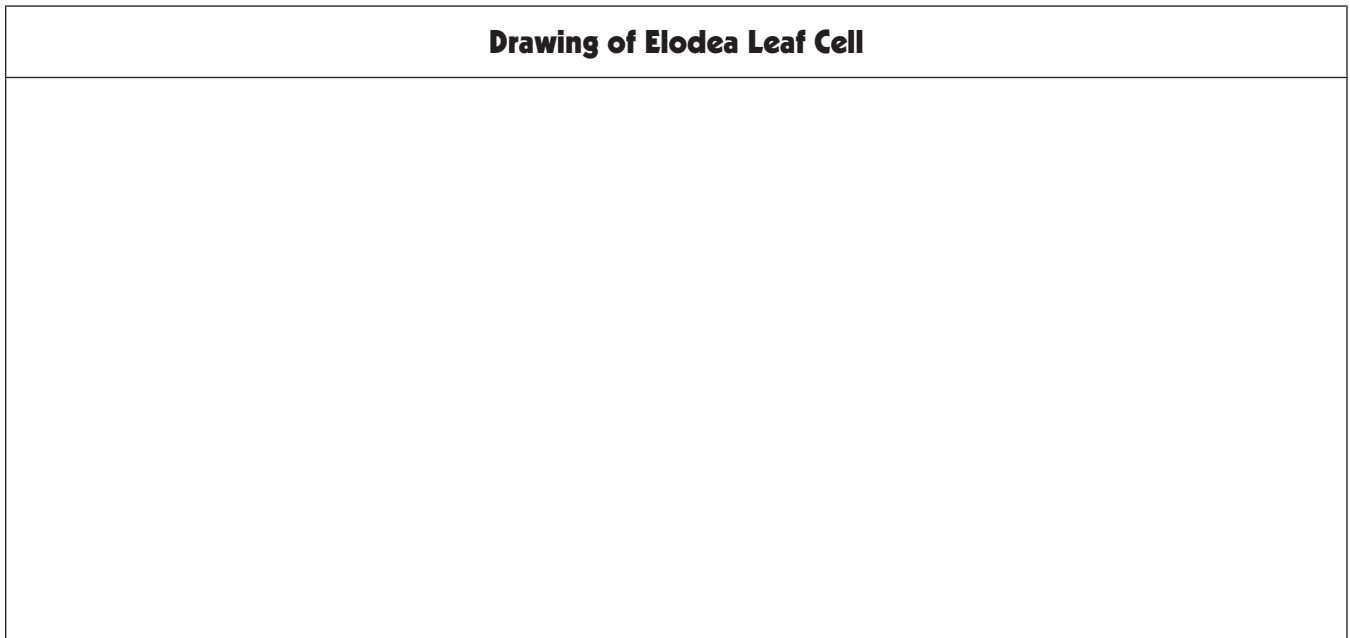
Chloroplast Observation

In this activity, you will see the food factory of the plant in action. The leaves of the Elodea plant can be examined under a microscope to view chloroplasts inside of the cells.

Procedure

- ▶ Obtain a microscope slide and place a small piece of an Elodea leaf in the center. Add a drop of water and a cover slip.
- ▶ Place the slide on the microscope stage. Always begin with your microscope in the lowest magnification, then focus and move up to the next level of magnification if needed.
- ▶ Draw the cell and label the cell wall, nucleus, cytoplasm, and chloroplasts.

Drawing of Elodea Leaf Cell



Plant Parts and Functions Lab *(continued)*

1. Why are the chloroplasts green?

2. Were the chloroplasts moving or stationary in the cell? Why?

3. What is the function of the chloroplasts?

4. Would you find chloroplasts in an animal cell? Why or why not?

5. What does a plant need in order to perform photosynthesis?

6. What does a plant produce from photosynthesis?

7. Write the equation for photosynthesis.

Plant Parts and Functions Lab Answer Key

Stomata Observation

1. Compare the concentration or abundance of stomata on each leaf. Why might this be different for different types of plants?

Some leaves may have a high concentration of stomata because they live in a wet climate where transpiration is not an issue because water is readily available to the plant. Another possibility is that the leaf is from a fast-growing plant and needs a lot of stomata to assist in material exchange for photosynthesis. Plants in a dry and arid desert climate have fewer stomata because this translates to less water loss through transpiration.

2. What time of day would stomata likely be closed? Why?

Stomata would usually be closed during the hot part of the day to prevent water from escaping through open stomata.

Chloroplast Observation

1. Why are the chloroplasts green?

Chloroplasts are green because of their chlorophyll, which is the pigment that captures the sunlight energy for photosynthesis.

2. Were the chloroplasts moving or stationary in the cell? Why?

The chloroplasts were moving because they are floating in the cytoplasm of the cell, which is constantly moving.

3. What is the function of the chloroplasts?

Chloroplasts are the organelles found in plants, and are the site of photosynthesis.

4. Would you find chloroplasts in an animal cell? Why or why not?

No, animal cells do not have chloroplasts because animals do not perform photosynthesis.

5. What does a plant need in order to perform photosynthesis?

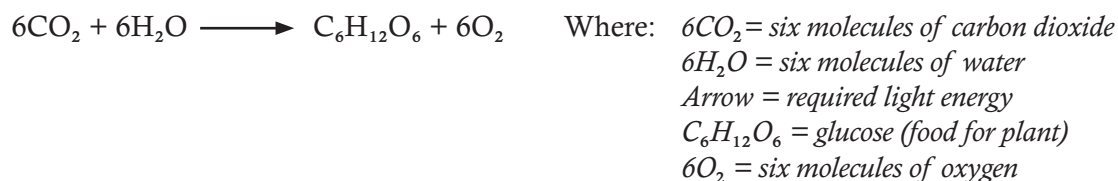
Plants need carbon dioxide, water, and sunlight for photosynthesis.

6. What does a plant produce from photosynthesis?

Plants produce oxygen and food as a product of photosynthesis.

7. Write the equation for photosynthesis.

The balanced equation for photosynthesis is:





Soil: More Than Dirt

Purpose

In this lesson students will learn that soil is more than “dirt.” They will investigate different types of soil through a hands-on lab.

Time

Teacher preparation:
20 minutes

Student activity:
Two 50-minute sessions

Materials

For the class:

- ▶ One bucket of a soil sample collected by the teacher

For each group:

- ▶ Resource materials on soil composition
- ▶ Hand lens
- ▶ Plastic spoon
- ▶ Paper cup

For each student:

- ▶ *Soil’s Soil—Or Is It?* Handout (pages 24-28)
- ▶ One sheet of white copy paper
- ▶ One soil sample collected as student homework

Background Information

Soil is defined as the top layer of Earth’s surface and is developed over time from the weathering of rocks and the decomposition of organisms. Soils consist of varying amounts of mineral materials, organic matter, water, and air. An average soil sample is 45 percent minerals, 25 percent water, 25 percent air, and 5 percent organic matter. Soil is made up of distinct horizontal layers called horizons. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith, and bedrock). The natural weathering and decomposition processes that form new top soil from parent material can take more than five hundred years to complete. Therefore, soil isn’t really a renewable resource and must be protected.

Soils are composed of particles with a variety of sizes and shapes. The smallest particles are called “clay,” midsized particles are called “silt,” and larger particles are called “sand.” These different-sized particles give soil its texture. Soil scientists have identified more than 70,000 kinds of soil in the United States. In 1997, the San Joaquin Soil Series became California’s official state soil as a result of collaboration between students and teachers from Martin Luther King Jr. Middle School in Madera, professionals from the Soil Scientists Association of California, state universities, and legislators. More than 500,000 acres of San Joaquin Soil Series have been mapped in California’s Central Valley. It is very fertile soil and has produced an abundance of agricultural crops in California including wheat, rice, almonds, figs, citrus, and grapes, and provides pasture land for livestock.

It is important for students to realize that soil does not only consist of inorganic substances such as clay, sand, and rocks. Organic materials—such as decayed plants, animals, and microorganisms, are also important soil components, as well as air and water. Fungi and bacteria help break down organic matter in the soil. Plant roots and lichens break up rocks, which become part of new soil. Roots loosen the soil, allowing oxygen to penetrate. Roots also hold soil together and help prevent erosion.

Soil is an important resource. Growing our food relies on farming, which depends on having good soil. Preservation and conservation is critical. Once soil is damaged it is very hard to replace.



Soil: More Than Dirt

California Standards

5th Grade

Common Core English Language Arts

RI.5.1
RI.5.2
RI.5.4
W.5.1b
W.5.1d
W.5.9b
SL.5.1

Next Generation Science Standards

5-LS2.A
5-LS2.B
5-ESS3.C

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.2
RST.6-8.3
RST.6-8.9
WHST.6-8.1e
WHST.6-8.4
WHST.6-8.7

Next Generation Science Standards

MS-LS4.D
MS-ESS3.A
MS-ESS3.C

Standards descriptions are listed
in the matrix on page 143.

Procedure

Preparation

As a homework assignment, ask each student to bring in one cup of a soil sample for examination in class. Samples should be placed in a plastic bag and labeled with the student's name. Instruct students to dig in an approved area, and provide some extra samples for those students who may not have a place to dig for soil. The soil must be dug no more than 24 hours prior to the class activity to ensure that soil organisms will be alive for observation. Make sure students know not to use pre-packaged soil from a garden center.

Collect one bucket of soil for the whole class to use as a comparison to the samples each student has collected for homework.

Complete the following introductory activity with your students.

Have students pick up a handful of soil from their sample bag and imagine that this is the Earth's surface. Immediately have them take away three fourths of the sample and put it back into their bag. Tell them this is how much of the Earth's surface is covered by oceans, rivers, and lakes. What's left in their hand is what represents the land. Now drop one half of the remainder back into their bag. This represents desert regions, glacial poles, and mountain peaks where many things won't grow. Now drop one tenth of what is left back into the bag to account for places where the land is used for cities, towns, and roads. Tell the students that what is now left in their hand represents all the soil we have to grow crops and support life on Earth. While this activity provides a good model to help students understand that soil is a precious resource, it is an approximation of the amount of soil available for farming as these numbers constantly change.

Divide the students into groups of three or four. Each group should obtain one cup of the soil sample you have provided for the class. Each student should bring their own soil sample to share with their group. Using a hand lens, have the students observe each of the different samples and complete the *Soil's Soil—Or Is It?* handout.

Variations

- ▶ Bring in a variety of different soil samples collected from different locations rather than having the students bring samples.

Soil: More Than Dirt

- ▶ Include the following interactive online activity: The Great Plant Escape: Soiled Again www.urbanext.illinois.edu/gpe/case2/case2.html

Extensions

- ▶ Further analyze soil samples by carrying out the Shake, Rattle & Roll activity. www.LearnAboutAg.org/wegarden
- ▶ Make an edible soil model. Use a clean 1–2 quart glass jar that has a sealable lid. Ask the students to list parts of the soil one at a time. As they list the items, place a snack representative in the jar. After all of the items are mentioned and the jar is full, seal it and keep it in a secure place until an appropriate time for the class to eat the soil model. Further directions for this activity can be found on page 59 of *What Do Plants Need To Grow?* www.LearnAboutAg.org/lessonplans/?details=401
- ▶ Research the natural disaster of the Dust Bowl and explain how modern farming practices and soil conservation were developed as a result of the impact of the Dust Bowl. Have the students make a list describing soil conservation techniques that helped farmers recover from the Dust Bowl. The following videos, slideshows, and books can help with research.
 - www.history.com/topics/dust-bowl
 - www.nature.org/ourinitiatives/regions/northamerica/when-the-dust-settled.xml
 - Garland, Sherry. *Voices of the Dust Bowl*. Pelican Publishing Company, 2012. This collection of representative narratives describes what life was like during the dust bowl. ISBN 978-1-58980-964-2
 - Lassieur, Allison. *The Dust Bowl: An Interactive History Adventure*. Capstone Press, 2009. This book catapults readers into the 1930s, where they will reel from the effects of the Great Depression. Readers make decisions that determine the ending of their story. ISBN 978-1-4296-2343-8

ELL Adaptations

- ▶ Demonstrate how student groups should dig and inspect their soil samples. Pair ELL students with other students who will model instructions.
- ▶ Add new vocabulary to a word wall and match photos to the new words.

Soil's Soil—Or Is It?

Name: _____

Introduction to Soil

The soil is the outermost layer of the Earth's surface. Soil is made up of a variety of substances, not just "dirt." These substances are categorized into four main groups: organic materials, also called biotic materials because they came from once living organisms; inorganic materials, also called abiotic because they are made up of material that was never living; air and water.

Organic material makes up only a small portion of the soil, yet it is very important. The organic material is composed of living plants and animals, decayed plants and animals, and the nutrients that come from these decomposed plants and animals. Fungi and bacteria are also part of the living organisms that make up soil. The amount of life present in a soil sample is surprisingly large. In just a handful of dirt you could be holding trillions of microscopic organisms!

The inorganic material in soil represents about half of the mass of most soils. These inorganic materials are the sand, silt, and clay that we commonly call "dirt." These particles are formed as rocks are weathered.

Most soils have a combination of soil particle sizes. Some particles can be seen by the naked eye, and some are microscopic.

The rest of the soil is composed of air and water that fills the connecting spaces between the particles. The amount of air and water in soil varies throughout the year and from one location to another.

Soil has distinct horizontal layers called soil horizons. Horizons in soil range

Decaying Leaves

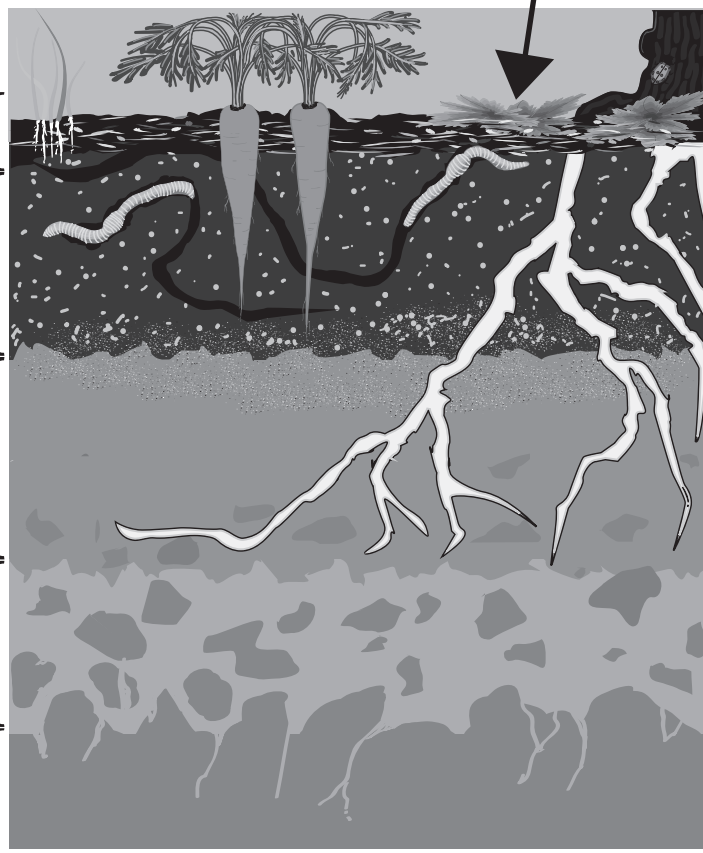
O Horizon
Surface litter

A Horizon
Topsoil

B Horizon
Subsoil

C Horizon
Parent material

Bedrock

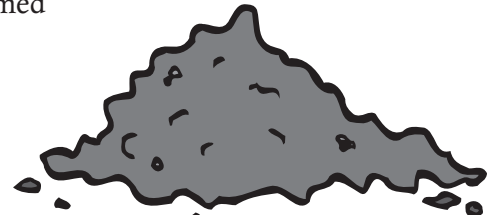


Soil's Soil—Or Is It? *(continued)*

from organic rich surface layers (humus and topsoil horizons) to underlying layers high in rock content (subsoil, regolith, and bedrock).

Topsoil is one of our most valuable natural resources. Topsoil is the upper layer of soil, usually the top two to eight inches. It contains the highest concentration of organic matter and microorganisms and is often a dark brown color. The topsoil is where plant roots grow. It provides vital support, structure, and nutrients. Everything from the smallest wildflower to gardens, shrubs, trees, and agricultural crops depend on the topsoil. In return, plant roots help prevent erosion of topsoil and provide the spaces for air and water to go.

It is important to protect and conserve the Earth's topsoil because without it we could not grow our food. Soil, plants, and animals, including humans, are all interconnected. Energy entering the ecosystem as sunlight is transformed by plants into food for plants and other organisms up the food chain. Decomposers break down dead plant and animal material and return the nutrients to the soil for use by plants. If soil is not productive, it can't support producers and this has an effect on all other organisms that depend on producers for food.



Activity

Take two samples of soil. One you will have collected on your own and the other is provided by your teacher. On a piece of plain white paper, carefully examine each of the samples with your unaided eye and then with a hand lens. Describe and sketch what you see.

Once you have observed these two samples, examine two other samples that members of your group have provided.

Examples of descriptive terms for your soil could include moist, sticky, slippery, dry, gritty, and rocky. Describe any plant debris such as leaves, roots, and bark that could be in your soil sample. Also describe any visible microorganisms.

- ▶ **Sand** has a gritty feel and individual particles of sand can be seen with the naked eye. If you rub a sample between your fingers it will not leave a residue.
- ▶ **Silt** has a powdery, smooth feel when it is dry, and is creamy or slippery when wet. It may leave a residue on your fingers that can be easily brushed off. Silt doesn't feel sticky. You can see individual particles of silt with a hand lens or microscope.
- ▶ **Clay** feels hard when dry and has a sticky-plastic feel when wet. It may stain your fingers. Individual clay particles can only be seen with a microscope.

If you compare the size differences of sand, silt, and clay to sports equipment, sand would be a basketball, silt would be a baseball, and clay would be a golf ball.

Why do farmers and home gardeners care about soil texture or the different amounts of sand, silt, and clay in their soil?

The texture of soil can tell us how well the soil will be able to absorb and retain water and nutrients for plants to use. A soil with roughly equal amounts of sand, silt, and clay are desirable for growing plants because they have just the right capacity for holding water and nutrients.

Soil's Soil—Or Is It? *(continued)*

Observations

Description of Your Soil Sample	Sketch
Description of Teacher's Soil Sample	Sketch

Soil's Soil—Or Is It? *(continued)*

Description of _____ Soil Sample	Sketch
Description of _____ Soil Sample	Sketch

Soil's Soil—Or Is It? *(continued)*

Conclusion

After examining all of the samples, answer the following questions.

1. List the items that make up your soil and categorize them into abiotic and biotic components:

Abiotic	Biotic

2. What descriptive words best explain your soil's texture and ingredients?

3. Which of the soil samples you observed do you think would be the best for growing a seed? Explain why.

4. Why are microorganisms such as bacteria, fungi, and insects so important in soils?

5. Write a concluding paragraph that describes the purpose of this lab. Include at least two things you learned about soil and one additional idea for studying soil.

Soil's Soil—Or Is It? Answer Key

1. List the items that make up your soil and categorize them into abiotic and biotic components:

Abiotic	Biotic
<p><i>(Non-living)</i></p> <p><i>rocks, sand, silt, clay, water, air</i></p>	<p><i>(Living or once living)</i></p> <p><i>worms, insects, plants and plant parts</i></p>

2. What descriptive words best explain your soil's texture and ingredients?

Gritty, smooth, coarse, sticky, slippery, dry, moist, spongy, descriptions of colors, etc.

3. Which of the soil samples you observed do you think would be the best for growing a seed? Explain why.

Answers will vary but students should know that a soil with a mixture of components that includes organic matter and roughly equal parts sand, silt, and clay would be a good choice for planting a garden.

4. Why are microorganisms such as bacteria, fungi, and insects so important in soils?

These organisms are decomposers. They break down plant and animal waste and recycle these nutrients so they are available for plants to use.

5. Write a concluding paragraph that describes the purpose of this lab. Include at least two things you learned about soil and one additional idea for studying soil.

Answers will vary. Students should describe what they learned about soil components and why soil is so important. Ideas for further soil studies could include inviting a farmer or soil specialist in to talk about soil conservation techniques on farms.



Soil Experiments

Purpose

In this lesson, students will learn that not all soil types are the same. Different soils provide different levels of nutrients for plant growth. A class experiment will explore the best soil for growing bean plants.

Time

Teacher preparation:

Three weeks to grow seedlings,
one hour to prepare soil samples

Student activity:

Two 50-minute sessions

Materials

For teacher preparation:

- ▶ Fill five sets of planting cups full of each type of planting material:
 - peat moss
 - sand
 - redwood bark (smallest size)
 - dried lawn clippings
 - heavy clay soil
 - potting soil
- ▶ Two gallons of distilled water
- ▶ 30 small, paper or plastic cups
- ▶ 30 plastic sandwich bags
- ▶ Bean seeds purchased from a garden store (not for cooking)

Background Information

Soils differ in the types and amounts of nutrients available to plants. Different plants have different nutrient needs. Farmers need to know the nutrient requirements of their crops as well as the nutrients present in the soil on their farm. Farmers collect soil samples and have them analyzed for various properties that help them decide if amendments such as fertilizer and organic material should be added to the soil in order to grow healthy crops.

Soils are composed of a variety of inorganic and organic materials. Particles such as clay, sand, and rocks are the main inorganic soil particles. Organic materials include decomposing plant and animal materials. Organic materials add nutrients, help the soil resist compaction, and provide more air spaces for roots to grow. Organic particles also act like a sponge to absorb and store water and nutrients in the soil. Decomposers such as earthworms, bacteria, and fungi are living components of the soil that play an important role in recycling nutrients.

One way soil can be described is by its texture. Soil texture is the size of particles that make up the soil. From smallest to largest, the particles are clay, silt, and sand. Most soils are a combination of all three. Soil can also be described by its color. Color is a result of the parent materials or bedrock that the soils originated from. Soils that are deep orange or reddish in color are usually high in iron. Dark brown or black soils are high in organic material.

While soil texture describes the different sizes of soil particles, soil structure is how those particles are bound together to form small clumps. A soil is considered to have good structure for plant growth if the pore spaces between clumps allow for adequate air circulation and water drainage while still being able to retain some water for plant roots to absorb.

Your class will use their knowledge of soil properties and plant growth requirements to make a hypothesis about the best soil for growing bean seeds.



Soil Experiments

▶ Permanent marker

▶ Ruler

For each group:

(divide class into five groups)

▶ Plastic sandwich bags with samples of the different planting materials.

▶ One sticky note

For each student:

▶ *Soil Experiment Lab* handout

California Standards

5th Grade

Common Core English Language Arts

RI.5.1

RI.5.2

RI.5.4

W.5.1b

W.5.1d

W.5.2e

W.5.4

W.5.9b

SL.5.1

Next Generation Science Standards

5-LS2.A

5-LS2.B

5-ETS1.A

5-ETS1.B

Procedure

Complete the following steps several weeks prior to beginning this lesson with your students:

1. Obtain the materials from the list. You will be growing enough plants for five groups.
2. Put each type of planting medium in a small cup for planting. Make five sets of each of the six planting mediums. Label the cups by number. You will not reveal the actual name of each planting medium to the students until the end of the lab.
3. Plant a bean seed in each type of planting medium. Treat each sample identically and water as needed with distilled water. Do not show your students the growing plants! Continue growing until your seedlings begin to show variation, about 2–3 weeks.
4. Place a sample of each of the six planting mediums into appropriately numbered plastic sandwich bags. Make five sets, one for each group. Student groups will observe the characteristics of the planting mediums prior to seeing the bean plants that you are growing in each medium. Groups will predict which planting mediums will be best suited for growing a plant.

Class Activity

1. Ask students to recall what they have learned about soil components in previous lessons. What soil characteristics do they think are important for growing healthy plants?
2. Read the *Soil Experiment Lab* instructions together as a class. Organize students into five groups.
 - a. Distribute the six samples of planting mediums in the plastic bags to each group. Do not tell students what is in each planting medium. Instruct groups to examine each medium and write down their observations under the activity section on their *Soil Experiment Lab* handout.
 - b. Draw the columns on the board and label them as planting medium 1–6. Instruct each group to make a hypothesis about which planting medium will be the best for growing plants.



Soil Experiments

California Standards (cont.)

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1

Common Core English Language Arts (cont.)

SL.6-8.1

RST.6-8.2

RST.6-8.3

RST.6-8.9

WHST.6-8.1e

WHST.6-8.4

WHST.6-8.7

Next Generation Science Standards

MS-LS2.A

MS-LS2.B

MS-LS2.C

Standards descriptions are listed
in the matrix on page 143.

Next, ask a representative from each group to come up to the board and place a sticky note in the column that represents the soil medium that they have predicted to be the best. You will have an instant visual bar graph of the predictions.

3. After discussing the bar graph with the students, distribute a set of the bean plants grown in each of the six planting mediums to each group.
 - a. Instruct groups to record their observations of each plant under the activity section on their *Soil Experiment Lab* handout.
 - b. Discuss the results with your class and instruct them to write their concluding paragraph.

Soil Experiment Lab

Name: _____

In this lab, you will learn how different types of soil affect plant growth. Humans depend on plants for food, fiber, shelter, fuel, and enjoyment. Healthy plant growth is dependent upon healthy soil. Rock and soil particles provide many of the nutrients plants need, and decomposers recycle dead plant and animal material into nutrients that plants can use. Farmers grow crops to feed and clothe us. As the crops grow, they take up nutrients from the soil. Those nutrients are harvested with the crop and farmers must carefully monitor their soil to determine when and which nutrients must be replaced in the soil to continue growing healthy crops.

Soils are made up of a variety of inorganic and organic materials. Particles such as clay, sand, and rocks are the main inorganic soil particles. These inorganic materials are abiotic, which means they are non-living components of the environment. Organic materials include decomposing plant and animal materials. These materials are biotic, which means they are made up of living or once living organisms. Organic materials add nutrients, help the soil resist compaction, and provide more air spaces for roots to grow. Organic particles act like a sponge to absorb and store water and nutrients in the soil. Decomposers such as earthworms, bacteria, and fungi play an important role in recycling nutrients.

One way soil can be described is by its texture. Soil texture is the size of particles that make up the soil. From smallest to largest, the particles are clay, silt, and sand. In comparable sizes, if sand is a basketball, a particle of silt would be a baseball, and a particle of clay would be a golf ball. Most soils are a combination of all three. Soil can also be described by its color. Color is a result of the bedrock that the soils originated from. Soils that are deep orange or reddish in color are usually high in iron. Dark brown or black soils are high in organic material.

While soil texture describes the different sizes of soil particles, soil structure is how those particles are bound together to form small clumps. A soil has good structure for plant growth if the pore spaces between clumps allow for adequate air circulation and water drainage while still being able to retain some water for plant growth. A soil has good texture for plant growth if it has a fairly equal mix of soil particle sizes.

Below are descriptions of possible soils that farmers and home gardeners might work with. Read these descriptions to help your group analyze which soil materials presented by your teacher will be the best for growing bean plants.

Sandy Soil

Sandy soil has the largest particles among the soil textures. The particles of sand have large air spaces between them so water and nutrients drain rapidly, often before plant roots have a chance to absorb them. Plants in sandy soil need watering and fertilizing more often than plants growing in less sandy soil.

Silty Soil

Silty soil has much smaller particles and air spaces between particles, thus it holds water and nutrients longer than sandy soil.

Soil Experiment Lab *(continued)*

Clay Soil

Clay soil has microscopic particles that are much smaller than sand or silt particles. Clay soils are sometimes called “heavy soils” because their particles are packed together very closely and have little pore space for air and water. Water and nutrients drain slowly from clay soils. It may be difficult for some plant roots to penetrate densely packed clay soils.

Loamy Soil

The best soil for plant growth is loamy soil. Loam contains a balance of all three soil textures—silt, sand, and clay—plus humus, which is decomposed organic material. Loam is dark in color and is soft, dry, and crumbly. It holds on to water and plant nutrients but it also drains well, and air moves freely between soil particles for healthy root growth.

Lab Activity

Carefully observe and describe each of the six different soil mediums provided by your teacher. Note the color, texture, and structure of the soil.

Sample 1: _____

Sample 2: _____

Sample 3: _____

Sample 4: _____

Sample 5: _____

Sample 6: _____

Soil Experiment Lab *(continued)*

Think about what you know about soil and plant growth and predict which of the six soil mediums will grow the healthiest plant. As a class, discuss the characteristics of a healthy plant.

Write a hypothesis

Example: If the bean seed is planted in x planting medium, then it will grow the healthiest bean plant.

- ▶ As a group, predict which planting medium will grow the healthiest plant. Your teacher will give your group a sticky note. Write your group name on it. When directed, put your sticky note on the class graph in the column that represents your group’s choice for the best planting medium.
- ▶ Fill in the graph to show the class predictions of which planting material will be the best.

Soil #1	Soil #2	Soil #3	Soil #4	Soil #5	Soil #6

Carefully observe the plants that were grown in the six planting mediums. Describe each plant’s appearance by noting color, size, and other characteristics. Use a ruler to compare sizes of the different plants.

Sample 1: _____

Sample 2: _____

Soil Experiment Lab *(continued)*

Sample 3: _____

Sample 4: _____

Sample 5: _____

Sample 6: _____

Which growing medium grew the healthiest plant? _____

Conclusion

Write a conclusion that states whether your hypothesis was proven or disproven. Explain which planting medium grew the healthiest bean plant and what soil characteristics you think contributed to this. If mixed together, do you think some of the planting mediums would make a good soil for growing healthy plants? Explain.

As a group, present your conclusion to the class.



Digging Into Nutrients

Purpose

In this lesson, students will gain background knowledge of the nutrient requirements of plants, how those nutrients are obtained by the plant, what farmers must do if the nutrients are not available in soils, and current issues related to agricultural production.

Time

Teacher preparation:
20 minutes

Student activities:
Two 40-minute sessions

Materials

For each group:

- ▶ *Why Must We Replace Nutrients Back Into the Soil?* reading handout (page 43)
- ▶ *Green Manure, and Nitrogen-Fixing Plants* reading handout (page 45)
- ▶ *Manure and Composting* reading handout (page 47)
- ▶ *Fertilizers* reading handout (page 49)

For each student:

- ▶ *What's in a Plant?* reading handout (page 42)
- ▶ *Digging Into Nutrients* student notes (pages 51-53)

Background Information

There are many ways to maintain or improve the quality of soil in order to provide the nutrients needed for successful plant growth. Soils, and even water, differ in the types and amounts of nutrients they store. Farmers know that production of healthy food and fiber crops depends upon good land stewardship. They use the latest science and technology to farm their land and protect natural resources.

Procedure

1. Tell students that they will be reading about plants, the nutrients they need to grow, and how they obtain them. Students will identify the main points of an assigned reading and share that information with other students.
2. Distribute the *What's in a Plant?* reading and *Digging Into Nutrients* student notes to each student. Instruct the class to silently read *What's in a Plant?*
3. As a class, identify five key points from the *What's in a Plant?* reading and instruct each student to record these key points in the appropriate place on their worksheet. Explain that students should follow this procedure for reading and writing key points for the next step of the lesson.
4. Divide students into groups of four. Pass out one packet of reading materials to each group. Each packet should contain one copy of the following readings:
 - ▶ Reading #1: *Why Must We Replace Nutrients Back Into the Soil?*
 - ▶ Reading #2: *Crop Rotation, Green Manures, and Nitrogen-Fixing Plants*
 - ▶ Reading #3: *Manure and Composting*
 - ▶ Reading #4: *Fertilizers*
5. Use the “jigsaw” cooperative learning approach for the readings.
 - ▶ Once in groups of four, have students number themselves 1, 2, 3, 4.
 - ▶ Student number one will read Reading #1; student number two will read Reading #2 and so forth.



Digging Into Nutrients

California Standards

5th Grade

Common Core English

Language Arts

RI.5.3
RI.5.4
W.5.2a
W.5.4
SL5.1

Next Generation Science Standards

5-PS3.D
5-LS1.C
5-LS2.A
5-LS2.B
5-ESS3.C
5-ETS1.A

6th-8th Grade

Common Core English

Language Arts

SL.6-8.1
RST.6-8.2
RST.6-8.4
WHST.6-8.4

Next Generation Science Standards

MS-PS3.D
MS-LS1.A
MS-LS1.C
MS-LS2.A
MS-LS2.B
MS-LS2.C
MS-LS4.4
MS-ESS3.A
MS-ESS3.C
MS-ETS1.B

Full standards alignment is listed in the matrix on page 143

- ▶ After students have finished reading the material, like numbers will meet and discuss what they have read, becoming experts on their readings. Each group of experts will record five key points about their reading on their *Digging into Nutrients* worksheet.
- ▶ Students will meet back with their original groups where each expert will explain to the rest of the group the general idea of his/her reading and some important key points. The rest of the team will take appropriate notes on their *Digging into Nutrients* worksheet.
- ▶ Each student should end up with five different sets of key points about plants (the one completed as a class and the four they completed as a group).
- ▶ Have a class discussion and ask students to provide examples of how they can use these key points about plant nutrients in their lives. Ideas include: establish a home garden and teach their family or neighbor about plant nutrients, start a compost bin, or start a school garden and teach younger students about plant nutrients.

Variations

- ▶ After like numbered students have finished reading and discussing their article, have them design a poster that they will use to report back to the entire class at the conclusion of this activity.
- ▶ This lesson employs group work that incorporates opportunities for students to exchange, write, present ideas, and ask questions.

Extensions

- ▶ Invite a farmer to explain to your class how plants in the field get their required nutrients. Your local county Farm Bureau may have some names of farmers who are using different fertilizer techniques. Master Gardeners, contacted through the University Cooperative Extension, may also be willing to speak on this topic.

ELL Adaptations

- ▶ Have students quickly scan articles for new words they'd like to have defined prior to reading. These words could be added to a classroom word wall or to student science journals.

What's in a Plant?

Imagine that you are floating around on an inner tube in a mountain lake, breathing in fresh air on a warm summer day. Every once in a while you get off your inner tube and wiggle your toes in the sand. This is so relaxing you feel like staying here all day, but you are getting hungry and you didn't bring any food with you. Unfortunately, you have to go home for lunch. As you are pedaling your bike home under the canopy of tall trees you think about how cool it would be to make your own food like plants do.

Plants are unique living things. They have the ability to photosynthesize; “photo” means light and “synthesize” means to put together. Through photosynthesis, plants capture the sun's energy to make their food. Plants take water and nutrients from the soil, along with carbon dioxide from the air, and convert them into the food they need to grow and be healthy. Sunlight is needed for this process to take place.

We all depend on plants for survival, without them there would be no life on Earth! All the food we eat and the oxygen we breathe can be traced back to plants.

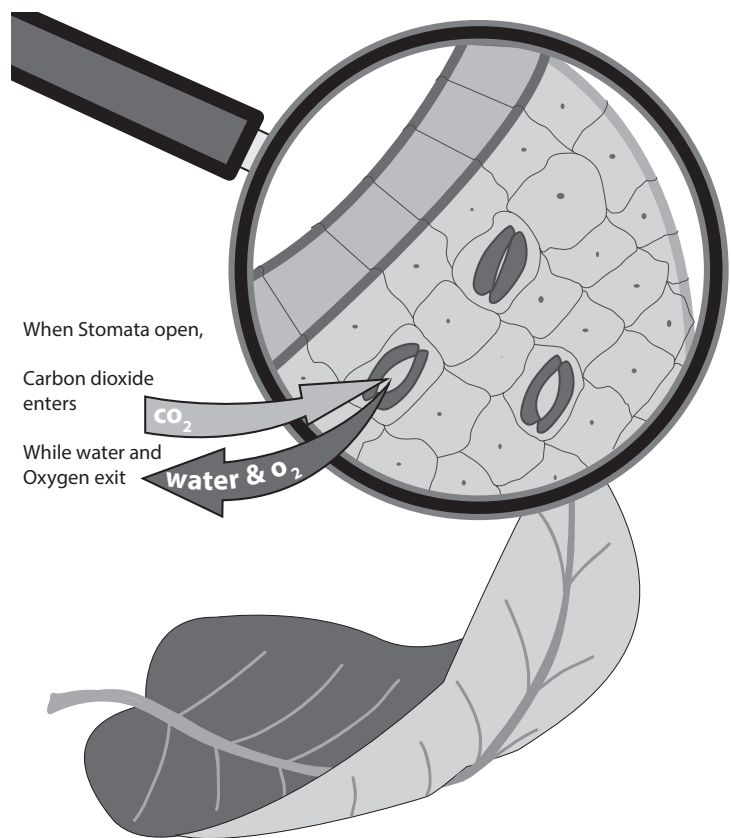
Think of leaves as the plant's kitchen. This is where sunlight is captured to give the plant the energy to mix carbon dioxide and water together to make the food the plant needs to grow and carry on life processes.

Plants absorb carbon dioxide through pores on their leaves called stomata (stomata means mouth in Greek). Guard cells surround the pore or stoma to regulate the opening, which allows the passage of carbon dioxide into the leaf and oxygen out of the leaf. Water vapor will also exit the open stomata through the process of transpiration. Sometimes stomata absorb other things too, like water molecules and nutrients. Most of the time, water and nutrients are absorbed through the root hairs of plants.

Like any living thing, plants need certain minerals and nutrients to stay healthy. Here are some of the nutrients required by plants:

Nitrogen

The element nitrogen (N) is required by all living things, including humans and plants. Nitrogen is needed to make the trunks, stalks, vines, flowers—basically every part of the plant.



What's in a Plant?

Nitrogen is found in chlorophyll, the green pigment that allows plants to capture energy from the sun to make food through photosynthesis. Nitrogen, sometimes called “the builder,” is also the basic element of plant and animal proteins, including the genetic material DNA and RNA, and is important in periods of rapid plant growth. Nitrogen gas makes up about 78% of Earth’s atmosphere, but this form of nitrogen must be converted into a type of nitrogen that can be used by plants. This is done by chemical processes or by nitrogen-fixing bacteria in the soil.

Legumes, such as beans and alfalfa, are great nitrogen fixers because they grow specialized nodules on their roots. Nitrogen-fixing bacteria called *Rhizobium* live in these root nodules and convert atmospheric nitrogen into nitrogen plants can use. Farmers take advantage of this unique symbiotic relationship by periodically growing legumes in nitrogen-deficient soil to boost nutrient levels.

Potassium

Potassium (K) is another nutrient that plants require. Potassium helps the plants open and close the guard cells that surround the stomata. This is important in efficient water use, especially during times of drought. Potassium is often called “the regulator” since it is involved in more than 60 different enzyme systems in plants. It helps plants resist disease, aids in the production of starches, and controls root growth. Most potassium is mined from underground deposits while some comes from the evaporation of water from natural salt lakes.

Phosphorus

Phosphorus (P) is often referred to as the “energizer” since it helps store and transfer energy during photosynthesis. It is also part of the genetic material of all cells: DNA and RNA. Plants require phosphorus during periods of rapid growth.

Legumes also require plentiful amounts of phosphorus. Established plants such as trees, shrubs, and vines—especially those grown in warm climates—require the least amount of phosphorus. In the soil, phosphorus is often found in chemical forms that cannot be absorbed by plants, so farmers often need to apply a phosphorus fertilizer.

Nitrogen, phosphorus, and potassium are known as primary nutrients since they are used by plants in relatively large amounts and are often deficient in the soil. In all, 17 chemical elements are known to be important for plant growth. Three of them, carbon, hydrogen, and oxygen, are taken in from the air and water. The other 14 elements are absorbed by plant roots from the soil.

Calcium, magnesium, and sulfur are less frequently deficient in the soil and are classified as secondary nutrients. Micronutrients are also essential to plants, but are only used in very small amounts. Micronutrients are: zinc, iron, manganese, copper, boron, molybdenum, chlorine, and nickel.

In the readings #1–4, you will learn how farmers make sure their crops get the essential nutrients so we can all have enough food to eat.

Reading #1

Why Must We Replace Nutrients Back Into The Soil?

Farmers and ranchers understand the connection between good land stewardship and making a living to produce food and fiber that people depend upon. They know if they take care of the land, it will produce healthy crops for generations to come.

Long ago, when people began to settle in one place to farm, they realized that particular lands were good for growing fruits and vegetables while other land was better suited as pasture land for their animals. There was enough land and water available for those who needed to grow their own food. People would settle in those prime farming areas, especially river fronts and valleys, due to the fertile soil. When an area became overcrowded, people would migrate to other desirable places. People noticed that the manure from their animals made the soil better, and learned that if they rotated their crops, their soil would not become “tired.” We now know to use crop rotation to enhance soil fertility and use it to help prevent insect and diseases in crops. Early farmers learned these techniques through trial and error.

As the human population has grown, the amount of available agricultural land has shrunk with the growth of shopping centers and housing developments. New and expanded towns are now covering much of the land that was once used for agriculture production. Farmers and ranchers must produce their crops on the limited land they own or lease, and much of this land has been farmed for generations.

For these reasons farmers must be creative in order to keep their soil fertile so it will continue to produce enough food to meet the demand of a growing human population. Farmers and scientists know that plants need more than just sunlight, water, and carbon dioxide to grow. Plants require the right amount of nutrients. Most of the needed nutrients are in the soil and water, but when a crop is harvested the nutrients contained in the harvest are removed with the crop, and soil nutrients must be replaced if another crop is to grow there.

Let's look at a scenario from the past:

Tractors are not yet invented, and teams of horses or oxen are used to plow the wheat fields to prepare the soil for planting. Wheat is planted and harvested by hand then sent to a small local mill to be made into flour for the people of the community of Wheatland.

Cattle roam in the harvested wheat field and eat what remains. Cattle manure and wheat stubble that are left after harvest is plowed back into the land to return soil nutrients. This land is left alone for at least one year before another crop is planted. The farmer has plenty of land and rotates fields that are planted each year. Perhaps the next time the field is planted it will grow beans or corn.



Reading #1 *(continued)*

This story gives one example of how agriculture has changed over the years. In the past, farmers produced less product per acre, and were responsible for feeding fewer people. Human populations continue to grow, yet the amount of farm land decreases as towns and cities become larger. This means that today's farmers must use the latest science and technology to grow more food crops on less land for more people than ever before.

For today's agriculture to remain sustainable, nutrients and plant matter that are removed from the soil and sold locally or far away must be returned to the soil in one form or another.

Reading #2

Crop Rotation, Green Manure, and Nitrogen-Fixing Plants

There are many ways to replace soil nutrients that are lost from the soil when crops are harvested. As the population of California and the rest of the world increases, farmers must produce more food from less land, while maintaining or improving the quality of the land. Limited water availability is also an issue in California. Farmers, ranchers, and scientists continually work together to develop innovative farming practices that will meet the increasing demand for an abundant and affordable food supply, while also protecting the environment. The next sections on crop rotation, green manure, and nitrogen-fixing plants describe some different ways of enhancing soil quality.

Crop Rotation

Many plants, including corn, cotton, and tomatoes require a significant amount of nutrients to grow, and if grown on the same land year after year, they can deplete soil nutrients, especially nitrogen. Farmers have learned that other crops, such as legumes (alfalfa, peas, peanuts, and beans), actually replace some soil nutrients that other plants take up during the growth process. Farmers rotate the crops that require more nutrients with crops that have fewer nutrient requirements in order to replenish the soil with organic matter and nitrogen. Below are some examples:

One year farmers might plant corn in a field. Corn requires a significant amount of nutrients. After the corn is harvested, a crop of beans is planted. The beans are a type of legume that help replenish the soil with nitrogen that was removed with the harvest of the corn crop.

A farmer might plant beans in between her plum trees. These beans put nitrogen back into the soil. Several things can happen to the bean plants once they mature. The beans may be plowed back into the soil, adding organic material and nutrients to improve soil quality, or the beans may be harvested before tilling the remainder of the plant back into the soil. The beans provide another crop for the farmer and more food for people. Beans may also attract beneficial insects that reduce the populations of harmful insects.

Green Manure

Green manure is fresh or growing, green vegetation that is not harvested, but is plowed into the soil to increase the amount of organic matter in the soil. Green manure is full of nutrients and replenishes soil with minerals it may be lacking. The optimal time to plow green manures into the soil is just as the flowers are beginning to form because this is when the protein content is highest.

Green manures often include crops such as alfalfa, clover, lupines, vetch, or other legumes because of their unique ability to fix nitrogen gas from the atmosphere into other forms of nitrogen that are usable to plants that don't have the ability to fix nitrogen. Legumes have symbiotic bacteria called *Rhizobium* in their root nodules that allows for nitrogen fixation. Mustard plants have deep taproots and are able to obtain nutrients that other plants cannot reach. For this reason, mustard may be planted in between grape vines or other crops then plowed into the field to provide the soil surface with nutrients obtained from deep within the soil.

Reading #2 *(continued)*

Nitrogen-Fixing Plants

Legumes are very special plants. A legume is a plant that has a pod, such as peanuts, peas, alfalfa, clover, and beans. Legumes are special because they have a unique “symbiotic” relationship with a certain type of bacterium called Rhizobium. Symbiotic means that both organisms help each other survive. The Rhizobium bacteria help the plant survive by fixing atmospheric nitrogen into a form of nitrogen that the plant can use. The plant provides habitat for the bacteria in the plant’s root nodules and supplies the bacteria with food. When farmers plant a field of legumes, they inoculate the soil with the Rhizobium bacteria to make sure there are enough beneficial bacteria in the soil to produce the needed nitrogen. Sometimes, the legume seeds are coated with the bacteria before they are planted. Often, after replanting the same type of legume, the soil does not have to have Rhizobium added to it because a sufficient population of bacteria has already been established. Next time you go to a nursery, ask to see the packets of Rhizobium they have for sale.

Summary

Crop rotation, green manure, and nitrogen-fixing plants are all important methods for maintaining and enhancing soil quality. However, these methods alone don’t solve all soil nutrient problems. These farming techniques help increase the amount of nitrogen and organic matter in the soil, but plants also need potassium and phosphorus. Other challenges arise if green manure or nitrogen fixing crops require more water than other crops. Planting and harvesting dates of rotated crops may conflict with one another, and there is not always a demand for one of the rotational crops. Each of these challenges requires continuing research and analysis. Farmers must consider the new strategies and techniques that become available to grow enough crops while keeping the land healthy and making a living.

Reading #3

Manure and Composting

There are many ways to keep soils healthy. It is important to enrich soils, especially ones that are used year after year to grow crops so that the plants grown in them are strong and healthy. This reading explains the use of animal manures and composting to improve soil quality.

Manure

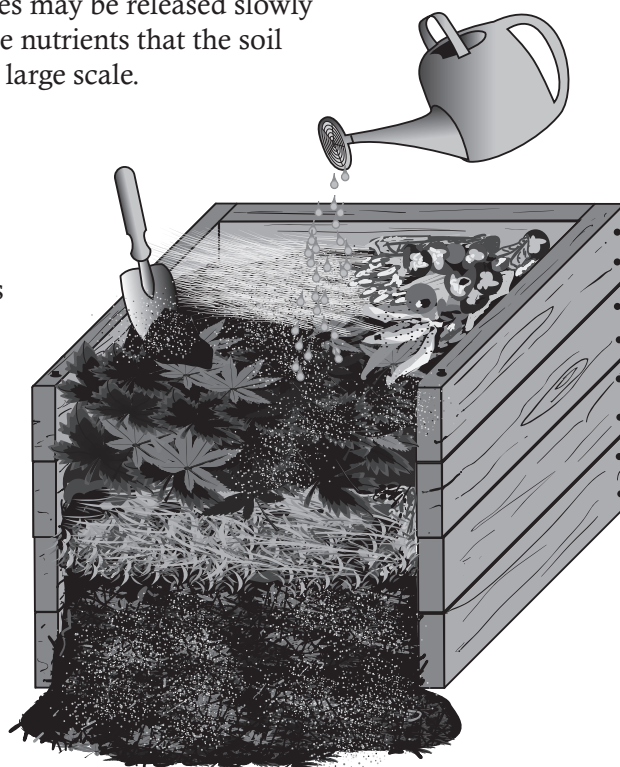
Centuries ago, farmers would cart animal waste from their barns and pastures out to their fields to get rid of it. They found that the animal waste, or manure, made the soil better for growing crops. This process of using manure to enhance soil quality is still used today. Perhaps you have been to a plant nursery and have seen bags of chicken manure, steer manure, or bat guano for sale in the fertilizer section.

Animal manure adds many things to soil. It provides organic matter, which improves soil quality by creating air spaces that plant roots and water can penetrate more easily. It also replaces nutrients, especially nitrogen that is removed from the soil when crops are harvested. Many different types of animal manure are available at nurseries and each type contains a different percentage of nitrogen, phosphorus, and potassium. The cost of manure per ton is generally less expensive than other types of fertilizer and it is readily available. However, there are some drawbacks to using manure as fertilizer. Uncomposted manures are high in salts that can burn plants if too much is applied. It can also be expensive and bulky to transport enough manure from animal farms to match the needs of the crop fields, which may be a great distance away. Additionally, the nutrients in manures may be released slowly and a large amount of manure may be needed to supply the nutrients that the soil needs. This makes it labor intensive to apply manures on a large scale.

Compost

Compost is a rich, natural fertilizer and soil conditioner. It adds both organic matter and nutrients to the soils, just as manures do. Compost is made by mixing materials such as lawn and tree clippings, straw, and kitchen waste with manure and topsoil. The compost pile must be allowed to sit and decompose. The decomposition process creates heat. As the temperature of the compost pile increases, seeds and a variety of plant diseases are killed. Topsoil that is added to the compost pile provides micro-organisms such as bacteria and fungi that are needed to decompose the waste into nutrient rich soil.

Earthworms can also be used to help decompose waste materials and add nutrient rich worm castings to the compost. This method is called vermicomposting.



Reading #3 *(continued)*

Composting is not only a great way to enrich the soil; it is also a good way to reduce the amount of waste put in landfills. Below are some tips for making your own compost bin at home.

- ▶ Start a pile of organic matter such as lawn clippings or leaves. Layer the pile with different types of leaves, and vegetable and fruit scraps so the compost will contain a variety of nutrients and will decompose faster. Acceptable materials for composting include: fruits and vegetables, eggshells, coffee grounds and filters, yard trimmings, sawdust, tea bags, and grass clippings.
- ▶ Do not add meat scraps, dairy products, fats, grease, or oil as these wastes will create bad odors and may attract flies and rodents. Don't add diseased plants as diseases might transfer to other plants when you apply compost. Don't add pet waste as it may contain pathogens that are harmful to people.
- ▶ Allow air to circulate through your compost pile by mixing the compost pile with a shovel or pitchfork once a week.
- ▶ Keep a well-like depression on top of the pile so rainwater can collect. Water your compost pile periodically if you don't get rain frequently.
- ▶ For more information on composting see this website from the EPA:
www2.epa.gov/recycle/composting-home

Summary

The two nutrient supplements mentioned above, manure and compost, are called organic fertilizers. They are fertilizers that originate from living things. These methods are often very suitable for smaller scale farming, although they can have drawbacks. Manures often contain seeds from weeds that the animals have consumed and these weeds can then sprout in crop fields where the manure has been applied. It is difficult to apply enough compost needed to supply required nutrients on large farms and the exact amount of nutrients present in the manure and compost is not known, so farmers may not know if they are under or over-fertilizing their crops. Research continues to discover ways to make organic fertilizers more feasible for different types and sizes of farms.

Reading #4

Fertilizers

A fertilizer is a substance that provides one or more nutrients necessary for plant growth and development. There are two classes of fertilizers: organic fertilizer and inorganic, or commercial, fertilizer. Either type can be used by farmers and home gardeners to replace nutrients removed from the soil by previously harvested crops or to add nutrients that may be naturally lacking in the soil. Plants do not have a preference for either type and can only take up nutrients that are dissolved in water regardless of whether their source is organic or commercial fertilizer. Some differences and similarities between these two types of fertilizers are described below.

Organic Fertilizers

Organic fertilizers are anything that an organic farming certification system considers to be acceptable for organic farming. Usually, these fertilizers originate from living organisms and go through little processing before being used on crops. Some organic fertilizers include fish and seaweed emulsions that are made by liquefying seaweed and fish. Other examples include compost, worm castings, bone meal, ground oyster shells, and steer and chicken manure. Organic fertilizers usually contain many different nutrients in low concentrations. Their nutrients are often in forms that must be broken down by microorganisms before they can be used by plants, and the release of nutrients takes time, especially in cold weather when microorganisms in the soil are less active. In addition to adding nutrients to the soil, organic fertilizers also add organic matter that improves soil structure by increasing pore spaces, air circulation, and water-holding capacity.

There are some disadvantages to organic fertilizers. Some have a disagreeable smell and can be very labor and cost intensive to apply on large fields. Since their nutrient concentrations are low, large quantities may be needed to supply sufficient nutrients for crops. If manures are not composted before being used as a fertilizer, they can be a source of weed seeds and can damage plants if the manure has high salt content. Also, the exact nutrient content of organic fertilizers is usually not guaranteed which makes it more difficult for the farmer to know just how much should be applied to the crop.

Inorganic (Commercial) Fertilizers

Commercial fertilizers are fertilizers that have been produced in factories from nitrogen gas from the atmosphere and other natural materials like rocks, minerals, petroleum, and animal products. Commercial fertilizers are prepared to contain exact amounts of nutrients in forms that can be immediately used by plants. They generally contain nitrogen, phosphorus, potassium, and a few trace minerals at concentrated levels. Some examples of commercial fertilizers are potassium sulfate and ammonium phosphate.

Nitrogen is the most abundant element in the Earth's atmosphere, but plants cannot absorb atmospheric nitrogen gas from the air. It must be converted to a special form to be used by plants. Inorganic nitrogen fertilizer is made by combining hydrogen from natural gas and nitrogen from the air. The scientific discovery of capturing nitrogen from the air to make fertilizer is called the Haber-Bosch process. It has often been called the most important invention of the 20th century and is responsible for feeding billions of people worldwide.

Reading #4 *(continued)*

Inorganic phosphorus is made by mixing phosphate rock, mined from the Earth, with sulfuric acid and water.

Potassium fertilizer is commonly called potash (pronounced “pot ash”). This name comes from the fact that the ashes left over from a campfire contain potassium and were, throughout history, put into fields. Potassium is usually obtained by mining from deep within the Earth. Potash is mined in New Mexico, Utah, and parts of Canada. Potassium can also be obtained from brine (salt) deposits on the Earth’s crust. Brine deposits are places where large bodies of salt water once existed and have since evaporated, leaving the salt behind. One example of a brine salt deposit is the salt flat near the Great Salt Lake in Utah.

Inorganic fertilizers are used by many farmers for a variety of reasons. They are easy to transport, store, and apply, and they are available in a variety of formulas to meet the specific nutrient requirements of crops. Some of these fertilizers are formulated to be high in nitrogen while others are high in phosphorus or potassium.

Whether using organic or commercial fertilizer, farmers and home gardeners must take care to use fertilizers appropriately. Farmers work closely with scientists and certified crop advisors to determine the best types of fertilizers for their crops, when to apply, how much to apply, and how to protect the environment. Home gardeners can take courses or obtain information about proper use of fertilizers from local garden clubs and University of California Cooperative Extension offices.

Digging Into Nutrients

Name: _____

Instructions: Write down five key points about each reading in the space provided.

What's in a Plant?

1.
2.
3.
4.
5.

Why Must We Replace Nutrients Back Into the Soil?

1.
2.
3.
4.
5.

Digging Into Nutrients *(continued)*

Crop Rotation, Green Manure, and Nitrogen-Fixing Plants

1.
2.
3.
4.
5.

Manures and Compost

1.
2.
3.
4.
5.

Digging Into Nutrients *(continued)*

Fertilizers

1.
2.
3.
4.
5.

Other Notes:



The Right Solution

Purpose

In this lesson, students will learn about solutes and solvents and will use serial dilution while investigating parts per million—a term commonly used to describe the nutrient concentration of a fertilizer solution.

Time

Teacher preparation:
30 minutes

Student activities:
60 minutes

Materials

- ▶ Two, 250 ml beakers
- ▶ One roll of paper towels
- ▶ Water
- ▶ One box of food coloring
(*exclude yellow*)
- ▶ Colored pencils or crayons

Optional:

- ▶ Becker Bottle from Flynn Scientific

For each group:

- ▶ One white ice cube tray(*or well reduction plate with 12 wells*)
- ▶ One permanent marker
- ▶ One eye dropper

Background Information

Fertilizers are used to provide nutrients that are not present in soil in amounts necessary to meet the needs of the growing crop. Plants can tolerate a wide range of watering and nutritional conditions, but for a commercial farming operation it is important to maximize production while minimizing environmental impact. Optimum watering and nutritional conditions vary depending on a variety of factors, including plant species, stage of life cycle, climate, and environmental conditions. Many growers purchase fertilizer in a concentrated solid or liquid form. The fertilizer is then mixed with water to create a fertilizer solution that can be applied to plants.

When fertilizer is applied in the field, farmers will calculate nutrient requirements in pounds per acre. However, in greenhouse production, the industry standard is parts per million. Greenhouses are often used for growing flowers, vegetables, fruits, and transplants. Greenhouses allow for greater control over the growing environment of plants. Depending upon the type of greenhouse, key factors that may be controlled include temperature, light, water, fertilizer, and atmosphere.

Proper fertilization of greenhouse plants is essential for producing a high-quality crop. Some nutrients (such as calcium and magnesium) may be mixed into the growing medium, or soil, prior to planting, but most of the nutrients are applied after planting using water-soluble fertilizers. Fertilizer injectors are used by most growers to deliver fertilizer to plants. These devices inject a small quantity of concentrated fertilizer into the irrigation line so that the solution leaving the hose is diluted to the proper concentration. Fertilizer injectors can be set at different ratios depending upon the needs of the plants. If the injector ratio in a greenhouse operation is 1:100, the injector delivers one gallon of fertilizer concentrate with every 99 gallons of water (*one part out of 100 parts is concentrated fertilizer*).

Show students a two-minute video highlighting the career of a greenhouse manager. Visit www.youtube.com/utahagclassroom and select the video titled “Greenhouse Manager.”



The Right Solution

- ▶ One, 1 liter beaker
- ▶ Three small plastic cups

For each student:

- ▶ *The Right Solution Lab* worksheet

California Standards

5th Grade

Common Core English Language Arts

- RI.5.1
- RI.5.4
- SL.5.1

Next Generation Science Standards

- 5-ETS1.A

6th - 8th Grade

Common Core English Language Arts

- SL.6-8.1
- RST.6-8.3
- RST.6-8.4

7th Grade

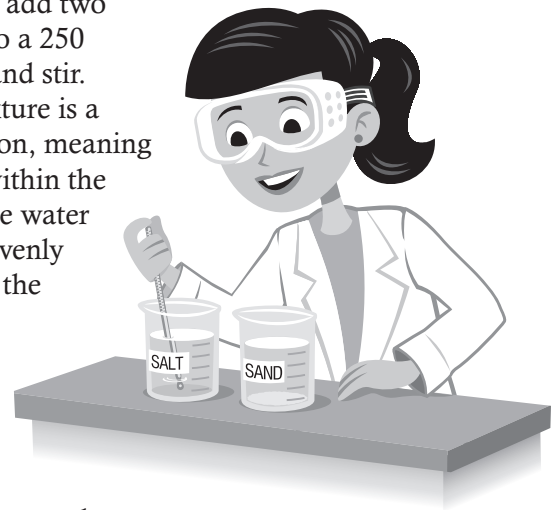
Common Core Mathematics

- 7.RP.2b

Standards alignment is listed in the matrix on page 143.

Procedure

- ▶ Ask the class if they have ever used a powdered concentrate to create a beverage such as hot chocolate or fruit punch. Explain that whether they realized it or not, they were creating a mixture. A mixture is a combination of two or more different substances, which are not chemically bonded, and can be a solid, liquid, or gas. Explain that there are two types of mixtures: homogeneous (*also called solutions*), which are uniform and particles are not typically seen, and heterogeneous mixtures, which are not uniform and the particles can be seen.
- ▶ As a demonstration, add two tablespoons of salt to a 250 ml beaker of water and stir. Explain that the mixture is a homogeneous solution, meaning that the molecules within the solution—in this case water and table salt—are evenly distributed and look the same throughout.
- ▶ In another beaker add two tablespoons of sand to 250 ml of water and stir. Have students compare and contrast the two mixtures. Ask student to describe the difference between the sand and water mixture and the salt and water mixture. Explain that the sand and water mixture is a heterogeneous mixture, meaning that the molecules will not be evenly distributed throughout the liquid.
- ▶ Explain that in agriculture, fertilizer solutions are one way that farmers supply their crops with essential plant nutrients. In science terms, the solute is the fertilizer added to the water. The water is the solvent, which does the dissolving. The solution, more or less, takes on the characteristics of the solvent. The concentration of a fertilizer solution is defined by the amount of fertilizer (*solute*) dissolved in water (*solvent*).



The Right Solution

Parts Per Million

1. Ask students to raise their hands if they've ever heard the term "one in a million." Discuss what the term means and why people say it.
2. Build on the classroom discussion by explaining how unique "one in a million" really is. Show students a "One in a Million" Becker Bottle (*Flinn Scientific, Inc.*) to illustrate the concept. This three liter bottle contains one million tiny colored spheres. Each colored sphere represents a different quantity, or concentration. The yellow spheres represent 100,000 in a million, the red spheres represent 10,000 in a million, the white spheres represent 1,000 in a million, the pink spheres represent 100 in a million, and the green spheres represent 10 in a million. The single black sphere in the bottle represents one in a million, or in scientific terms, one part per million. Explain that today the class is going to investigate the scientific concept of "parts per million"—a unit of measurement used to describe a very small amount of material.
3. Explain that in the scientific community, parts per million is expressed as "ppm." Parts per million is the unit of measurement commonly used to describe the nutrient concentration in a fertilizer solution. It can also be used to analyze contaminants in food, groundwater, air, and more.
4. Introduce the lab by explaining that students will use a dilution activity to create and investigate solution concentrations. Review laboratory safety instructions. Distribute and review the *The Right Solution* lab worksheet. Divide the class into pairs or triads, and direct students to the necessary materials.
5. After students complete the dilution lab activity and *The Right Solution* lab worksheet, use a classroom discussion to debrief their findings. Discussion points may include:
 - a. Good fertilizer practices that match fertilizer inputs to crop nutrient requirements will achieve high-quality, economically sustainable yields that reduce negative environmental impacts. Arable land available for growing food will continue to diminish as population growth continues. Efficiently managing inputs, such as water and fertilizer, will be essential to feeding a growing population.
 - b. Improperly applied fertilizer can lead to environmental problems. It is important for anyone who applies fertilizer to follow application instructions. Farmers and researchers are

The Right Solution

constantly testing and implementing new methods for high precision use of fertilizers.

- c. Fertilizer is expensive. It is in the farmer's best interest to apply the correct amount of fertilizer, supplying the plants with only the nutrients they need.

Extensions

- ▶ Offer an incentive for students who locate (and show you) the black sphere in the Becker Bottle.
- ▶ Review your city's annual water quality report. All public water systems are required to sample their source water and treated water for the presence of biological, inorganic, organic, and radioactive constituents. This report typically uses parts per million and parts per billion to summarize constituent levels. Look up and define unknown terms and create a public service announcement that highlights key findings and provides recommendations for community members.
- ▶ One part per million is equivalent to one hole in 55,555 rounds of golf! Put a million into perspective by challenging students to use the factor-label method to convert one part per million (or one part per billion) to a number that is meaningful to them. Consider expressing the unit of measurement in seconds, miles, U.S. population, etc.
- ▶ Have students write the ppm data from their chart in scientific notation. For example, $700 = 7 \times 10^2$
 $0.0055 = 5.5 \times 10^{-3}$

ELL Adaptations

- ▶ Create a Venn diagram to capture the differences and similarities of homogeneous and heterogeneous mixtures.
- ▶ Use an overhead projector to demonstrate complex math problems.

The Right Solution Lab

Today is your first day of on the job training at Green Thumb Growers, a greenhouse operation that produces a variety of flower and vegetable seedlings for home and garden centers throughout the state. Your job involves watering plants and applying the correct amount of fertilizer solution. Your boss has given you and your coworker *The Right Solution Lab* exercise to help you understand measurements and dilution before you can begin working on your own. You have been instructed to read the directions and carry out the lab. Your boss encourages you to ask questions to clarify anything you don't understand since these types of tasks will be part of your daily work at the greenhouse.

Fertilizers are used to provide nutrients that are not present in soil (or other growing media) in amounts necessary to meet the needs of the growing crop. Fertilizers are available in several forms:

- ▶ Pre-mixed liquid concentrates that are then diluted with water
- ▶ Pre-mixed powder concentrates that are then diluted with water
- ▶ Made from “scratch”—many commercial growers buy the individual compounds and mix the nutrient solution themselves

In this example, the fertilizer concentrate is the solute and the water is the solvent. The two are mixed to create a homogeneous solution. Dilution is the process of making the solution weaker or less concentrated, and can be used to regulate the amount of nutrients applied. In this lab, we'll be diluting the original substance to a concentration of one part per million (ppm) and one part per billion (ppb).

Very small quantities of a substance can be measured in parts per million and parts per billion. The ability to measure substances in such minute amounts allows growers to strategically apply the specific nutrients a plant needs to grow. But what do parts per million and parts per billion actually mean? These are difficult numbers to comprehend. The following activity will help illustrate the terms ppm and ppb.



Procedure

1. Collect materials.
2. Fill three plastic cups about half full of water. Two cups will be used for cleaning the eye dropper, and one will be used for diluting. Label the cups so they don't get mixed up.
3. Label ice cube tray “cells” 1 to 10 with a permanent marker.
4. In cell #1, place 10 drops of food coloring. This represents a pure substance, or a concentration of 1 million parts per million.

The Right Solution Lab *(continued)*

5. Using an eye dropper, take one drop of food coloring from cell #1 and place it in cell #2. Return any excess food coloring back to cell #1.
6. Rinse the dropper in one of the plastic cups to remove all traces of food coloring. Then rinse again in the second cup you have reserved for rinsing.
7. Add 9 drops of clean water to cell #2 and stir the solution.
8. Take one drop of the solution from cell #2 and place it in cell #3. Return any excess solution back to cell #2.
9. Rinse the dropper in one of the plastic cups to remove all traces of food coloring.
10. Add 9 drops of clean water to cell #3 and stir the solution.

Continue repeating the procedure through cell #10, taking a drop of the solution from the previous cell and adding 9 drops of water. Remember to clean the dropper thoroughly between uses.

The Right Solution Data Collection

Name: _____

1. Determine the concentration of the solution for each cell and record it in the data table below.
Example: In cell #2, one out of 10 drops was food coloring. The concentration of food coloring is $\frac{1}{10}$ or .10, or 100,000 ppm.

Cell #	Concentration <i>(fraction and decimal)</i>	ppm	Color <i>(use colored pencils)</i>
1			
2	$\frac{1}{10}$ or .10	100,000	
3			
4			
5			
6			
7			
8			
9			
10			

2. Compare and contrast the solutions in each cell. In which cell is the color most intense? Why?

In this activity, what agriculture concept does the solution in the first cell represent?

3. In which cell is the color least intense? Why?

In this activity, what agriculture concept does the solution in the last cell represent?

The Right Solution Data Collection *(continued)*

4. Carefully examine your cells. Are there any cells where the liquid is colorless? _____ Is there any food coloring in these cells? _____ How do you know? _____

5. A fertilizer solution contains 1% nitrogen and 12% calcium. Write these percentages as concentrations in ppm.

There is a factor of 10,000 between ppm and percentage; ppm stands for parts per million, whereas percent means per hundred, and there is a factor of 10,000 between one hundred and one million. To go from ppm to percentage divide by 10,000 and from percentage to ppm multiply by 10,000. For example: 1.5% would be $1.5 \times 10,000 = 15,000$ ppm and 0.12% would be $0.12 \times 10,000 = 1,200$ ppm

6. Which cell is closest to the concentration of nitrogen? Which cell is closest to the concentration of calcium?

7. Nitrogen, phosphorus, potassium, magnesium, and calcium are essential nutrients for plant growth. Deficiencies in these nutrients can be corrected by fertilizer application. **General recommended nutrient concentrations for cucumbers are listed below.** Convert the ppm concentrations to ppb. Which of your cells of food coloring is closest in concentration to each fertilizer concentration?

Nutrient	Concentration	Cell Number
Nitrogen (N)	230 ppm = ppb	
Phosphorus (P)	40 ppm = ppb	
Potassium (K)	315 ppm = ppb	
Magnesium (Mg)	42 ppm = ppb	
Calcium (Ca)	175 ppm = ppb	

Why do greenhouse growers use the process of dilution?

8. Explain at least two possible problems associated with applying a fertilizer solution that is too concentrated?

The Right Solution Data Collection *(continued)*

9. Explain at least two problems associated with applying a fertilizer solution that is too diluted.

10. Your boss gives you a bag of fertilizer with the following chart and instructs you to prepare a fertilizer solution for the stock tank that will deliver 100 ppm nitrogen to the flower seedlings in one of the greenhouses. Your boss tells you that the injector ratio is set to 1:200.

Nitrogen ppm	Injector Ratios		
	<i>1:100</i>	<i>1:200</i>	<i>1:300</i>
50	3.38 oz	6.75 oz	10.13 oz
75	5.06 oz	10.13 oz	15.19 oz
100	6.75 oz	13.50 oz	20.25 oz
150	10.13 oz	20.25 oz	30.38 oz

- a. Find the column that matches the type of injector you have with the row that matches the desired concentration of fertilizer in ppm. This will tell you how many ounces of fertilizer mix you need. Write the amount here: _____ oz of fertilizer mix needed per gallon of concentrated fertilizer solution.
- b. Your boss tells you to make enough concentrated fertilizer solution for the 5 gallon stock tanks. How many ounces do you need to make 5 gallons? _____ oz.
- c. You look for a way to measure out your dry fertilizer mix and notice that your scale is in grams. If 1 oz = 28.3 grams, how many grams should you weigh out for your 5 gallon mixture? _____ grams. What is your next step?

The Right Solution Data Collection Lab Answer Key

1. Determine the concentration of the solution for each cell and record it in the data table below.
 Example: In cell #2, one out of 10 drops was food coloring. The concentration of food coloring is $\frac{1}{10}$ or .10 or 100,000 ppm.

Cell #	Concentration (fraction and decimal)	ppm	Color (use colored pencils)
1	$\frac{1}{1}$ or 1 (a pure substance)	1,000,000	
2	$\frac{1}{10}$ or .10	100,000	
3	$\frac{1}{100}$ or .01	10,000	
4	$\frac{1}{1,000}$ or .001	1,000	
5	$\frac{1}{10,000}$ or .0001	100	
6	$\frac{1}{100,000}$ or .00001	10	
7	$\frac{1}{1,000,000}$ or .000001	1	
8	$\frac{1}{10,000,000}$ or 0000001	.01	
9	$\frac{1}{100,000,000}$ or .00000001	.001	
10	$\frac{1}{1,000,000,000}$ or .000000001	.0001	

2. Compare and contrast the solutions in each cell. In which cell is the color most intense? Why?

Cell #1. This cell represents a pure substance, with no solvent present.

In this activity, what agriculture concept does the food coloring in the first cell represent?

A pure fertilizer concentration.

3. In which cell is the color least intense? Why?

Cell #10. This cell has the largest quantity of solvent and is therefore the most diluted. Cell #10 has 1 part food coloring and 999,999,999 parts water.

In this activity, what agriculture concept does the solution in the last cell represent?

A very diluted fertilizer solution.

The Right Solution Data Collection Lab Answer Key *(continued)*

4. Carefully examine your cells. Are there any cells where the liquid is colorless? _____ Is there any food coloring in these cells? _____ How do you know?

Yes. Cells 6 through 10 are colorless; however there is still some food coloring in the cells. The concentration is so weak, color is not visible. We know there is food coloring because in a homogeneous solution, the solute is evenly distributed throughout the solvent, regardless of sample size.

5. A fertilizer solution contains 1% nitrogen and 12% calcium. Write these percentages as concentrations in ppm.

There is a factor of 10,000 between ppm and percentage; ppm stands for parts per million, whereas percent means per hundred, and there is a factor of 10,000 between one hundred and one million. To go from ppm to percentage divide by 10,000 and from percentage to ppm multiply by 10,000.

Nitrogen: $1\% \times 10,000 = 10,000 \text{ ppm}$

Calcium: $12\% \times 10,000 = 120,000 \text{ ppm}$

6. Which cell is closest to the concentration of nitrogen? Which cell is closest to the concentration of calcium?

Cell # 3 (10,000 ppm) is closest in concentration to nitrogen.

Cell # 2 (100,000 ppm) is closest in concentration to calcium.

7. Nitrogen, phosphorus, potassium, magnesium, and calcium are essential nutrients for plant growth. Deficiencies in these nutrients can be corrected by fertilizer application. General recommended concentrations for cucumbers are listed below. Convert the ppm concentrations to ppb. Which of your cells of food coloring is closest in concentration to each fertilizer concentration?

Nutrient	Concentration	Cell Number
Nitrogen (N)	230 ppm = 230,000 ppb	5
Phosphorus (P)	40 ppm = 40,000 ppb	6
Potassium (K)	315 ppm = 315,000 ppb	5
Magnesium (Mg)	42 ppm = 42,000 ppb	6
Calcium (Ca)	175 ppm = 170,000 ppb	5

Why do growers use the process of dilution?

Dilution allows growers to strategically apply the specific nutrients a plant needs to grow. Most fertilizers are purchased in concentrated formulas that cannot be directly applied to plants without dilution.

The Right Solution Data Collection Lab Answer Key *(continued)*

8. Explain at least two possible problems associated with applying a fertilizer solution that is too concentrated.

Plants can only use a certain amount of nutrients. In some cases, too much of a single nutrient can be toxic to the plant or even induce a deficiency in another nutrient. High concentrations applied in excessive amounts can pollute water sources and encourage weed growth. It is in the grower's best interest to apply the correct concentration and quantity of a fertilizer solution. The grower is also losing money when paying for the extra fertilizer that is being used to over fertilize the crops.

9. Explain at least two problems associated with applying a fertilizer solution that is too diluted.

A fertilizer solution that is too diluted may not contain the sufficient nutrients required for healthy plant development. This can impact crop yield, and in some cases cause plant death and the grower will lose money. Additionally, a solution that is too diluted will require more solvent (water) to deliver the same amount of nutrients. Water is a precious resource in California and must be used conservatively.

10. Your boss gives you a bag of fertilizer with the following chart and instructs you to prepare a fertilizer solution for the stock tank that will deliver 100 ppm nitrogen to the flower seedlings in one of the greenhouses. Your boss tells you that the injector ratio is set to 1:200.

a. 13.50 oz, b. 67.50 oz, c. 1,910.25 grams. Next you will mix the 1,910.25 grams of fertilizer concentrate with 5 gallons of water in the stock tank and make sure that the fertilizer injectors are calibrated to a 1:200 ratio.

Can We Have Too Much of a Good Thing?

Purpose

In this lesson students will understand that plants require nutrients in the proper concentrations. Students will discover that plants can be damaged or killed by either too many or too few nutrients.

Time

Teachers preparation:
One hour

Student activities:

- ▶ One 50-minute class session
- ▶ Five 15-minute observations
- ▶ One 50-minute class session for analyzing results

Materials

For the teacher:

- ▶ Six, six-packs of one type of vegetable or flower seedling from a nursery
- ▶ Sand or perlite for potting seedlings
- ▶ Plastic or wax lined paper cups with a hole in the bottom for planting seedlings
- ▶ Liquid fertilizer
- ▶ Distilled water
- ▶ Jars or beakers that can hold 300 ml of liquid

Background Information

Plants require 17 different essential elements for successful growth and reproduction. Carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium are required in relatively large quantities and are classified as macronutrients. These elemental nutrients are obtained from the air and from water in the soil. Nitrogen (N) is known as the *builder*. Nitrogen is needed to make proteins and to carry out photosynthesis. Phosphorus (P) is known as the *energy supplier* and is needed for energy transfer in photosynthesis and is important for seed germination and efficient water use. Potassium (K) is known as the *regulator* because it plays an important role in catalyzing chemical reactions involved in plant growth and protection from stress.

Eleven other elements are also important to plants but are classified as micronutrients because they are needed in smaller quantities than macronutrients. It is important that plants receive the correct amount of nutrients for proper growth and reproduction. There are many different types of fertilizers that can provide needed nutrients to plants. Farmers have been fertilizing their crops for thousands of years. As the human population continues to grow, farmers must produce more, from the same amount of land. In order to sustain soil health, nutrients must be replaced after they are removed from the soil with harvested crops. A variety of different fertilizers are available for farmers and home gardeners. Organic fertilizers, such as manures, undergo very little processing before being applied to a crop. Commercial fertilizers are made from natural ingredients that undergo chemical processing in order to increase their nutrient content and ensure that they deliver a guaranteed amount of nutrients. Many farmers use both types and make their selections based upon the needs of their crop, the characteristics of their soil, climate, topography, and many other factors.

Many liquid plant “foods” are purchased in concentrated forms. Before they are used they must be diluted with the proper amount of water. Fertilizers in solid form also have a specific amount that should be applied in order to provide only what will be taken up by the crop. Just as a person can become sick after taking more vitamins than the recommended dosage, plants can be harmed if a gardener or farmer applies more fertilizer nutrients than recommended. In addition, farmers and home gardeners must follow fertilizer application instructions to protect the environment by making sure that the nutrients applied are the amount that will be taken up by plants



Can We Have Too Much of a Good Thing?

- ▶ 500 ml graduated cylinder or other measuring device
- ▶ Wax marking pencil or masking tape

For each student:

- ▶ Copies of the student lab handouts (pages 71-77)

For each group of four students:

- ▶ Four seedlings potted in sand
- ▶ Prepared fertilizer concentrations
- ▶ Grow or fluorescent light for the plant area (optional)

California Standards

5th Grade

Common Core English Language Arts

W.5.1d
W.5.2a
W.5.2e
W.5.4
SL.5.1

Next Generation Science Standards

5-LS1.C
5-LS2.A
5-LS2.B
5-ESS3.C
5-ETS1.A
5-ETS1.B

and will not run off into waterways and other fields. The fertilizer manufacturer, through extensive research and testing, provides instructions on the proper application of the fertilizer, including concentrations, proper dilution, frequency of application, and storage. This research guides farmers and gardeners to use the 4-Rs when managing fertilizer application: Right Rate, Right Time, Right Place, Right Product.

Procedure

It may be helpful to try this experiment ahead of time, especially preparing the solutions and determining how far away the light source should be for optimal outcome. Consider how often, and with how much, the plants will need to be watered in the classroom environment. Evaluate how much your students can participate in set-up.

1. Designate a well-lit area of the classroom for the plants. An optional grow light or a fluorescent fixture can improve results. Place sand or perlite in cups and plant one seedling in each cup.
2. Prepare the fertilizer mixtures ahead of time for each student group.
 - a. Label sets of four jars or beakers for each group with a wax marking pencil or piece of tape at the 300 ml mark. Label one container in each set with the fertilizer concentrations: 0%, 0.5%, 1%, and 2%. Use the following directions to prepare the concentrations of fertilizers:
 - **0% solution:** Fill jars or beakers, labeled 0%, with distilled water. No fertilizer is to be added to these jars.
 - **0.5% solution:** Put 1.5 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 0.5%.
 - **1% solution:** Put 3 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 1%.
 - **2% solution:** Put 6 ml liquid plant fertilizer in a 500 ml graduated cylinder and add distilled water to the 300 ml mark. Do this for each of the jars or beakers labeled 2%.

Can We Have Too Much of a Good Thing?

California Standards (cont.)

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.3
WHST.6-8.4
WHST.6-8.7

Next Generation Science Standards

MS-LS2.A
MS-LS2.C
MS-LS4.D
MS-ETS1.A
MS-ETS1.B

Standards alignment is listed in the matrix on page 143.

- b. When time permits, make a reserve stock of each of the same solutions to use during the experiment to replenish the solutions. Keep the solution jars covered and away from heat and possible contamination.
3. Divide the students into groups of four. Each group will carry out the experiment using the scientific method. At the completion of the experiment each individual student will write a lab report.
4. Review the Scientific Method and the components of a properly written lab report with the students. Give students a reference for lab report expectations by providing examples that range from high to low quality.
5. Guide the students in the proper set up of their experiment. Check each student's hypothesis prior to beginning the lab experiment. Monitor their process and reinforce the concept of having only one variable. Have the student's take detailed notes and use them to write their final reports. They should include their notes as an attachment to the final report.
6. Complete the following activity with your students. Give as much or as little instruction as appropriate for the class. You can give your students detailed instructions or this experiment can be done as a Design-Your-Own-Experiment.
7. Discuss the results of the experiment as a class. What did your students learn about fertilizers? What are some examples of fertilizers? Why are fertilizers important to farmers? Why are they important to the students? What should a farmer or home gardener know before applying fertilizers?

Variations

- ▶ Do the experiment as a class with just one set of plants.
- ▶ Have each group produce one lab report and put it on a poster board for display.
- ▶ Have the students follow directions to mix the various fertilizer solutions for their own group.
- ▶ Grow plants from seeds as a class project.

Can We Have Too Much of a Good Thing?

Extensions

- ▶ Set up two class experiments: one on how fertilizer in various concentrations affects the germination of seeds, and one on how the fertilizer dosage affects the growth of seedlings. This can also be done in student groups.
- ▶ Set up two identical aquariums to include water, Elodea, and water snails. In one aquarium add a cup of liquid fertilizer made according to package directions. The fertilizer represents excess nutrients that have run off the land as a result of a homeowner not following package directions and adding too much fertilizer to his lawn. Observe the changes and differences that occur in the two ecosystems. This activity can be extended to three aquariums so different levels of fertilizer can be tested.

ELL Adaptations

- ▶ Employ group work and cooperative learning. These activities provide opportunities for students to exchange, write, and present ideas. Students use a variety of skills that work together to increase understanding and retention.

Can We Have Too Much of a Good Thing? Lab

Introduction

Plants require 17 essential chemical elements for successful growth and reproduction. Carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium are required in relatively large quantities. These elemental nutrients are obtained from the air and from water in the soil. Nitrogen (N) is known as the *builder*. Nitrogen is needed to make proteins and to carry out photosynthesis. Phosphorus (P) is known as the *energy supplier* and is needed for energy transfer in photosynthesis and is important for seed germination and efficient water use. Potassium (K) is known as the *regulator* because it plays an important role in catalyzing chemical reactions involved in plant growth and protection from stress. Eleven other elements must also be available to plants in smaller amounts.

The soil is like a “grocery store” for plants. The plant roots go “shopping” in the soil to get the nutrients they need. Similar to people, if plants do not get all the nutrients they need they do not stay healthy. Conversely, if the concentration of nutrients is too high, plants can be damaged or killed.

A perfect soil will have good texture and structure that provide spaces for air, water, and roots and also contains the proper nutrients in the correct concentrations. Most soil must be amended or improved in some way to give crops or garden plants what they need to be healthy and abundant year after year.

A fertilizer is any substance that is added to the soil or water to increase the amount of nutrients available to a plant. Fertilizers can be manufactured from natural substances in factories or can be substances that go through little processing before being used on the farm or garden. Manure, fish emulsion, composted plant materials, and store bought commercial materials are all considered to be fertilizers. Commercial fertilizers contain a mixture of nitrogen, phosphorus, and potassium in known quantities that can be immediately used by plants.

As the human population continues to increase, farmers face the challenge of growing more food on the same amount of land. As food crops grow, they take up nutrients from the soil. When the crops are harvested, the nutrients that they have assimilated are also removed from the soil. Farmers must replace nutrients in the soil to continue to grow healthy crops. Wide ranging research continues to improve agricultural efficiency. Every time a fertilizer is purchased in California, a portion of those proceeds is set aside for research and education.

Directions for preparing and applying liquid and solid fertilizers should be followed carefully. Extensive research has been done to determine the best application that provides the proper amounts of nutrients to your plants. Applying too much fertilizer can harm a plant and applying too little can result in nutrient-deficient plants that are unhealthy.


The experiment that follows will allow you to explore the effects of applying different fertilizer concentrations on plants.

Can We Have Too Much of a Good Thing? (continued)

Experiment Instructions

Follow the directions carefully. At the end of the experiment you will write a complete lab report. Refer to the handout for lab report guidelines. Take careful notes throughout the experiment. These notes may be kept in a journal or in a folder.

1. Your teacher will provide your group with four labeled plants that are the same in appearance and size, and are potted in the same type of soil. Make detailed beginning observations of each plant. Use descriptive words and sketches. During the experiment you will be watering these plants with different concentrations of fertilizers to see the effect of fertilizer concentration on the plants. Which fertilizer solutions will be best for overall plant health? Will higher concentrations of fertilizer be better or will lower concentrations be better? You will experiment and find out.
2. Make notes of all the materials you use and the procedure you follow.
3. Write a hypothesis prior to the start of the experiment. Take detailed notes on observations of your plants throughout the experiment.
4. You will be watering each plant with one of four concentrations of liquid fertilizer that your teacher has prepared for you. Plant A will have a 0% fertilizer concentration. This is your control. Your teacher will tell you how much and how often to water the plants. Be careful to give each plant the same concentration of fertilizer that has been designated for that plant throughout the experiment. Water them the same amount each time. For example you will always water Plant A with the 0% fertilizer solution and you will give it the measured amount specified by your teacher each time you water it.
5. When using fertilizers on the farm or in a garden, instructions need to be followed carefully and precisely for best results. **Below is an example** of a type of fertilizer and the instructions provided for the consumer. A Guaranteed Fertilizer Analysis gives the proportion of Nitrogen (N), Phosphorous (P), and Potassium (K) that are present in the fertilizer.

Guaranteed Fertilizer Analysis Statement for Super-Gro	
	<p>Total N = 8% Available Phosphate = 12% Soluble Potash = 4%</p> <p>Directions: Add one tablespoon per gallon of water. Mix until dissolved. Apply to plant foliage and soil. Repeat monthly. Do not apply during heat of day.</p>

6. On the last day of the experiment make your final observations and analyze the results.
7. Complete a lab report using the lab report guidelines. Attach your notes to your lab report.

Lab Report and Guidelines

These guidelines explain each of the sections of a lab report.

Name _____ Date _____

Title _____

1. Background Information

Provide information on the general topic that is being studied in order to help the reader understand the problem. Refer to your textbook, notes from the teacher, library books, and credible Internet sources. Include information that is relevant to the topic. (Keep track of all sources for your bibliography.)

2. Purpose or Problem

Write the experimental question/problem that accurately states what is being investigated. What is the question you are going to answer? The problem should be stated as clearly as possible and may be written as a question.

Lab Report and Guidelines *(continued)*

3. Hypothesis

The hypothesis suggests an answer to the experimental question. It is an educated, scientific guess taking into consideration the background information you researched and prior knowledge or evidence that you already have. Write a hypothesis in the if... then... because... format.

Example: If... (independent variable), then... (dependent variable), because... (a reason for your prediction).

If different types of basketballs are dropped, then they will bounce to different heights, because they are made of different materials. This can be simplified into just the if... then... format.

4. Materials

Make a bulleted list of all the materials you used. Be sure to give the sizes and quantities of items. Be specific and descriptive with every item.

5. Procedure

Include numbered steps in the order that you took to complete the lab. The reader should be able to use this section to duplicate your experiment exactly. Your description should be detailed, yet concise.

Lab Report and Guidelines *(continued)*

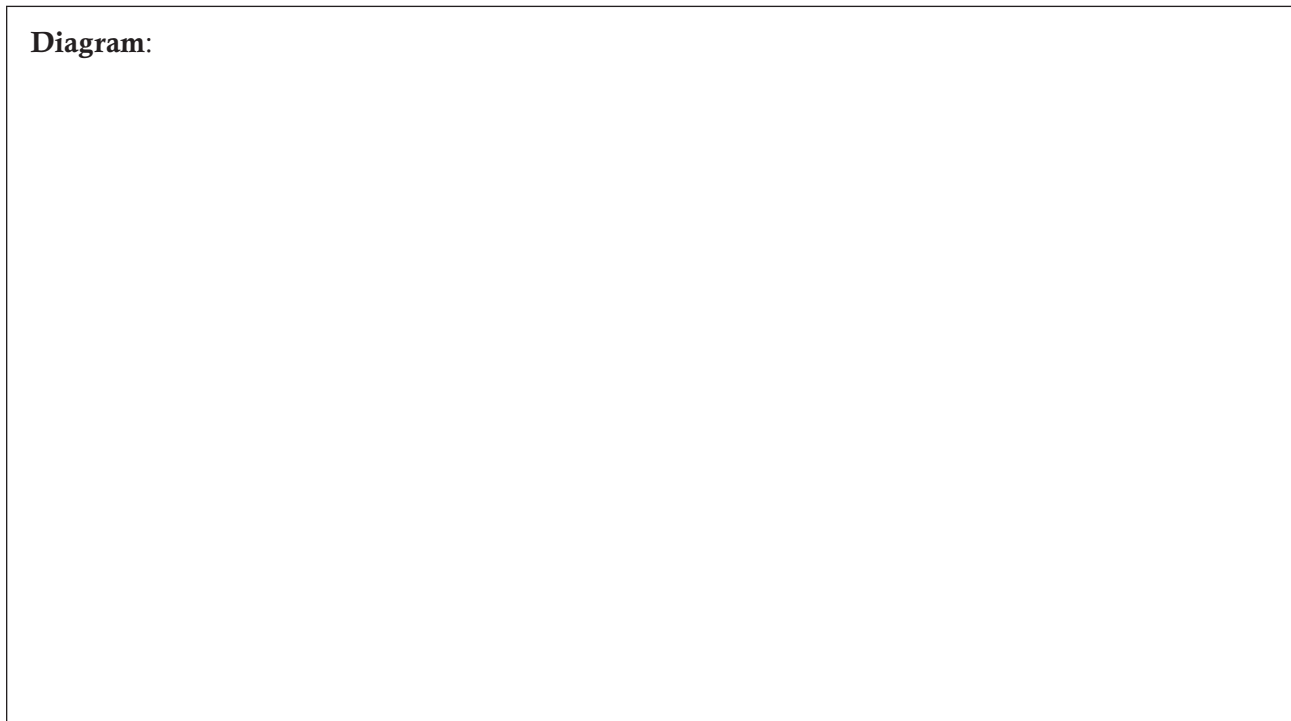
6. Observations and Data

Provide a summary of your data in the form of labeled graphs, tables, diagrams, and calculations. Types of observations that should be included are:

- a. Written observations: sights, sounds, and smells you have observed during your experiment.
- b. Graphs representing data: include a title, labeled axes, and data points. Also include the data table used to record measurements during your experiment. Examples of information that might be recorded in data tables are frequencies, times, and amounts.
- c. Diagram of experiment: this is a drawing of what your experiment looks like. All diagrams should be neat and include proper labels.

Lab Report and Guidelines *(continued)*

Diagram:



7. Discussion

Explain the significance of your results. Were they what you predicted? Why or why not?

Do not re-write your results. This section is where you explain your results and what they mean.

- a. Explain why certain data was important and decide if and how the data supported your hypothesis.
- b. Discuss any weaknesses in the experimental design. Identify sources of error. Give suggestions for improvement.

Lab Report and Guidelines *(continued)*

8. Conclusion

- a. State whether or not the data supported the hypothesis.
- b. Discuss results and explain how your experiment's data fits into current knowledge on the topic.
- c. Identify limitations. There are always factors you cannot control that influence your results. It's important to identify these factors.
- d. Write a new question. A good experiment raises new question(s). List any further questions that you have and any suggestions for further research.

9. Bibliography

It is important that you cite all sources used for your experiment. This includes graphics. You may skip this section if the only materials used were instructions given by your teacher.



California Foundation for
Agriculture in the Classroom

The Right Diet for Your Plants

Purpose

In this lesson, students will learn how to read a fertilizer label and understand the components of fertilizers. Students will also explore factors for choosing the appropriate fertilizer for a given situation.

Time

Two 50-minute sessions

Materials

For the class:

- ▶ Packaged fertilizer labels (optional)
- ▶ Copies of 11th edition of *What's Growin' On?* Elements for Life pages 8-9, downloadable from www.LearnAboutAg.org/wgo

For each student:

- ▶ *How to Read a Fertilizer Label* handout

California Standards

5th Grade

Common Core English Language Arts

RI.5.1
RI.5.2
RI.5.4
W.5.1b
W.5.9b
SL.5.1

Background Information

A fertilizer is any natural or manufactured material added to the soil or water to increase or replace one or more nutrients needed for plant growth. In California, all commercial fertilizers are monitored by the California Department of Food and Agriculture (CDFA) and are required to follow specific label guidelines. The three numbers on the fertilizer package are standardized and represent the percentages of nitrogen (N), phosphorus (P), and potassium (K) in that order.

Manures and commercial fertilizers are illustrated in this lesson so that students can compare and contrast two basic types of fertilizers. The issues revolving around plant nutrients are complex. Plant nutrient requirements are not a “one size fits all” situation.

Different amounts of nutrients are required for different crops, and nutrients may be taken up at different rates during various growth stages of the plant. The percentages of N, P, and K are lower in manure than in commercial inorganic fertilizers. Commercial inorganic fertilizers require mining and the use of fossil fuels for manufacturing. Commercial inorganic fertilizers are generally easier to apply than manure and composts.

Manures provide the organic matter needed to increase the water absorption and aeration of soils. Discuss with your students the importance of continuing research in the area of nutrient requirements of plants and sustainable practices that will conserve resources and produce enough food for the growing population.

Procedure

Complete the *How to Read a Fertilizer Label* handout with your students. This may be done as a class, group, or individual activity.

Variations

- ▶ Adapt the lesson to use real fertilizer labels.
- ▶ Refer to and use CFAITC Agricultural Fact and Activity Sheets on phosphorus, potassium, and nitrogen.
www.LearnAboutAg.org/factsheets.



California Foundation for
Agriculture in the Classroom

The Right Diet for Your Plants

California Standards (cont.)

5th Grade (cont.)

Next Generation Science Standards

5-LS1-1
5-ESS3-1

6th-8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.2
RST.6-8.4
WHST.6-8.4

Next Generation Science Standards

MS-LS2.A
MS-ESS3.A
MS-ESS3.C

Standards alignment is listed in
the matrix on page 143.

Extensions

- ▶ Have students design a brochure that summarizes the particular nutrient requirements of their favorite garden plant or crop.
- ▶ Read and do the activities from the 11th edition of *What's Growin' On? Elements for Life*. www.LearnAboutAg.org/wgo

ELL Adaptation

- ▶ Employ group work and cooperative learning. These activities provide opportunities for students to exchange, write, and present ideas. Students use a variety of skills that work together to increase understanding and retention.

How to Read a Fertilizer Label

Name: _____

Read the following passage and answer the questions that follow.

For healthy growth, all plants require certain nutrients that normally come from the soil. Different types of plants require different amounts of nutrients. Proper balance is necessary. Sometimes the excess of one nutrient can cause the deficiency of another and damage the plant. Soil with added fertilizer nutrients can usually produce more crops and healthier garden plants than soil alone.

The three primary nutrients and their chemical symbols are: Nitrogen (N), Phosphorus (P), and Potassium (K). These are the most important nutrients and are commonly the first in the soil to be depleted. These elements are the ones that most frequently need to be replaced in the soil with some type of fertilizer, however, a total of 17 elements are thought to be essential for plant growth and reproduction. Oxygen, carbon, and hydrogen come from the air and water. Other required nutrients come from water dissolved in the soil. Since plants use up nutrients in the soil, growers often need to replace those nutrients by fertilizing.

Any type of substance that is added to the soil or water to increase the nutrients available to plants is considered a fertilizer. Fertilizers can be in the form of solids, such as stakes or pellets, liquids, or gases.

Soil nutrients can be replenished by either organic or inorganic materials. For example, ground lobster shells and animal manure are good sources of nitrogen; potato skins and banana peels are good sources of potassium; and animal bone meal is a good source of phosphorus. Nitrogen gas from the air can be converted to a form of nitrogen plants can use through chemical reactions. Phosphate rock can be mined and converted to a usable source of phosphorus. Potash is a source of potassium gathered from salt deposits.

Growers and scientists are continually looking for new ways to replenish soils with necessary nutrients for better crop yields. Farmers must match the amount of applied nutrients with the amount of nutrients the plant can use. When this is done, farmers ensure they are not wasting fertilizer and that fertilizers stay on site and are used by plants rather than moving off site to areas where crops are not being grown. Farmers use practices that protect our environment through soil, air, and water quality management. Fertilizer production is heavily regulated in the U.S. with California having some of the most restrictive standards. In addition, the agricultural use of fertilizers is heavily regulated and monitored by many agencies.

In this activity you will learn how to read and understand a fertilizer label. This will enable you to better understand plant nutrients and make the best choice when purchasing a fertilizer for your own lawn, garden, or farm.

How to Read a Fertilizer Label *(continued)*

Reading Questions

1. Name the three primary elements that come from the soil that plants must have for healthy growth.

2. Name two elements that plants get from the air or water.

3. What is the general name for a substance used to put nutrients back into the soil?

4. Why must you follow directions when applying fertilizer?

5. Explain one other thing that you learned from the reading.

Activity

1. Fertilizer labels are written in a standard way so the nutrient content can easily be determined by consumers. The California Department of Food and Agriculture (CDFA), along with the U.S. Department of Food and Agriculture (USDA), make sure that the regulations are followed for labeling foods, fertilizers, pesticides, and other substances.

On the front of any type of fertilizer container there are three numbers. The first number always represents the percentage of nitrogen (N) that is in that particular fertilizer. The second number represents the percentage of phosphorus (P) and the third number represents the percentage of potassium (K). There are also other substances in fertilizers, but the main ingredients are always nitrogen, phosphorus, and potassium.

How to Read a Fertilizer Label *(continued)*

Look at the labels shown below:



- a. What percentage of the fertilizer is nitrogen in the all purpose fertilizer?

 - b. What percentage of the fertilizer is nitrogen in the tree and shrub fertilizer?

 - c. What percentage of the fertilizer is phosphorus in the tree and shrub fertilizer above?

2. Farmers and gardeners use different fertilizers for a variety of reasons. As an example, certain crops or garden shrubs may require more nitrogen than others. If this was the case, the gardener or farmer would use a fertilizer high in the first number, which represents nitrogen. If the soil was too low in phosphorus a good choice might be a fertilizer high in the second number, which represents phosphorus.
- Proper plant growth requires good nutrition, but there can also be too much of a good thing. Plants can be harmed if too much fertilizer is applied. Farmers and gardeners understand that if they use too much of a fertilizer they are wasting money and could possibly harm the plant or allow excess fertilizer to run off the field, lawn, or garden.
- a. State one reason why fertilizers do not all contain the same amounts of nitrogen, phosphorus, and potassium.

3. A “General Guaranteed Fertilizer Analysis Statement” must appear on each fertilizer container. Look at the GGFAS on the following three fertilizer labels:

How to Read a Fertilizer Label *(continued)*

<p>Lawn King Granular Lawn Fertilizer 17-23-6</p>	
<p>Ammonium Sulfate with Coated Urea Guaranteed Analysis</p>	
Total Nitrogen (N)	17%
Available Phosphate (P ₂ O ₅)	23%
Soluble Potash (K ₂ O)	6%
Sulfur (S)	20%
<p>Directions: Uniformly spread 3 ¾ lb of product per 1,000 sq.ft. Water well immediately after application. Repeat every 4 to 8 weeks. Do not apply near water, storm drains, or drainage ditches. Do not apply if heavy rain is expected. Apply this product only to your lawn and clean up any product that spills onto surfaces other than your lawn. Caution: Keep this product out of reach of children and pets. Wash hands with soap and water after handling product. Avoid contact with eyes and mouth. If product gets in eyes, rinse with water for 15 minutes.</p>	
<p>Net Wt. 35 lbs. Manufactured by: Super Nutrient Source, USA</p>	

<p>Tall Trees Tree and Shrub Fertilizer 11-15-9</p>	
<p>Continued Release Spikes Guaranteed Analysis</p>	
Total Nitrogen (N)	11%
Available Phosphate (P ₂ O ₅)	15%
Soluble Potash (K ₂ O)	9%
Boron (B)	0.02%
<p>Directions: Pound spike into soil at least 2 feet away from the tree trunk and under the drip line of the tree's branches. Apply spikes once in the spring and once in the fall when the soil is moist. Store spikes in a sealed plastic bag in a dry area. Store unused spikes in a sealed, plastic bag. Caution: Keep this product out of reach of children and pets. Wash hands with soap and water after handling product.</p>	
<p>Contains 15 Spikes Manufactured by: Trees R Us, USA</p>	

How to Read a Fertilizer Label *(continued)*

Super-Gro Water Soluble All Purpose Plant Food 8-12-4	
Guaranteed Analysis	
Total Nitrogen (N)	8%
Available Phosphate (P ₂ O ₅)	12%
Soluble Potash (K ₂ O)	4%
Copper (C)	0.15%
<p>Directions: Add one tablespoon of product to one gallon of water and mix thoroughly. Reapply every 7 to 10 days. Caution: Keep this product out of reach of children and pets.</p>	
Net Wt. 4 lbs. Manufactured by: The Nutrient Connection, USA	

a. According to the three labels listed above which one has the highest percentage of:

- Nitrogen? _____
- Phosphorus (phosphate)? _____
- Potassium (potash)? _____

b. Name three other substances besides nitrogen, phosphorus, or potassium that can be found in fertilizers. _____

4. You have been applying Super-Gro fertilizer to your tomato plants and watering them appropriately. You are disappointed when large brown spots appear on the base of each red tomato. Your local nursery expert says your tomato plants are lacking calcium. Could you use Lawn King or Tall Trees fertilizer to provide calcium to your tomatoes or should you come up with another method? Explain your reasoning.

5. All fertilizer labels have a warning or caution section. These sections inform you on how to properly store the fertilizer and if any protective clothing or eyewear should be used when handling the fertilizer. What do all three of these labels say in the warning section?

How to Read a Fertilizer Label *(continued)*

6. Natural fertilizers are also used commercially. Animal manures are one example of a natural fertilizer and contain many of the same nutrients as chemical fertilizers. Manures also include organic material that improves soil quality, helps prevent soil erosion, and increases the ability of the soil to hold water. The release of nutrients is slower with animal manure than with a manufactured fertilizer. Animal manure is also more labor intensive to apply than manufactured fertilizer. The following table contains information about four types of manure. It shows how many pounds of each nutrient are contained in one ton of animal manure.

Nutrients in One Ton (2,000 lbs.) of Manure			
Type of Manure	Percentage of N	Percentage of P₂O₅	Percentage of K₂O
Chicken	1.6	0.9	0.4
Dairy Cattle	0.6	0.3	0.6
Turkey	2.0	2.0	2.0
Swine	0.5	0.3	0.5

- a. What type of animal manure contains the most:

- Nitrogen (N)? _____
- Phosphorus (Phosphate P₂O₅)? _____
- Potassium (Potash K₂O)? _____

- b. If you were to buy a bag of chicken manure what would the three numbers on the label be?

What would the three numbers be on the bag of cattle manure? _____

Generally, which have higher percentages of N, P, K; manufactured fertilizer or animal manures?

- c. What is at least one advantage to using animal manure over manufactured fertilizers?

- d. What is a disadvantage of using animal manures over manufactured fertilizers?

How to Read a Fertilizer Label *(continued)*

Conclusion

- 1. List two possible problems with overusing fertilizers.

- 2. In a well written paragraph, explain how fertilizers are important in your life.

How to Read a Fertilizer Label Answer Key

Reading Questions

1. Name the three primary elements that come from the soil that plants must have for healthy growth.

Nitrogen, phosphorus, potassium

2. Name two elements that plants get from the air or water.

Oxygen, carbon, and hydrogen

3. What is the general name for a substance used to put nutrients back into the soil?

Fertilizer

4. Why must you follow directions when applying fertilizer?

It is important to follow directions on fertilizer label because you need to apply enough fertilizer to provide the nutrients your plants need while you also need to be careful not to apply too much fertilizer because this can harm or kill your plants.

5. Explain one other thing that you learned from the reading. Answers will vary.

Activity Questions

1. What percentage of the fertilizer is nitrogen in the houseplant fertilizer?

8%

What percentage of the fertilizer is nitrogen in the tree and shrub fertilizer?

11%

What percentage of the fertilizer is phosphorus in the tree and shrub fertilizer above?

15%

2. State one reason fertilizers do not all contain the same amounts of nitrogen, phosphorus, and potassium.

All plants do not have the same nutrient requirements. The nutrient levels that are already in the soil should also be taken into account.

3. According to the three labels listed:

- a. Which one has the highest percentage of:

- Nitrogen?

Lawn fertilizer

How to Read a Fertilizer Label Answer Key *(continued)*

- Phosphorus (phosphate)?

Lawn fertilizer

- Potassium (potash)?

Tree and Shrub fertilizer

- b. Name three other substances besides nitrogen, phosphorus, or potassium that can be found in fertilizers.

Boron, copper, sulfur, and more

4. You have been applying *Super-Gro* fertilizer to your tomato plants and watering them appropriately. You are disappointed when large brown spots appear on the base of each red tomato. Your local nursery expert says your tomato plants are lacking calcium. Could you use *Lawn King* or *Tall Trees* fertilizer to provide calcium to your tomatoes or should you come up with another method? Explain your reasoning.

No you could not because calcium is not listed on the guaranteed analysis of any of the three fertilizers mentioned. Consult with your local nursery expert about soil amendments that would provide the calcium needed by the tomatoes.

5. All fertilizer labels have a warning or caution section. These sections inform you on how to properly store the fertilizer and if any protective clothing or eyewear should be used when handling the fertilizer. What do all three of these labels say in the warning section?

Keep out of the reach of children.

6. Natural fertilizers are also used commercially. Animal manures are one example of a natural fertilizer and contain many of the same nutrients as chemical fertilizers. Manures also include organic material that improves soil quality, helps prevent soil erosion, and increases the ability of the soil to hold water. The release of nutrients is slower with animal manure than with a manufactured fertilizer. Animal manure is also more labor intensive to apply than manufactured fertilizer. The following table contains information about four types of manure. It shows how many pounds of each nutrient are contained in one ton of animal manure.

- a. What type of animal manure contains the most:

- Nitrogen (N)?

Turkey manure

- Phosphorus (Phosphate P_2O_5)?

Turkey manure

- Potassium (Potash K_2O)?

Turkey manure

How to Read a Fertilizer Label Answer Key *(continued)*

- b. If you were to buy a bag of chicken manure what would the three numbers on the label be?

1.6-0.9-0.4

What would the three numbers be on the bag of cattle manure?

0.6-0.3-0.6

- c. Generally, which have higher percentages of N, P, K; manufactured fertilizer or animal manures?

Manufactured

- d. What is at least one advantage of using animal manure over manufactured fertilizers?

Natural fertilizers such as manure add organic material to the soil, which improves the soil quality and help the soil hold water.

- e. What is a disadvantage of using animal manures over manufactured fertilizers?

The release of nutrients is slower and you need more labor to apply manure. Using the chart students may see you need greater amounts of manure to get the same percentages of nutrients into the soil. A guaranteed analysis isn't usually available for manures, so a farmer or gardener may not know the exact amount of nutrients being applied to crops.

Conclusion

1. List two possible problems with overusing fertilizers.

Overuse can result in harm to the environment, damage to the plants, and wasting money.

2. In a well written paragraph, explain how fertilizers are important in your life.

Answers will vary. Students should recognize that without the required nutrients, farmers would not be able to grow healthy crops year after year on their land. Nutrients that are taken out of the soil by growing crops must be replaced in order to maintain soil health and to grow enough food for people to eat.



Plant Doctor® for a Day

Purpose

In this lesson, students will learn about nutrient deficiencies in plants. Students will act as plant doctors® to explore the important role of agricultural professionals who are trained to accurately diagnose and treat plant diseases to protect our valuable crops.

Time

Teacher preparation:
20 minutes

Student activities:
50 minutes

Materials

For the class:

- ▶ From the CFAITC website www.LearnAboutAg.org/402 download the “Nutrient Deficient Plants” PowerPoint presentation
- ▶ One water deficient plant (wilted) *
- ▶ One pest-damaged plant (damaged by insects or mold) *
- ▶ One over-watered plant *
- ▶ One rusted or yellowing plant *

* *These may be any type of plant*

Background Information

Plants have certain requirements to grow and be healthy. How do we know, short of plants dying, if they are getting enough sunlight, water, nutrients, and carbon dioxide? Similar to humans, plants show symptoms when they are not healthy. Scientists and farmers are constantly researching methods to efficiently diagnose and treat plant diseases. During this lesson, students will model a systematic approach used by agriculture professionals to diagnose plant nutrient deficiencies. Students will understand that many factors can cause a plant to become diseased and not all diseases can be identified easily. Scientific knowledge and years of practice help farmers identify plant health issues.

Farmers’ livelihoods depend on the food they grow, and people depend on the food the farmers provide, therefore, it is critical that farmers have the ability to quickly and accurately diagnose and remedy plant diseases.

Plants require 17 essential elements for proper nutrition. Carbon, hydrogen, and oxygen are taken in from the air and water and the other 14 elements are absorbed by plant roots.

Primary nutrients are nutrients that plants require in the greatest amounts and they are the most commonly deficient nutrients. These nutrients are nitrogen, phosphorus, and potassium or N, P, K.

- ▶ Plants usually require more nitrogen than any other nutrient. Nitrogen is important in forming plant proteins. Deficiencies in nitrogen first appear when older leaves begin to turn light green to yellow. Deficient plants are spindly, have stunted growth, and fewer leaves.
- ▶ Phosphorus plays an important role in photosynthesis, and root and shoot growth. Symptoms of phosphorus deficiencies include stunted growth, purplish color on lower leaves in corn, and distorted leaf shapes with dark green color. The purplish color is due to accumulation of sugars in the plant, especially when temperatures are low.
- ▶ Potassium regulates many plant processes. Symptoms of potassium deficiency include scorching along edges of leaves beginning with older leaves first, poor root growth, weak stalks, and slow growth.



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Plant Doctor[®] for a Day

For each pair of students:

- ▶ *Plant Doctor[®] Reference Manual* handout (page 95)
- ▶ *Plant Doctor[®] to the Rescue* student worksheet (page 98)

California Standards

5th Grade

Common Core English Language Arts

RI.5.2
RI.5.7
W.5.2e
SL.5.1

Next Generation Science Standards

5-LS1.C
5-LS2.A
5-ESS3.C
5-ETS1.A

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.2
RST.6-8.3
WHST.6-8.1e

Next Generation Science Standards

MS-LS2.A
MS-LS2.C
MS-ESS3.C
MS-ETS1.B

Standards alignment is listed in the matrix on page 143.

Secondary nutrients are usually required by plants at slightly lower levels than primary nutrients but are less likely to be deficient than primary nutrients. Secondary nutrients include calcium (Ca), magnesium (Mg), and sulfur (S).

- ▶ Calcium is important in maintaining favorable soil pH and water holding capacity. Calcium deficiency symptoms include browning and die back of growing tips of roots and leaves. Fruit quality is reduced and blossom end rot and fruit decay are common.
- ▶ Magnesium is an important component of chlorophyll. Plants deficient in magnesium exhibit chlorosis, or yellowing between the veins of leaves. Leaves may cup or curve up.
- ▶ Sulfur is important to photosynthesis and protein formation. Sulfur deficient plants are light yellow to light green with yellowing that starts on younger leaves rather than older leaves, as is the case with nitrogen deficiency.

Micronutrients are essential to plant growth but are needed in much smaller amounts than secondary and primary nutrients. Micronutrients include boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and nickel (Ni).

Procedure

1. Gather the variety of sick plants listed in the materials section.
2. Show the sick plants to the students and ask them if they have ideas of what may be wrong with each plant. Discuss possible problems that could lead to a decline in plant health. Plant diseases are caused by many factors including:
 - a. Non-living agents such as air pollutants, nutrient imbalances, and environmental factors such as too much or too little water, frost, or sunburn.
 - b. Living organisms, including bacteria, fungi, viruses, nematodes, protozoa, and parasitic plants.
3. Tell your students that they are going to act as plant doctors[®] and will be diagnosing plant diseases. Today, the Plant Doctors[®] will be specializing in nutrient deficiencies. Explain that professional plant doctors[®] are called plant pathologists. Plant pathologists are plant experts. They know a great deal about the factors that cause

Plant Doctor[®] for a Day

disease and how plants are affected by diseases. A college degree is required to become a plant pathologist.

4. Have students work in pairs and distribute the *Plant Doctor[®] to the Rescue* worksheet to each student.
5. Complete the introductory section as a class.
6. Discuss the purpose of the lesson and the *Plant Doctor[®] Reference Manual*.
7. Walk through the example of how to use the key. First, determine which chart to start with, A, B, or C. Then work through the chart to reveal which nutrient the plant is deficient in.
8. Show the PowerPoint presentation, *Nutrient Deficient Plants*. Stop on each slide and give student pairs time to key out the deficiency they see in the slide. Do slide one together as an example.
9. After students have completed their worksheet, review as a class. If you want to make the activity a contest, a prize may go to the team of students with the highest score.
10. As a closing discussion, ask students for reasons that a plant may become sick and list these on the board. Note that nutrient deficiencies are only one reason that a plant may become sick. Choose one of your slides from the presentation and ask students what was wrong with that plant. As a class, list three next steps they should take as a Plant Doctor[®] to bring the plant back to good health.

Examples:

1. Which types of soil amendments could be added to provide the deficient nutrient?
2. Determine how much of the amendment should be applied.
3. Research the best time of year for the amendment to be applied and if it should be worked into the soil, mixed into irrigation solutions, or another method.

Plant Doctor® for a Day

Variations

- ▶ Make one print of each nutrient deficiency slide from the PowerPoint presentation. Place each picture at a different station. Have students circulate through the stations and identify plant illnesses.
- ▶ Divide the class into three teams and make up your own “Jeopardy” type game that includes the entire class.

Extensions

- ▶ Invite a certified Pest Control Advisor (PCA) to speak to your class. Ask the PCA to bring props he or she uses on the job and perhaps some examples of diseased plants to show students how they diagnose and recommend treatment. Contact the California Association of Pest Control Advisers for possible speakers:
www.pathwaytopca.com
www.plantdoctor.org
www.capca.com
- ▶ Have students research one type of pathogen that causes disease in food crops. Have students make a poster about that pathogen, how it affects the plant, and how it is treated. Students should present their poster to the class.
- ▶ To illustrate the impact that some plant diseases can have, look up information about the Irish Potato Famine. Ask students how the potato blight changed history in 1845.

ELL Adaptations

- ▶ Provide the opportunity for English language learners to partner with a student who is proficient in English. Cooperative learning activities provide opportunities for students to exchange, write, and present ideas.
- ▶ Students can define new terms on a classroom word wall with photos to illustrate definitions.

Plant Doctor[®] Reference Manual

When a household plant looks sick, the owner can attempt to make it better by reducing or increasing the amount of water, looking for pests such as aphids or whiteflies, providing more sun or shade, or adjusting the amount of fertilizer, or plant food, that is being applied. If the houseplant dies, the owner can usually replace the plant by purchasing a new one at the garden center.

There is much more at stake for a farmer. With large crops of vegetables or fruit orchards, plant health problems must quickly be identified and treated so the whole crop is not lost. It is very costly if a crop does not make it to harvest. All of the money that went into preparing the fields, fertilizing, pruning, weeding, watering, and more, is lost. Farmers and crop advisors learn to diagnose plant problems quickly so the crop can be treated in the appropriate fashion.

The following pages contain a Nutrient Deficiency Key. Farmers use keys like this one to diagnose real crop problems that occur. You will become familiar with this key while you identify nutrient deficiencies in plants. Flip through the pages of the key to determine which nutrient may be lacking from the soil while observing the sick plant. Remember, there are many other reasons plants may be sick. The plant could have a problem with the amount of water it is getting, or with insect, bacteria, fungi, or viral infestations. People called plant doctors[®], or plant pathologists, help farmers figure out what is wrong with crops and orchards. Today, you will be a plant doctor[®] and will figure out what is wrong with the sick plants you see in the presentation.

Vocabulary

Chlorosis: leaves look light green, yellow, or white because chlorophyll does not develop.

Necrosis: death of plant tissue.

Terminal bud: the growing part of the plant.

Vein: the tube that carries water and nutrients to all parts to the plant.

Mottling: spots on green leaves that indicate a deficiency or disease.

Midrib: main vein in the center of the leaf.

START

- ▶ Plant is discolored on older or larger leaves or entire plant..... Use Chart A
- ▶ Plant is discolored on younger or smaller leavesUse Chart B
- ▶ Plant looks sick, but is not discolored Use Chart C

Chart A – Symptoms on Older, Lower Leaves of Plant

Follow the directions of this key to determine in which nutrient the plant is deficient in.

1. If corn or sorghum plant Go to 2
If legumes (beans, peanuts, etc.) Go to 5
If citrus (orange, lemon, grapefruit, etc.) Go to 8
If wheat Go to 5
2. Yellow discoloration Go to 3
Discoloration other than yellow Go to 4
3. Yellow discoloring makes a V-shape from tip backwards Nitrogen
Yellowing between veins, edges might be reddish-purple Magnesium
Light green to yellowish; stunted growth Sulfur
Pale yellow to white over entire plant Iron
4. Brown discoloration and edges slightly crispy Potassium
Purple and brown moving from tip backwards Phosphorus
5. Color change over entire plant Go to 6
Color change in leaf tips Go to 7
6. Plant light green. Older leaves affected first but then entire plant turns
pale yellow or brown (lacking nitrogen-fixing bacteria) Nitrogen
Plant is light or dark green. Leaflets tilting upward Phosphorus
7. Yellow mottling around the edges of the leaf that eventually
dries up and falls off Potassium
Brown spots with yellowing between main vein: yellow tissue dries
up and falls off Zinc
Other appearance Magnesium or Manganese
8. Gradual fading of green throughout leaves Go to 9
Fading of green except near midrib Go to 10
9. Fade to yellow-green to yellow or possibly white Nitrogen
Fade to dull green and eventually orange-yellow; fruit may be coarse and
spongy with hollow center Phosphorus
10. Fading of green, blotchy on outer half of leaf; browning of leaf tips; leaves wilt Potassium
Other type of fading Magnesium, Calcium, or Molybdenum

Chart B – Symptoms on Upper Leaves or New Growth

1. If corn or sorghum plant Go to 2
If legumes (beans, peanuts, etc.) Go to 4
If citrus (orange, lemon, grapefruit, etc.) Go to 6
If wheat Go to 4

Plant Doctor® Reference Manual (continued)

2. New leaves are showing chlorosis Go to 3
New leaves remain green..... Go to 11
3. Yellowing between veins along entire leaf Iron
White, irregular spots between veins Boron
Young leaves have yellow to whit bleached bands at lower part of leaf Zinc
4. Growing bud stays alive Go to 5
Growing bud dies Go to 6
5. Leaves yellow to white but veins are green. Some dead spots may be
on leaves..... Iron or Manganese
Leaves and veins turn pale green or yellow Sulfur or Copper
6. Leaves uniformly colored Go to 7
Leaves have irregular color pattern Go to 8
7. Leaves normal colored Go to 9
Leaves pale green, yellow, or white Go to 10
8. Green veins, yellow or white leaves..... Iron or Manganese
Pale green or gray with green background..... Manganese
9. Leaves very dark green; gummy spots Copper
Other problems..... Go to 11
10. Leaves are pale green or yellow, fruit pale in color..... Nitrogen
Noticeably yellow Sulfur
11. Leaves are green but parts of leaf are missing Insects
Leaves green but brown around edges..... High Salinity or Over fertilized

Chart C

Plants, just as humans, can become “ill” for a variety of reasons. This key cannot assist you in diagnosing all plant illnesses but it gives you an idea of how a home gardener or farmer might uncover the cause of a sick plant.

Your plant may be ill because of pest infestation, over or under watering, too many or too few nutrients, not enough or too much sun, temperature variation, air problems, and more. If you have a sick plant, carefully observe the entire plant to see if you notice the cause of the problem. Take a leaf sample or a photograph of your plant to a local nursery or University Cooperative Extension and find out if their garden experts can assist you in diagnosing your plant’s illness.

Remember, symptoms from one problem may look like symptoms caused by a different problem. Often more than one condition will affect plants at the same time. As plants become weakened from disease, pests, deficiency, or drought they become more susceptible to other problems. If you are interested in plant diseases, take a class that is put on by your local Master Gardener chapter or take botany and plant pathology classes in college.

Plant Doctor® to the Rescue!

Name: _____

Introduction

The purpose of this activity is for you to learn how to diagnose what is wrong with plants. Plant doctors®, like your family doctor, are licensed by the State of California to doctor plants and prescribe various treatments to help farmers grow healthy crops. Plant doctors® are licensed to help farmers with various plant pests, diseases, parasitic worms, weeds, plant growth regulators and California laws and regulations relating to agriculture.

1. Before beginning the activity, read the introduction in the Plant Doctor Reference Manual. List two key points:
 - a. _____
 - b. _____
2. The object of the activity is for you to correctly identify the disease of the sick plants you see in the presentation. For each slide in the presentation, use the Plant Doctor Reference Manual to determine the nutrient that is deficient in the plant or another problem that may exist. Fill in the chart.

Plant Name	Plant Description	Chart Used (A, B or C)	Nutrient Deficiency or Other Problem

Conclusion

Explain at least two reasons why it is important for farmers to keep their crops as healthy as possible.

1. _____

2. _____

Besides nutrient deficiencies, what other factors could cause plants to become sick?



It All Ads Up

Purpose

Students will learn fundamental concepts about plant nutrients while conducting in-depth research on one type of soil supplement and designing a persuasive product advertisement.

Time

Two or three 50-minute class sessions, plus homework

Materials

For the class:

- ▶ 1 or 2 copies of the *Advertisement Options List*
- ▶ Reading #1: *Why Must We Replace Nutrients Back into the Soil?* (page 43)
- ▶ Reading #4: *Fertilizers* (page 49)
- ▶ Possible reference websites:
 - www.sunset.com/garden/garden-basics and type “fertilizers” into the search window
 - www.growingthenextgeneration.com

For each student:

- ▶ Magazines containing numerous ads
- ▶ Scissors

Background Information

Farmers and home gardeners may find that their soil is lacking in important plant nutrients. Soils can be improved in a variety of ways. A visit to your local garden center will give you an idea of just how many choices are available for improving your soil with nutrients. You might find yourself asking how to choose the best fertilizer for your garden, and may want to ask one of the garden center experts to help compare different products. In this lesson, students will research a specific soil supplement that they have been assigned. The research will provide background information for an advertisement students will design to entice consumers to purchase their product.

Advertising plays a major role in marketing new and existing products to consumers. Your students will practice what it takes to persuade someone to purchase and use a product. This lesson provides a perfect opportunity for you to lead a class discussion on supply and demand, the cost of items, and how advertising affects what people purchase. At the same time, the students will learn about the different soil supplements that can be used to grow healthy plants.

Procedure

1. Have students look through a magazine and analyze the ads. Have students pick a favorite and a least favorite ad. Share some of the ads with the class and discuss what makes an advertisement effective.
2. Make one or two copies of the *Soil Supplement List*. Cut list into strips, and place in hat or container. There are 20 different soil supplements on the list. Have each student pull a soil supplement description out of the hat.
3. Explain to students that their assignment is to design a magazine ad for the soil supplement item they pull out of the hat.
4. Review the *Soil Supplement Advertisement* handout directions with the class. Provide the readings *Why Must We Replace Nutrients Back into the Soil?* and *Fertilizers* (pages 49 and 43). Discuss the main points of these readings with students. Explain to students that many consumers may not know that fertilizers provide plants with essential nutrients for growth. Explain that nutrients must be replaced back into the soil after they have been removed along with harvested crops. As advertisers, students will want consumers to know why their product is important.



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It All Ads Up

- ▶ Blank, white paper and construction paper
- ▶ Markers or colored pencils
- ▶ Glue
- ▶ One Advertisement Option
- ▶ *Soil Supplement Advertisement Handout* (page 104)

California Standards

5th Grade

Common Core English Language Arts

RI.5.7
W.5.2a
W.5.2b
W.5.2e
W.5.4
W.5.9b
SL.5.1
SL.5.2
SL.5.4
SL.5.5

Next Generation Science Standards

5-LS1.C
5-LS2.A
5-LS2.B
5-ESS3.C

Visual Arts Content Standards

Connections, Relationships,
Applications 5.2

5. Explain that student ads should look authentic and professional and should not simply copy an advertisement from an existing product.
6. During class, have each student research his/her product and review references. Also, have students decide what type of magazines or newspapers they will design for: a family magazine, a gardening magazine, a farming magazine, etc. This will help them determine how their ad should look. Discuss how the audience will affect what they design.
7. Have students begin work in class. The creation of this ad will probably be assigned as homework and will be brought back completed in 3 or 4 days. Some students may need time to look at possible ideas in stores so they should be given several days to complete the assignment.
8. When completed projects are brought into class to be shared, have four or five students come to the front together. Each student will show his/her poster. Have classmates identify, or try to identify, what the student was advertising. Have the student explain in a few sentences what was being advertised and what they learned about the topic. They should include why someone would want to buy that product.

Variations

- ▶ Have students share their final product in a small group instead of in front of the class.
- ▶ Give students the option to use other types of technology to create their ads. Examples include radio broadcast, iMovie, and more.
- ▶ Have students use reference books instead of online sources of information. Possible reference books:
 - The New Western Garden Book by Sunset Magazine
 - California Master Gardener Handbook by Pittinger
 - Western Fertilizer Handbook by Western Plant Health Association



California Foundation for
Agriculture in the Classroom

It All Ads Up

California Standards (cont.)

6th Grade

Visual Arts Content Standards

Connections, Relationships,
Applications 5.4

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
SL.6-8.2
SL.6-8.4
SL.6-8.5
RST.6-8.2
RST.6-8.9
WHST.6-8.1b
WHST.6-8.1e
WHST.6-8.4
WHST.6-8.7

Standards alignment is listed in
the matrix on page 143.

Extension

- ▶ Have students include a written report, explaining what they learned about soil supplements while researching their topic.

ELL Adaptations

- ▶ Partner ELL students with English-proficient students.
- ▶ Provide ELL students with an actual sample of their assigned soil supplement.

Soil Supplement Advertisement

Name: _____

-
1. What soil supplement have you drawn from the hat? _____
 2. You will create an advertisement that will encourage consumers to purchase your soil supplement product. First, you need to do some research about your soil supplement. Consumers will expect that you will be able to tell them:
 - a. What is the soil supplement used for? For example, is it intended for use on lawns, flower beds, fruit trees, corn fields, or something else? _____

 - b. How will the soil supplement benefit their plants? For example, it provides nitrogen or other essential nutrients, or it lowers the soil pH for acid-loving plants, or it provides home gardeners with a way to make their own compost for their plants. _____

 - c. What are the ingredients in the soil supplement? _____

 - d. What are the directions for applying the product to plants? _____

 - e. What safety measures should be taken when working with the product? _____

 - f. Where is your product made? _____
 - g. Why should consumers choose your product over others? _____

 3. What types of magazines will you target to advertise your product? Examples include, but are not limited to, magazines for farmers, home vegetable gardeners, nursery managers, families, golf course managers, and flower enthusiasts. _____

Soil Supplement Advertisement *(continued)*

Who is your target audience and how will your design appeal to them? _____

4. Give your product an appealing name and slogan that are relevant to what you are trying to sell.

Product Name: _____

Product Slogan: _____

5. Your ad may be designed on a poster or as a digital illustration. It is due on _____.

Be creative!

Advertisement Options

(cut on dotted lines)

Fertilizer High in Nitrogen

Fertilizer High in Phosphorus

Fertilizer High in Potassium

Fertilizer High in Micronutrients

Common Houseplant Fertilizer

Orchid Fertilizer

Dairy Farmer Who Wants to Sell Cow Manure

Chicken Farmer Who Wants to Sell Chicken Manure

Fertilizer Company Selling Fish Emulsion

Company Selling Home Compost Bins

Advertisement Options *(continued)*

Aerial Fertilizer Application Company

Fertilizer Company Selling Seaweed

Lawn Fertilizer Company

Slow Release Fertilizer

Earthworm Farmer

Company who Manufactures Rhizobium Bacteria

Fruit Tree Fertilizer Company

Fertilizer Company Selling Bat Guano

Pulverized Limestone

Peat Moss

Let's Vote On It

Purpose

In this lesson, students will hold a mock election to learn the importance of becoming well informed on the pros and cons of voting measures that affect our local economies, our environment, and our quality of life.

Time

Teacher preparation:
20 minutes

Student activities:

- ▶ Two 50-minute sessions
- ▶ 30 minutes of homework

Materials

For each student:

- ▶ *Faraway Fields* handout (page 113)
- ▶ Four official ballots
- ▶ Graph paper
- ▶ Markers or colored pencils

Background Information

As rural areas become urbanized and people become more aware and concerned about the environment, voters are constantly asked to make decisions that affect their local communities and, ultimately, the world. Agricultural issues are complex and involve intricate social, economic, and environmental relationships. During this lesson, students will apply their knowledge to realistic situations and should be able to recognize that knowledgeable voters are needed to make appropriate decisions for their communities and the world.

Procedure

1. Ask students what they can do around their homes to be good stewards of our natural resources. For example, how might they dispose of old paint or car engine oil? What if one of their parents asks them to apply lawn fertilizer, how should they do that?
 - a. Ask students what precautions farmers might take to be good caretakers of the soil and water so that food and fiber production can continue while protecting the environment for future generations? Ask students how the general public depends upon farmers and ranchers.
2. Have students create a table that is similar to the one below, then pass out the *Faraway Fields* student handout. Instruct students to jot down key points as they read about the propositions that residents of Faraway Fields will be voting on.

Proposition	Pros	Cons
N		
F		
5		
Q		
Z		



California Foundation for
Agriculture in the Classroom

Let's Vote On It

California Standards

5th Grade

Common Core English Language Arts

RI.5.1
RI.5.2
RI.5.3
RI.5.4
W.5.1b
W.5.2b
SL.5.1
SL.5.2
SL.5.4
SL.5.5

Common Core Mathematics

5.MD.2

Next Generation Science Standards

5-ESS3-1
5-ESS3.C
5-ETS1.A
5-ETS1.B

7th Grade

Common Core Mathematics

7.RP.2b

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.2

Standards alignment is listed in
the matrix on page 143.

3. After they have read the propositions, have students form groups of three or four to discuss what each proposition means. What would a no vote mean? What would a yes vote mean? What are the pros and cons of voting either way? Do voters have all the information they need to make an informed vote? Tell students to be prepared to explain this to the class.
4. Call on a student group and ask a representative to explain what a yes vote means for proposition N and what the benefits would be.
 - a. Call on a different group and ask a representative to explain what a no vote means for proposition N and what the benefits are for not passing the proposition.
 - b. Do this for each of the propositions. Have students keep their personal vote to themselves.
5. Instruct students to read over their notes for homework and come to class prepared to vote on the propositions the following day.
6. The next day, create an authentic voting setting:
 - a. Have the students vote on the propositions using the provided ballot.
 - b. Tally the votes.
 - c. Make a graph that illustrates how many “yes,” “no,” and “undecided” votes there were for each proposition.
 - d. Discuss what the outcome of the election would mean to the town of Faraway Fields.
7. Have students take the propositions and blank ballots home and ask three people who are not part of the class to vote on the propositions. The student should not discuss what has taken place in the classroom with the voters. Graph the public’s results. Compare those results with the class results. If appropriate, explain why the results are different (knowledge of subject matter, how informed people are on the issues, and how concerned they are about the issues). Discuss how the outcome of the public’s vote would affect the city of Faraway Fields.

Let's Vote On It

Conclusion

After comparing class and public voting results, discuss the following issues as a class.

Did each student think about these issues before voting? How about the “public,” did they think about these issues before casting their votes?

Proposition N

Who will pay for the cost of the repairs to septic tanks that will cost approximately \$2,500? What will happen if the bill can't be paid? Is it known for certain that the problem is being caused by septic tanks or could it be related to nutrients running off lawns or the local golf course?

Proposition F

What are some different types of fertilizers? Are fertilizers toxic? How do you know? Does it depend on how they are produced, transported, or applied? Will employment opportunities benefit the community?

Proposition 5

What about liquid and gaseous fertilizers? Will this affect the homeowners who buy lawn fertilizers? Will this cause people to buy smaller quantities more often to avoid the fees? Fertilizers come in different forms such as liquid or granular and the purchase of 10 lbs. of fertilizer is common when homeowners purchase lawn and garden fertilizers.

Proposition Q

How will plants get their nutrients if all fertilizers are banned? Aren't manures and composts fertilizers that also contain nitrogen? The proposition is unreasonable due to the fact that nutrients will eventually be depleted if crops continue to be planted and harvested without replacing soil nutrients with any type of amendment.

Proposition Z

Is protective gear really necessary when spreading manures and composts? This proposition applies to all fertilizer, including manure and compost. Who will pay for the extra cost to enforce this law? Applicators should follow safety guidelines on each individual fertilizer and take the appropriate measures for safe handling and application. This may vary for different fertilizers.



Let's Vote On It

People vote certain ways on issues for a variety of reasons. It is important for the students to realize that the more informed they are about political issues, the better off their community will be.

Through the class discussion, students should understand that there are many questions to be explored about all of these issues and that campaign and voting material does not always include the information needed to make an informed decision.

Faraway Fields

Name: _____

Once, Faraway Fields was a small agricultural community of 3,000 people. Faraway Fields is located 30 miles west of a large state capital. Because of its desirable setting and proximity to the state capital, Faraway Fields has more than doubled in size in the last ten years and is now home to 7,000 residents. A large chain grocery store has moved into the area, and a computer company has established a service center employing 200 people. The Faraway Fields community is slowly changing. Residents of Faraway Fields are going to vote on many important issues in the next election.

Proposition N

Since there has been an increase in the nitrates (a form of nitrogen) in waters of a local lake, all homeowners with septic tanks (approximately 50% of the homes) must pay a \$100 fee to have their septic tank area checked annually. They must correct detected septic tank problems within two years. If needed, repairs to septic tank systems will cost homeowners approximately \$2,500. This proposition was recommended by the city council to determine if the nitrates are coming from the human waste. A septic tank is a below-ground tank where sewage is decomposed and then leached into the surrounding soil.

Proposition F

Friendly Food Fertilizer Company has purchased 35 acres of land ½ mile outside of the town limits to mix and prepare fertilizers for local farmers. Passage of this proposition will allow the Friendly Food Fertilizer Company to continue operation. A yes vote means that you approve of the mixing and preparing of fertilizers in this setting, including increased semi truck traffic in the area. A no vote means that the farmers will need to pay more for the fertilizers to cover transportation costs since the fertilizers will need to be trucked in from a fertilizer plant that is many miles away, thus you will pay more for your food.

Proposition 5

Beginning January 1st of next year, a license will be required for any person purchasing more than 10 lbs. of granulated fertilizer labeled 5-5-5 or higher at any one time of purchase. Licenses will be filed with the county and will show proof that the licensed person has taken a two-hour online course to learn about fertilizer storage and application. The course will cost \$25 and only needs to be taken one time. Licenses will need to be renewed annually and will cost \$25 per year.

Proposition Q

Since nitrates were found in the well water of a local home, the selling and use of nitrogen fertilizers by all people will be banned in Faraway Fields for one year beginning on January 1st.

Proposition Z

All people using fertilizers, organic or inorganic, must wear protective eye gear, dust masks, and disposable gloves. Any person seen by local police not wearing protective gear will be issued a \$100 fine. This is an attempt to reduce agricultural-related illnesses from fertilizers.

Official Voters Ballot

City of Faraway Fields

Directions: Cut on the dotted lines, fill in the appropriate bubbles and sign the bottom of the ballot.

Official Ballot				
Proposition N	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition F	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition 5	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Q	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Z	<input type="radio"/>	YES	<input type="radio"/>	NO
I certify that I am a citizen of Faraway Fields and am voting only once on these propositions.				
Signature _____				

Official Ballot				
Proposition N	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition F	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition 5	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Q	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Z	<input type="radio"/>	YES	<input type="radio"/>	NO
I certify that I am a citizen of Faraway Fields and am voting only once on these propositions.				
Signature _____				

Official Ballot				
Proposition N	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition F	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition 5	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Q	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Z	<input type="radio"/>	YES	<input type="radio"/>	NO
I certify that I am a citizen of Faraway Fields and am voting only once on these propositions.				
Signature _____				

Official Ballot				
Proposition N	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition F	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition 5	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Q	<input type="radio"/>	YES	<input type="radio"/>	NO
Proposition Z	<input type="radio"/>	YES	<input type="radio"/>	NO
I certify that I am a citizen of Faraway Fields and am voting only once on these propositions.				
Signature _____				

Its a Dirty Job!

Purpose

In this lesson, students will create mini habitats to observe earthworm behavior and learn about the important role that earthworms play in decomposition and plant growth.

Time

Teacher preparation:
45 minutes

Student activities:

- ▶ Two 60-minute sessions
- ▶ Four 10-minute observations over a two week period

Materials

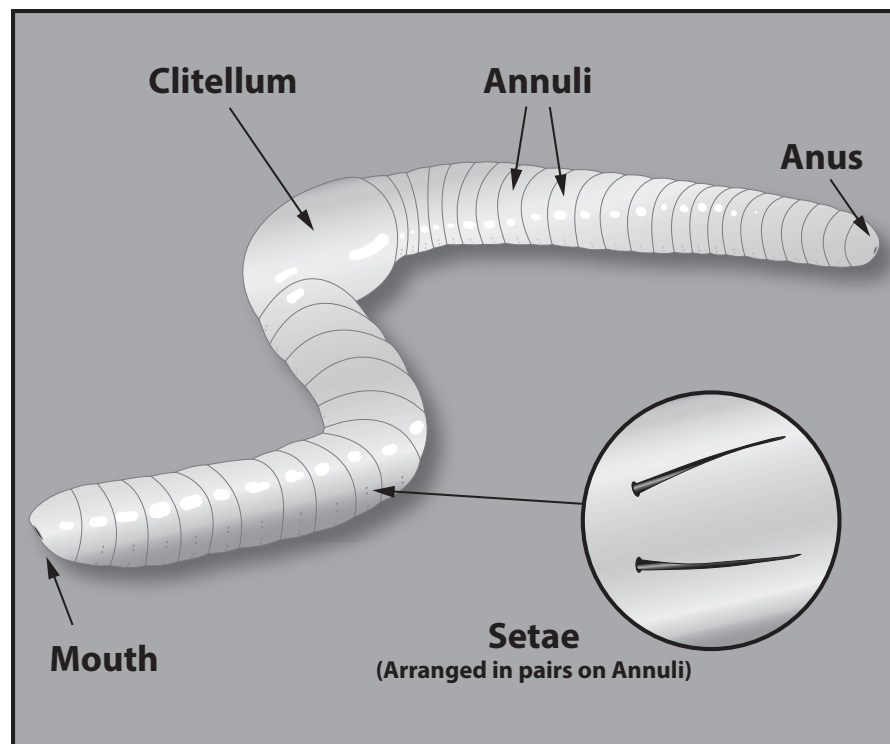
For each pair of students

- ▶ One 2-liter plastic bottle
- ▶ One small plastic water bottle (16 oz)
- ▶ Scissors
- ▶ One cup of sand
- ▶ Two cups of soil
- ▶ Two earthworms (purchase from bait shop, garden store, or online)
- ▶ Piece of cheesecloth to cover top of bottle
- ▶ Rubber band or string to secure cheese-cloth

Background Information

Although they often go unnoticed, earthworms play a significant role in our lives. As decomposers, worms have the important job of recycling waste material into nutrients that plants can use to grow and provide food for people and other animals. As worms burrow through the soil, they ingest soil particles and obtain nutrition by digesting any dead plant or animal remains, fungi, and bacteria in the soil. Through this process, the worms mix up the soil, providing air spaces for roots and water to penetrate. Worm excrement, or castings, provides excellent fertilizer. This is why many home gardeners put worms into their compost piles.

If you have ever held an earthworm, you probably noticed that it was moist. Earthworms do not have lungs, they breathe through their skin, which must be moist in order for oxygen to dissolve and pass into their bloodstream. Earthworms need a cool, dark, moist environment. They do not have eyes but do have special receptor cells to sense ground vibrations and light. The rings on an earthworm's body are called annuli. Tiny bristles called setae help the worms pull themselves through the soil. The lighter colored "bump" in the middle of the





Its a Dirty Job!

- ▶ Worm food
- ▶ Brown paper grocery bag
- ▶ Tape

For each student:

- ▶ *An Earthworm's Dirty—but Important—Job* worksheet (page 119)
- ▶ *Earthworm Project Agreement* (page 120)
- ▶ *Directions for Earthworm Habitat Construction and Observations*

Tip: Ask students to bring plastic bottles, soil, and earthworm food from home if possible.

California Standards

5th Grade

Common Core English Language Arts

W.5.2a
W.5.2e
SL.5.1

Next Generation Science Standards

5-PS3.D
5-LS2.A
5-LS2.B

earthworm is the clitellum, the structure responsible for secreting mucous required for the worm to breathe, reproduce, and for protection as the worm burrows through rough soil. Worms have a special organ called a gizzard to help them grind up and digest the soil that they eat.

Earthworms come in a variety of sizes. The largest known earthworm species in Australia can reach nearly ten feet in length! Some worms live close to the surface of the soil, while others burrow six or seven feet deep.

Earthworms can be classified into three main groups based upon the soil areas where they prefer to eat and burrow.

- ▶ The worms you find in compost piles are in the Epigeic group. Epigeic earthworms live in plant litter near the surface of the soil and need a lot of decaying organic matter to feed on. These worms are relatively small and can tolerate living in conditions with many other worms. This makes them well suited for composting.
- ▶ Endogeic earthworms live in the upper-to mid-soil layers and feed on soil and decomposing organic matter. Endogeic earthworms don't have permanent burrows.
- ▶ Anecic earthworms are deep burrowing and have permanent burrows that can be spotted by little piles of worm castings at the soil surface. These worms are large and are often referred to as "night crawlers." Anecic earthworms feed on decaying vegetation that they pull into their burrows from the topsoil.

Earthworms are hermaphrodites, meaning they have both female and male reproductive parts. After mating, earthworms lay eggs inside a cocoon covering that hatches in about two or three weeks, but this can vary depending on species and weather conditions. Baby worms are called wormlets and look like tiny pieces of thread when newly hatched.

In addition to improving soil and decomposing waste, earthworms are important food for a variety of animals such as birds, snakes, amphibians, rodents, and other small animals.



Its a Dirty Job!

California Standards (cont.)

6th - 8th Grade

Common Core English Language Arts

SL.6-8.1
RST.6-8.1
WHST.6-8.4
WHST.6-8.7

Next Generation Science Standards

MS-PS3.D
MS-LS2.A
MS-LS2.B
MS-LS2.C
MS-LS2-3

Standards alignment is listed in
the matrix on page 143.

Procedure

Several days before starting construction of the worm habitats, introduce the project to the class so students have time to gather materials from home. Have students bring plastic bottles, soil, and worm food as identified on page 120. Students will work in pairs and should decide which partner will be in charge of providing the listed items from home.

During this introduction, brainstorm answers to the following questions with the class and keep a list of ideas on the board:

1. What would the world look like without earthworms?
2. What role do earthworms play in the ecosystem?
3. What do earthworms eat?
4. How do earthworms help plants?
5. How do earthworms help people?
6. What type of habitat do earthworms need?
7. How can we turn our food scraps into fertilizer?
8. How should worms be cared for during their stay in our earthworm habitats? (At the end of a two week period, worms will be released into the school garden).

Instruct students to transfer the notes from the class brainstorm onto the graphic organizer called, *An Earthworm's Dirty—but Important—Job*. Also, have students fill out the Earthworm Project Agreement showing that they understand the rules for caring for the earthworms in the habitats the class will create. Discuss the rules as a class and collect the signed Earthworm Project Agreement.

Variation

- ▶ Instead of having groups of students create their own earthworm habitat, make one large worm habitat in an aquarium for the entire class to observe.

Its a Dirty Job!

Extensions

- ▶ Have students research and learn about earthworm anatomy. There are a number of free “virtual earthworm dissections” on the web.
- ▶ Plant two identical plants in pots in the classroom. Place a few earthworms in one pot. Over the next several months, determine if there is any growth difference between the plant potted with earthworms and the one without. Be sure to keep the soil moist.

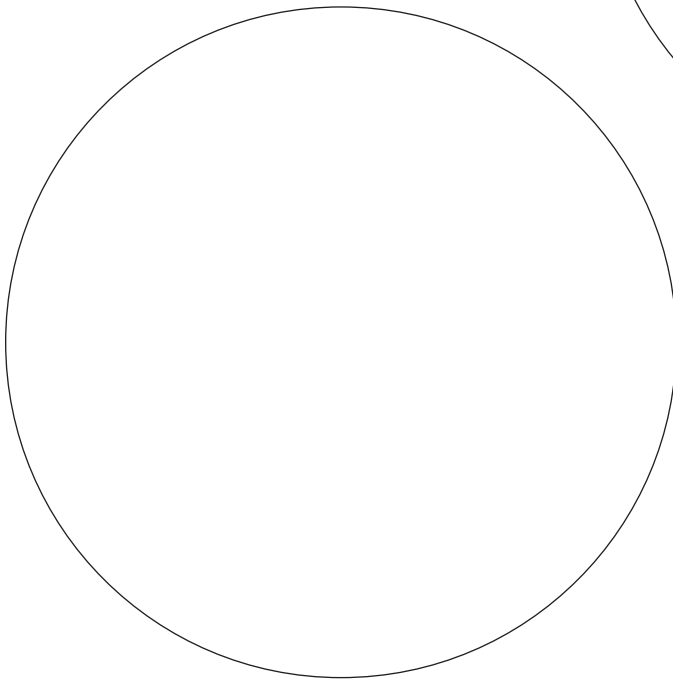
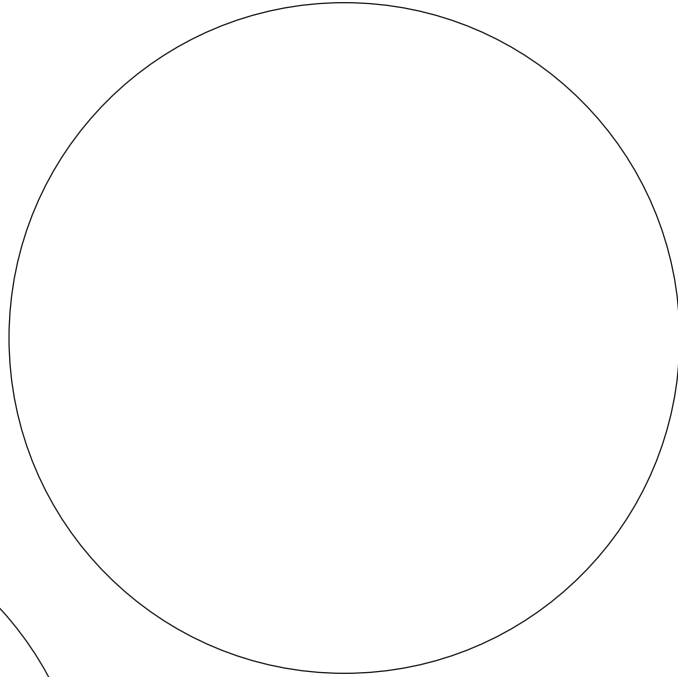
ELL Adaptations

- ▶ This lesson employs hands-on activities and cooperative learning. Activities provide opportunities for students to exchange, write, and present ideas.
- ▶ Provide a model of the finished worm hotel project so ELL students can see what their completed project should look like.

An Earthworm's Dirty—But Important—Job

Name: _____

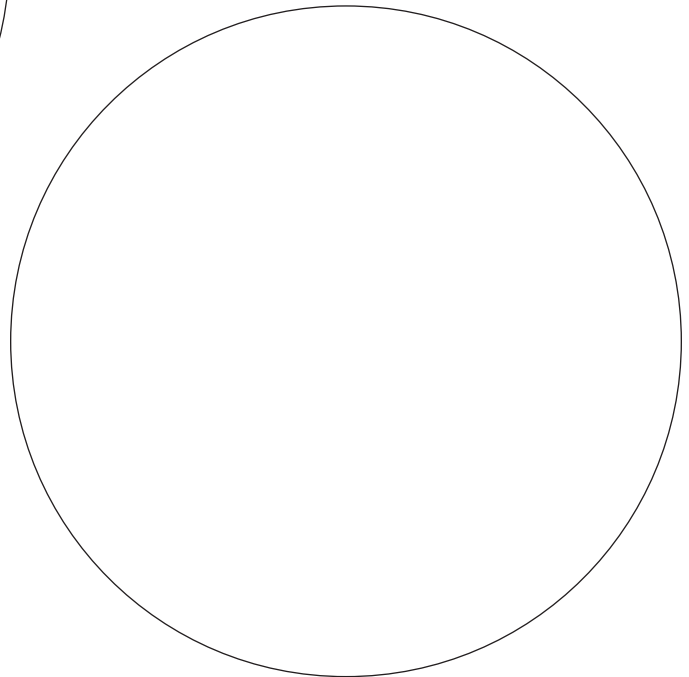
Without earthworms, the world would look like this



This picture is an example of a good earthworm habitat.



This picture shows how earthworms help plants and people.



Earthworm Project Agreement

I will bring the following materials to class by _____.

- ▶ One 2-liter plastic bottle
- ▶ One small water bottle
- ▶ Two cups of soil
- ▶ Brown paper grocery bag
- ▶ Earthworm food consisting of three of the items from the possible list.

1. _____
2. _____
3. _____

- ▶ Acceptable Earthworm Food (cut into small pieces)

Raw vegetable scraps

Squash

Melon rinds

Lawn clippings

Berries

Cornmeal

Apples

Coffee grounds

Pears

Leaves

Prohibited foods: citrus, onions, garlic, meat, dairy, oil/grease, cooked foods

I promise to provide my earthworms with:

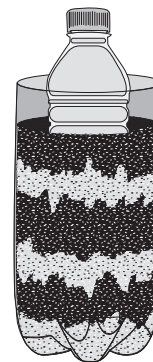
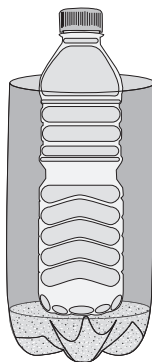
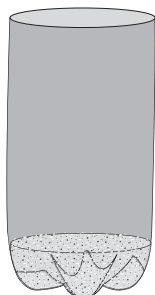
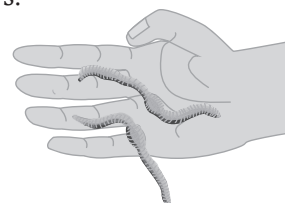
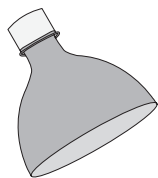
- A habitat constructed according to class directions
- A habitat containing damp soil
- Acceptable earthworm food
- A habitat stored in a cool dark space

We will keep our worm habitats in class for observation over a two week period. At the end of that time, we will place our earthworms in our school garden or another suitable area.

Signature _____ Date _____

Directions for Earthworm Habitat Construction and Observations

1. Gather all necessary materials.
2. Use scissors to carefully cut the top off of a plastic two-liter bottle.
3. Put the empty, small plastic bottle inside the center of the two-liter bottle.
4. While one person holds the small bottle in place, another person can pour alternating layers of sand and garden soil into the space between the wall of the small plastic bottle and the two-liter bottle until it is about two-thirds full, as shown in the illustration. This design will keep the worms near the interface of the soil and two-liter bottle wall so we can see them.
5. Do not pack the soil down, it should remain loose so the earthworms can easily burrow through.
6. Use a spray bottle to squirt enough water onto the soil to make the layers damp but not soggy.
7. Earthworms like their habitat to be dark. Cut a strip of brown paper bag that can be taped around the habitat to keep the light out.
8. Sprinkle your selected earthworm foods on top of the soil.
9. Once your teacher has inspected your habitat, you will receive two earthworms to gently place on top of your soil. Cover your earthworm habitat with cheesecloth and secure with a rubber band.
10. Place your earthworm habitat in a cool, dark place for two or three days before uncovering the paper cover to observe earthworm behavior.
11. Replenish habitat with food and dampen soil as needed every few days.



Keep worm habitats in a cool, dark place. Be careful not to let the habitat dry out or get too hot, this could kill the worms. Food waste that is too salty or contains a lot of acidic remnants like tomatoes and citrus can also kill worms.

Directions for Earthworm Habitat *(continued)*

Journal Observations

Each time you uncover the paper cover from your earthworm habitat, use a piece of binder paper to record the following observations:

- Date
- Conditions of the habitat (water, food, etc.)
- What foods did earthworms eat from the last time you fed them? What foods remain uneaten?
- What food did you provide today, if any?
- Can you see the worms? If so, describe their location in the habitat.
- What evidence is there of worm activity?

Concluding Paragraph

At the end of the two-week observation period, write a paragraph or create a slideshow presentation or video to explain the following:

- ▶ How this earthworm habitat is a model of how matter cycles among plants, animals, decomposers, and the environment.
- ▶ How earthworms can help reduce waste that people throw away, giving examples from your own household.

Answers to Commonly Asked Questions

What is fertilizer?

A fertilizer is a substance that provides one or more chemical elements necessary for plant growth and development. There are two classes of fertilizers: organic fertilizer and inorganic, or commercial, fertilizer. Either type can be used by farmers and home gardeners to replace nutrients removed from the soil by previously harvested crops or to add nutrients that may be naturally lacking in the soil. Plants do not have a preference for either type. Some differences and similarities between these two types of fertilizers are described below.

Organic fertilizers are fertilizers that originate from living organisms and go through very little processing before being used on crops. Some organic fertilizers include fish and seaweed emulsions that are made by liquefying seaweed and fish. Other examples include compost, worm castings, bone meal, ground oyster shells, and steer and chicken manure. Organic fertilizers usually contain many different nutrients in low concentrations. Their nutrients are often in forms that must be broken down by microorganisms before they can be used by plants. The release of nutrients takes time, especially in cold weather when microorganisms in the soil are less active. In addition to adding nutrients to the soil, organic fertilizers also add organic matter that improves soil structure by increasing pore spaces, air circulation, and water holding capacity.

Some organic fertilizers can be labor and cost intensive to apply on large fields; with their low nutrient concentrations, large quantities may be needed to supply sufficient nutrients for growing crops. If manures are not composted before being used as a fertilizer, they can be a source of weed seeds or can damage plants if the manure has high salt content.

Inorganic or commercial fertilizers are fertilizers that are created in factories from nitrogen gas from the atmosphere and other natural materials like rocks, minerals, petroleum, and animal products. Commercial fertilizers are prepared to contain exact amounts of nutrients in forms that can be immediately used by plants. They generally contain nitrogen, phosphorus, potassium, and a few trace minerals at concentrated levels. Some examples of commercial fertilizers are potassium sulfate and ammonium phosphate.

Nitrogen is the most abundant element in the Earth's atmosphere, but plants cannot absorb atmospheric nitrogen gas from the air. It must be

Answers to Commonly Asked Questions

in a special form to be used by plants. Inorganic nitrogen fertilizer is made by combining hydrogen and nitrogen from the air.

Inorganic phosphorus is made by mixing phosphate rock, mined from the earth, with sulfuric acid and water.

Potassium fertilizer is commonly called potash (pronounced “pot ash”). This name comes from the fact that the ashes left over from a campfire contain potassium and were, throughout history, put into fields. Inorganic potassium is usually obtained by mining. Potash is mined in New Mexico, Utah, and parts of Canada. Potassium can also be obtained from brine (salt) deposits on the Earth’s crust. Brine deposits are places where large bodies of salt water used to exist and evaporated, leaving the salt behind. One example of a brine salt deposit is the salt flats near the Great Salt Lake in Utah.

Inorganic fertilizers are used by many farmers for a variety of reasons. They are easy to transport, store, and apply, and exist in a variety of formulas to meet the specific nutrient requirements of crops. Some of these fertilizers are formulated to be high in nitrogen while others are high in phosphorus or potassium.

Whether using organic or commercial fertilizer, farmers and home gardeners must take care to use fertilizers appropriately. Applying too much of either organic or commercial fertilizer can damage plants, waste money, and impact the environment. Farmers work closely with scientists to determine the best types of fertilizers for their crops, when to apply, how much to apply, and how to protect the environment. Home gardeners can take courses or obtain information about proper use of fertilizers from local garden clubs and university cooperative extension offices.

Why has composting become so popular?

Compost is a mixture of decayed organic matter. With an increase in public concern over environmental issues such as overflowing landfills, an increasing human population, and finite resources, we are constantly searching for ways to re-use and recycle materials we consume.

Composting allows farmers, gardeners, and the general public to turn everyday organic waste, such as kitchen scraps and lawn clippings, into organic matter that can be used to fertilize plants. Composting not only provides plants with nutrients but also improves soil quality. Adding organic matter to the soil increases the amount of air available to plant roots and improves the soil’s ability to absorb water. Compost bins

Answers to Commonly Asked Questions

can be constructed from scratch, and pre-made containers are widely available in home improvement stores and nurseries. Composting is an interesting and responsible way to reduce waste and fertilize plants.

Why do plants die if they get too much water?

With the help of light, plants are able to convert water and carbon dioxide into food for themselves. The process of converting plant food into energy for plant growth is known as respiration, which requires the intake of oxygen into the root of the plant. If the soil is too wet, it becomes waterlogged and does not provide enough oxygen to the roots for plants to grow. Therefore, the plants cannot respire and will die. You could say plant roots “suffocate” without oxygen, the same way humans and animals will die from a lack of oxygen.

Why do plants grow towards the light?

Plants are phototropic, which means they are attracted to light sources because they need it for energy. Plants contain a growth hormone called auxin that only functions in the dark. Plant cells on the shady side of the plant tend to elongate due to the presence of auxin, allowing plants to reach and bend in the direction of the light source. Essentially, the shady side of the plant grows faster than the sunny side of the plant, thus causing the plant to lean over and face the sun.

Why do plants yellow if they do not have enough nutrients?

Yellowing is a sign of an unhealthy plant. There are many causes of yellowing, but generally it means that the process of chlorophyll formation is interrupted. This can be due to over watering, under watering, or too little exposure to light. Chlorophyll is the green substance in plants that is able to absorb energy from the sun and convert carbon dioxide and water into sugars and starches. The chemical formula for chlorophyll is $C_{55}H_{72}O_5N_4Mg$. As the chemical formula illustrates, specific elements are needed to build the molecule. If the required nutrients cannot be produced, the plant turns yellow and eventually dies.

Why do plants need fertilizer?

Just like humans, plants need certain nutrients to grow and thrive. The most important of these nutrients are the chemical elements

Answers to Commonly Asked Questions

carbon, hydrogen and oxygen, which are used to produce sugars and starches that serve as plant food. Other essential elements are nitrogen, phosphorus, and potassium (potash), which can be found in most packaged fertilizers. Nitrogen and phosphorus are important because they are necessary to sustain a plant's basic building blocks, such as chlorophyll, plant proteins, amino acids, and cell membranes. It is commonly believed that healthy plants require 17 chemical elements. If all of these elements are available to plants in the right quantities, fertilizers do not need to be added to soils. However, if these nutrients are not present in the soil, fertilizers can be used as a supplement. As plants grow they take up nutrients from the soil. When plants are harvested the nutrients that they have taken up are removed from the soil. If we continue the cycle of growing and harvesting plants without replacing nutrients, the soil becomes depleted of essential nutrients. Farmers and home gardeners have various methods for replacing soil nutrients. Fertilizers include manures as well as store-bought concentrated fertilizers.

How are fertilizers made?

Fertilizers can be natural or man-made. Natural fertilizers are substances such as manures and composts. Nitrogen can be made available to plants by the natural process of nitrogen fixation, where bacteria convert atmospheric nitrogen to nitrogen that can be used by plants. Many fertilizers are manufactured in factories using materials from the earth and atmosphere.

- ▶ Nitrogen gas makes up approximately 78% of our atmosphere. Nitrogen gas can be combined with natural gas in a complex factory process to change it into a form that plants can utilize.
- ▶ Phosphorus is usually made into fertilizer by mining phosphate rock and combining it with sulfuric acid (which comes from fossil fuels).
- ▶ Potassium is often obtained from salt deposits throughout the world like those of the Great Salt Lake in Utah.

How does manure benefit plant growth?

Manure is another word for animal excrement, and is often used as organic fertilizer in agriculture. Manure contains nutrients that contribute to the health of plants, such as nitrogen, and components that can improve the fertility and aeration of the soil. Animal manures

Answers to Commonly Asked Questions

vary in nutrient composition, depending on the type of animal and the diet of the animal.

What do the three numbers on a fertilizer label mean?

Most commercial fertilizers have three numbers on the front label, separated by dashes. For example: 5-10-5. The series of numbers stand for the percentages of nitrogen, phosphorus, and potassium in that particular fertilizer. These are abbreviated as N-P-K, always in this order. These three elements are the major nutrients required by plants for growth and reproduction. When buying a fertilizer, consider whether the plant requires higher levels of a specific nutrient(s) and purchase a fertilizer with higher levels of the required nutrient(s). The example above, purchased as a ten pound bag, would contain 5% nitrogen, 10% phosphorus and 5% potassium. The remaining 80% could be comprised of other nutrients and filler.

Why do plants die if they get too much fertilizer?

Most fertilizers are salts. Any type of salt will draw out and absorb any available water supply. Fertilizers draw water from plant cells. If too much fertilizer is applied to a plant, the plant cells will dehydrate and may become brittle and discolored. This drying out of plants is often referred to as plants being “burned” by fertilizer.

Why do some fertilizers require people to wear protective clothing such as masks or gloves?

Most commercial fertilizers are more concentrated than natural manures and composts. They are also applied in salt form. Large quantities of salt can draw water out from not only plant, but also human and animal cells and cause them to dehydrate. This can cause irritation to skin cells, eyes, and lungs. For most household fertilizers, rinsing exposed areas with generous amounts of water will prevent damage. Manufacturer’s application instructions are designed to keep people and the environment safe.

What would happen to food prices without fertilizer?

A fertilizer is a substance that provides one or more chemical elements necessary for plant growth and development. This could include prepackaged fertilizers bought from your local garden center, compost

Answers to Commonly Asked Questions

from kitchen waste, or animal manure. Both conventional and organic farmers use fertilizer to provide crops with the nutrients needed to supply consumers with nutritious, affordable food.

The United Nations projects that the world's human population will increase by at least two billion in the next 40 years. While the human population is growing, the amount of available farmland is not. Fertilizers make it possible to grow more food on less land. As crops grow, they take up nutrients from the soil and assimilate them into plant parts that people and livestock eat. These nutrients must be replaced back into the soil to maintain fertile farmland that is capable of producing crops year after year.

Without fertilizer, soil fertility and productivity drop. Prices go up when food is in short supply. People in the U.S. spend less on food than any other country in the world. U.S. farmers use science and technology to make the most efficient use of resources possible, which helps keep food prices down while supplying safe, abundant, and nutritious food.

Agricultural Organizations

General

American Farm Bureau Foundation for Agriculture

600 Maryland Avenue SW, Suite 1000W

Washington, DC 20024

Phone: (202) 406-3700

Toll free: (800) 443-8456

E-mail: curtism@fb.org

Website: www.agfoundation.org

Website: www.myamericanfarm.org

California Farm Water Coalition

6133 Freeport Boulevard, 2nd Floor

Sacramento, CA 95822

Phone: (916) 391-5030

Fax: (916) 391-5044

Website: www.farmwater.org

California Foundation for Agriculture in the Classroom

2300 River Plaza Drive

Sacramento, CA 95833-3293

Phone: (916) 561-5625

Toll free: (800) 700-AITC

E-mail: info@LearnAboutAg.org

Website: www.LearnAboutAg.org

National 4-H Cooperative Curriculum System, Inc.

405 Coffey Hall, 1420 Eckles Avenue

St. Paul, MN 55108-6068

Phone: (612) 624-4900

Toll free: (800) 876-8636

E-mail: shopext@umn.edu

Website: www.n4hccs.org

Website: www.4-hmall.org

Agricultural Organizations

University of California

Agriculture & Natural Resources Communication
Services Publications
1301 South 46th Street, Building 478
Richmond, CA 94804
Toll-free: (800) 994-8849
Email: anrcatalog@ucdavis.edu
Website: anrcatalog.ucdavis.edu

Botany

PlantingScience.org

A learning and research resource bringing together students, plant scientists, and teachers from across the nation. Students engage in hands-on plant investigations, working with peers and scientist mentors to build collaborations and improve their understanding of science.
Grades 6-12
Free online

Botanical Society of America Business Office
Post Office Box 299
St. Louis, MO 63166-0299
Phone: (314) 577-9566
Website: www.botany.org/bsa/careers
Website: www.PlantingScience.org

The Budding Botanist: Investigations With Plants

Investigate how the structure and function of flowers, leaves, roots, and stems help plants live, grow, and reproduce. Students develop content knowledge along with process skills such as observing, measuring, and organizing data and communicating results. Includes 26 activities over 122 pages and a CD with printable student pages.
Grades 3-6
\$21.95 plus s/h; request item #1213

AIMS Education Foundation
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Fresno, CA 93747-8120
Phone: (559) 255-4094
Toll-free: (888) 733-2467
E-mail: aimsedu@aimsedu.org
Website: www.aimsedu.org

Agricultural Organizations

Gardening

California School Garden Network

Detailed step-by-step instructions for creating a school garden. Includes a list of resources, training opportunities, and fundraising ideas.

Grades K-Adult

Free; available online

Website: www.csgn.org

Common Ground Garden Program

Information on many gardening topics, including tips, school & community gardens, composting, container gardening, saving water, and recycling.

Adult

Free; available online only

University of California Cooperative Extension

4800 East Cesar E. Chavez Avenue

Los Angeles, CA 90022

Phone: (323) 260-3407

Email: ydsavio@ucdavis.edu

Website: celosangeles.ucdavis.edu/Common_Ground_Garden_Program

Create from Waste!

This activity guide has 20 hands-on activities designed to educate students to find ways to reduce the amount of waste they send to the landfills. Some activities include investigating food, exploring soil, and worm composting.

Grades K-3

\$19.95

Life Lab Science Program

1156 High Street

Santa Cruz, CA 95064

Phone: (831) 459-2001

Fax: (831) 459-3483

Email: admin@lifelab.org

Website: www.lifelab.org

Agricultural Organizations

Math in the Garden

This engaging curriculum uses a mathematical lens to take children on an education-filled exploration of the garden. Dozens of hands-on activities hone math skills and promote inquiry, language arts, and nutrition. All were developed to support mathematics and science standards and were extensively trial tested by educators and youth leaders nationwide. Developed by the University of California Botanical Garden and Lawrence Hall of Science in Berkeley, California.

Grades K-8

\$29.95

National Gardening Association

237 Commerce Street, Suite 101

Williston, VT 05495

Phone: (802) 863-5251

Fax: (802) 864-6889

Email: customerservice@garden.org

Website: www.kidsgardening.org

Nutrients for Life Foundation

Students learn about food production, soil quality, and fertilizer use around the world in this interactive website. Students practice identifying nutrient deficiencies in the game “Humanity Against Hunger.” Teachers may also request free curriculum, posters, flashcards, and more through the website.

Grades 7-12

Free; available online only

Nutrients for Life Foundation

Capitol View

425 Third Street SW, Suite 950

Washington, DC 20024

Phone: (800) 962-9065

Fax: (202) 962-0577

E-mail: info@nutrientsforlife.org

Website: www.nutrientsforlife.org

Agricultural Organizations

Operation WATER: Dr. Thistle Goes Underground

This Junior Master Gardening curriculum combines the teacher/leader guide with reproducible pages. Through dozens of engaging and fun activities, students can investigate important soils and water concepts, take part in service learning projects, and earn Junior Master Gardener certification—all while undertaking an urgent mission to foil the newest plans of Dr. Thistle! Aligned with National Content Standards.

Grades 6-8

\$35

Junior Master Gardener

225 Horticulture/Forest Building, MS 2134

College Station, TX 77843-2134

Phone: (979) 845-8565

Toll-free: (888) 900-2577

Email: programinfo@jmgkids.us

Ten Things Kids Want to Know About Farming

This 22-minute educational video or DVD takes students on a series of field trips to farm and ranch locations throughout the United States, offering them a firsthand view of how the food and clothing we use every day is produced.

Grades 3-6

VHS \$18.50; DVD \$17; quantity discounts available

American Farm Bureau Foundation for Agriculture

600 Maryland Avenue SW, Suite 1000W

Washington, DC 20024

Phone: (202) 406-3700

Fax: (202) 314-5121

Toll-free: (800) 443-8456

Email: curtism@fb.org

Website: www.agfoundation.org

Website: www.myamericanfarm.org

Agricultural Organizations

WE Garden Lesson Packet

California Foundation for Agriculture in the Classroom (CFAITC) worked side-by-side with First Lady Maria Shriver and staff to plan and install an edible garden at the state capitol. As a capstone to the project, CFAITC collaborated with other agriculture literacy organizations to provide 11 garden-related lesson plans aligned to content standards for grades 1-6. These downloadable lesson plans highlight activities that complement garden-related education and can be performed inside or outside the classroom. Lesson plans include California Crops, Read the Roots, Eat Your Plants, Frozen Canned or Fresh, and more.

Grades 1-6

Free; available online only

California Foundation for Agriculture in the Classroom

2300 River Plaza Drive

Sacramento, CA 95833-3293

Phone: (916) 561-5625

Fax: (916) 561-5697

Toll-free: (800) 700-AITC

Email: info@LearnAboutAg.org

Website: www.LearnAboutAg.org

Worms Eat My Garbage

This 176-page book, written by Mary Appelhof, is a guide to vermicomposting, a process using redworms to recycle food waste into nutrient-rich food for plants. ISBN 978-0-9778045-1-1

Grades K-adult

\$12.95 plus \$3.50 s/h

Flowerfield Enterprises, LLC

10332 Shaver Road

Portage, MI 49024

Phone: (269) 327-0108

Email: nancy@wormwoman.com

Website: www.wormwoman.com

Agricultural Organizations

A Slice of Soil

An apple is used to model the Earth. Students learn that just $\frac{1}{32}$ of its surface is devoted to farmland. Discuss in class what sacrifices may be needed to feed a larger population.

Grades 2-4

Free

Growing the Next Generation Agrium

13131 Lake Fraser Drive SE

Calgary, AB

T2J 7E8

Toll-Free: 1-877-247-4861

Website: www.growingthenextgeneration.com

California Fertilizer Foundation

The California Fertilizer Foundation provides information about plant nutrients and agriculture in California. School garden grants are also available.

Grades K-12

Free online information

California Fertilizer Foundation

4460 Duckhorn Drive, Suite A

Sacramento, CA 95834

Email: corriep@healthyplants.org

Website: www.calfertilizer.org

Agricultural Organizations

Healthy Foods from Healthy Soils

Healthy Foods from Healthy Soils invites you and your students to discover where your food comes from, how our bodies use food, and what happens to food waste. You'll participate in the ecological cycle of food production and compost formation, while helping children understand how their food choices affect not only their own health, but farmers, the environment, and your local community. Includes over 45 hands-on activities. ISBN 978-0-88448-242-0

Grades K-6

\$19.95, paperback

Tilbury House Publishers

103 Brunswick Avenue

Gardiner, ME 04345

Phone: (207) 582-1899

Fax: (207) 582-8227

Toll-free: (800) 582-1899

Email: tilbury@tilburyhouse.com

Website: www.tilburyhouse.com

Soil Biology Primer

The Soil Biology Primer introduces the living component of soil and how it contributes to agricultural productivity and to air and water quality. The primer includes information on the soil food web and how the web relates to soil health. Chapter topics include bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.

Grades 8-Adult

\$18 plus s/h

Soil and Water Conservation Society

945 SW Ankeny Road

Ankeny, IA 50023

Phone: (515) 289-2331 ext. 126

Toll-free: (800) THE-SOIL

Email: pubs@swcs.org

Website: www.swcs.org

Agricultural Organizations

Soil Stories—Second Grade Science Exploration

This grouping of six lesson plans, taken from the Life Lab Science Curriculum, focuses on soil studies and meets the second grade California Content Standards for California Public Schools in science. Packet includes recommended literature, a master materials list, and a blackline science journal.

Grade 2

Free; available online

Life Lab Science Program
1156 High Street
Santa Cruz, CA 95064
Phone: (831) 459-2001
Email: admin@lifelab.org
Website: www.lifelab.org

Soils Sustain Life

Soil science is the study of Earth's land and water resources as they relate to agriculture, forestry, rangeland, ecosystems, urban uses, and mining and reclamation. This brochure defines soil science and its importance, identifies soil scientists and what they do, and provides information about career opportunities.

Grades 7-12

Free; online

Soil Science Society of America
677 South Segoe Road
Madison, WI 53711
Phone: (608) 268-4949
Email: lmalison@soils.org
Website: www.soils.org

Agricultural Organizations

Field Trips

The Center for Land-Based Learning

Two programs: the FARMS Leadership Program (statewide) and the SLEWS Program (Northstate, Sacramento Valley, Napa, and San Joaquin). Both are hands-on, experiential learning programs that take students out of the classroom and onto farms, ranches, wildlife areas, and post-secondary institutions to teach them about sustainable agriculture, conservation, and the environment. The headquarters in Winters is also an educational farm, which can host school classes for outdoor activities and field days.

Center for Land-Based Learning
5265 Putah Creek Road
Winters, CA 95694
Phone: (530) 795-9569
Website: www.landbasedlearning.org



California Foundation for
Agriculture in the Classroom

Related Websites

Alltech

www.alltech.com/kidzone

California Department of Food and Agriculture, Kids' Page

www.cdfa.ca.gov/kids

California Foundation for Agriculture in the Classroom

www.LearnAboutAg.org

Fertilizer 101

www.fertilizer101.org

The Fertilizer Institute

www.tfi.org

Growing the Next Generation

www.growingthenextgeneration.com

International Plant Nutrition Institute

www.ipni.net

Natural Resources & Conservation Service

www.nrcs.usda.gov

Nutrients for Life Foundation

www.nutrientsforlife.org

Sci4 Kids

www.ars.usda.gov/is/kids

Master Gardeners School Gardens: Resource Guide

www.mastergardeners.org/school-gardens-resource-guide

Natural Resources & Conservation Service Soils Website

www.soils.usda.gov

Plants Database

www.plants.usda.gov

United States Department of Food and Agriculture

www.usda.gov



California Foundation for
Agriculture in the Classroom

Related Websites

University of California Agriculture and Natural Resources

www.ucanr.org

Wisconsin Fast Plants/Bottle Biology Notes

www.fastplants.org

Related Literature

Adair, Gene. *George Washington Carver, Botanist*. Chelsea House Publishers, 1990. This biography describes the life of George Washington Carver and how he became the first black man of science to emerge as an American folk hero. ISBN 978-0-7910-0234-6

Fertilizer 101. *The Fertilizer Institute, 2010*. This book serves as a tool for fostering a better understanding of fertilizer and its role in world food production, the environment, and the global economy. This new book answers readers' questions about different types of fertilizer, how fertilizers are used, information on the world's fertilizer industry, and answers to commonly asked questions about fertilizer's role in the environment. www.fertilizer101.org

Lauber, Patricia. *Earthworms: Underground Farmers*. Henry Holt and Company, 1994. Take a look at the world of earthworms and learn how important these creatures are to a healthy ecology. ISBN 978-0-8050-1910-0

Mehling, Randl. *Worm World*. Newbridge Educational Publishing, 2006. Worms are all around and serve many purposes. ISBN 978-1-4007-4475-6

Rosenbaum, Judith. *Looking at Soil*. Newbridge Educational Publishing, 2007. A book that explains the components of soil in an easy to understand format. ISBN 978-1-4007-5213-3

Rosinsky, Natalie M. *Dirt: The Scoop on Soil*. Picture Window Books, 2002. Vivid illustrations and clear, fact-filled text explore the amazing science of soil. ISBN 978-1-4048-0012-0

Roulston, Larriane. *Pee Wee and Magical Compost Heap*. Recycling Resource Service, 1992. Follow Pee Wee through the compost system learning about the different insects involved. ISBN 978-0-9697883-0-0

Rushing, Felder. *New Junior Garden Book*. Better Homes and Gardens, 1999. This colorful and student-friendly book provides hundreds of projects for kids to grow and make. Projects are ranked from simple to more advanced. ISBN 978-0-696-20849-2

Stille, Darlene. *Soil: Digging Into Earth's Vital Resource*. Compass Point Books, 2005. Learn how soil management is crucial, as it is used in so many ways—from producing food to making homes and producing fibers. ISBN 978-0-7565-0857-9

Related Literature

Stille, Darlene R. *Erosion: How Land Forms, How Land Changes*. Compass Point Books, 2005. Learn how erosion is constantly changing, creating, and erasing features on Earth's surface. ISBN 978-0-7565-0854-8

Stille, Darlene R. *Minerals: From Apatite to Zinc*. Compass Point Books, 2005. Learn about minerals and how more than 3,000 minerals build the rocks on Earth. ISBN 978-0-7565-0855-5

Stille, Darlene R. *Natural Resources: Using and Protecting Earth's Surface*. Compass Point Books, 2005. Learn about the substances found in nature that people use, how they are obtained, and how they can be conserved. ISBN 978-0-7565-0856-2

The New Sunset Western Garden Book: The Ultimate Gardening Guide. Sunset Magazine Editors, Oxmoor House, 2012. This easy-to-use gardening book, written for gardeners of the western United States, provides general information on soils, pest control, planting techniques, and fertilizing, plus problem-solving tips and plant selection guides. Available at most bookstores. ISBN 978-0-376-03920-0

Tunkin, David. *How Does My Garden Grow?* National Geographic, 2003. Learn that plants in the garden need sunlight, water, and soil to grow. ISBN 978-0-7922-4264-2

Western Fertilizer Handbook. Western Plant Health Association. Waveland Press, Inc., 2010. This well-organized book provides information on the nutrient requirements of plants and nutrient management strategies. ISBN 978-0-8134-3210-6

Winkler, Peter. *Feeding the World*. National Geographic, 2002. Many current issues about the need for food and world food production are discussed. A scenario about growing plants at a school that encourages critical thinking is included. ISBN 978-0-7922-8871-8

The Teacher Resource Guide, compiled by the Foundation, is a must-have tool for professionals and volunteers searching for resources to improve the agricultural literacy of California's youth. The guide lists numerous agriculture education lessons, websites, books and fieldtrips. The guide is available in hardcopy and on our website. The online bookshelf search www.LearnAboutAg.org/books allows users to search the database for literature related to your lesson topics.

Matrix of Standards

5th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
Common Core English Language Arts												
RI.5.1 Reading Informational Text	Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.	x	x	x	x	x	x	x	x	x	x	x
RI.5.2 Reading Informational Text	Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.	x	x	x	x	x	x	x	x	x	x	x
RI.5.3 Reading Informational Text	Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.				x						x	
RI.5.4 Reading Informational Text	Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a <i>grade 5 topic or subject area</i> .		x	x	x	x		x			x	
RI.5.7 Reading Informational Text	Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.							x		x		
W.5.1b Writing	Provide logically ordered reasons that are supported by facts and details.		x	x				x			x	
W.5.1d Writing	Provide logically ordered reasons that are supported by facts and details.		x	x			x					x

Matrix of Standards

5th Grade

	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
<p>California Standards</p>												
<p>Common Core English Language Arts (continued)</p>												
<p>W.5.2a Writing</p>	<p>Introduce a topic clearly, provide a general observation and focus, and group related information logically, include formatting (e.g., headings), illustrations, and multimedia when useful to aiding comprehension.</p>	x			x		x			x		x
<p>W.5.2b Writing</p>	<p>Develop the topic with facts, definitions, concrete details, quotations, or other information and examples related to the topic.</p>									x	x	
<p>W.5.2e Writing</p>	<p>Provide a concluding statement or section related to the information or explanation presented.</p>			x			x		x	x		x
<p>W.5.4 Writing</p>	<p>Produce clear and coherent writing (including multiple-paragraph texts) in which the development and organization are appropriate to task, purpose, and audience.</p>			x	x		x		x	x		
<p>W.5.9b Writing</p>	<p>Apply <i>grade 5 reading standards</i> to informational texts (e.g., “Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point[s]”).</p>		x	x			x		x	x		
<p>SL.5.1 Speaking and Listening</p>	<p>Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on <i>grade 5 topics and texts</i>, building on others’ ideas and expressing their own clearly.</p>	x	x	x	x	x	x	x	x	x	x	x
<p>SL.5.2 Speaking and Listening</p>	<p>Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.</p>									x	x	x



Matrix of Standards

5th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Lets Vote On It	It's a Dirty Job
Common Core English Language Arts (continued)												
SL.5.4 Speaking and Listening	Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.									x	x	
SL.5.5 Speaking and Listening	Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.									x	x	
Common Core Mathematics												
5.MD.2 Measurements and Data	Represent and interpret data.										x	
Next Generation Science Standards												
5-PS3.D Energy and Chemical Processes	The energy release [from] food ws once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water).	x			x							x
5-LS1-1 Support an Argument	Support an argument that plants get the materials they need for growth chiefly from air and water.	x					x					
5-LS1.C Organization for Matter and Energy Flow in Organisms	Plants acquire their material for growth chiefly from air and water.	x			x		x		x			

Matrix of Standards

5th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Adds Up	Let's Vote On It	It's a Dirty Job
Next Generation Science Standards (continued)												
5-LS2.A Interdependent Relationships in Ecosystems	The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.	x	x	x	x	x	x	x	x	x		x
5-LS2.B Cycles of Matter and Energy Transfer in Ecosystems	Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	x	x	x	x		x		x	x		x
5-ESS3-1 Obtain and Combine Information	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and Environment.						x				x	
5-ESS3.C Human Impacts on Earth Systems	Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.		x	x	x		x		x	x	x	



Matrix of Standards

5th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
Next Generation Science Standards (continued)												
5-ETS1.A Defining and Delimiting Problems	Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.				x	x	x		x		x	
5-ETS1.B Developing Possible Solutions	Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.			x			x				x	
Visual Arts Content Standards												
Connections, Relationships, Applications 5.2	Identify and design icons, logos, and other graphic devices as symbols for ideas and information.										x	



Matrix of Standards

6th Grade

California Standards	Description	
Visual Arts Content Standards Connections, Relationships, Applications 5.4	Describe tactics employed in advertising to sway the viewer's thinking and provide examples.	Plant Parts and Functions
		Soil: More Than Dirt
		Soil Experiments
		Digging Into Nutrients
		The Right Solution
		Can We Have Too Much of a Good Thing?
		The Right Diet for Your Plants
		Plant Doctor for a Day
		It All Ads Up
		Let's Vote On It
		It's a Dirty Job



Matrix of Standards

7th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Lets Vote On It	It's a Dirty Job
Common Core Mathematics												
7.RP.2b Ratios and Proportional Relationships	Identify the constant of proportionality in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.					x					x	



Matrix of Standards

6th-8th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
Common Core English Language Arts												
SL.6-8.1 Speaking and Listening	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.	x	x	x	x	x	x	x	x	x	x	x
SL.6-8.2 Speaking and Listening	Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.											
SL.6-8.4 Speaking and Listening	Present claims and findings (e.g., argument, narrative, informative, response to literature presentations), sequencing ideas logically and using pertinent descriptions, facts, and details and nonverbal elements to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.											
SL.6-8.5 Speaking and Listening	Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.											
RST.6-8.2 Reading for Literacy in Science and Technical Subjects	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	x	x	x	x			x	x		x	
RST.6-8.3 Reading for Literacy in Science and Technical Subjects	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	x	x	x			x	x	x			



Matrix of Standards

6th-8th Grade

California Standards	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
Common Core English Language Arts (cont.)												
RST.6-8.4 Reading for Literacy in Science and Technical Subjects	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to <i>grades 6–8 texts and topics</i> .	x			x	x		x				
RST.6-8.9 Reading for Literacy in Science and Technical Subjects	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.		x	x						x		x
WHST.6-8.1b Writing for Literacy in History/SS, Science and Technical Subjects	Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.								x	x		
WHST.6-8.1e Writing for Literacy in History/SS, Science and Technical Subjects	Provide a concluding statement or section that follows from and supports the argument presented.	x	x	x					x	x		

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Common Core English Language Arts (cont.)												
WHST.6-8.4 Writing for Literacy in History/SS, Science and Technical Subjects	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	x	x	x	x		x	x		x		x
WHST.6-8.7 Writing for Literacy in History/SS, Science and Technical Subjects	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	x	x	x			x			x		x
Next Generation Science Standards												
MS-PS3.D Energy in Chemical Processes and Everyday Life	The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen.	x			x							x
MS-LS1.A Structure and Function	All living things are made up of cells, which are the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).	x			x							
MS-LS1.B Growth and Development of Organisms	Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.	x										



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Next Generation Science Standards (continued)												
MS-LS1.C Organization for Matter and Energy Flow in Organisms	Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.	x		x	x							
MS-LS2.A Interdependent Relationships in Ecosystems	<ul style="list-style-type: none"> Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to resources. 	x		x	x		x					x
MS-LS2.B Cycles of Matter and Energy Transfer in Ecosystems	Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.	x		x	x							x
MS-LS2.C Ecosystem Dynamics	Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.			x	x		x					x

Matrix of Standards 6th-8th Grade

	Description	Plant Parts and Functions	Soil: More Than Dirt	Soil Experiments	Digging Into Nutrients	The Right Solution	Can We Have Too Much of a Good Thing?	The Right Diet for Your Plants	Plant Doctor for a Day	It All Ads Up	Let's Vote On It	It's a Dirty Job
Next Generation Science Standards (continued)												
MS-LS2-3 Develop a Model	Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem											x
MS-LS4.D Biodiversity and Humans	Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.		x	x	x		x					
MS-ESS3.A Natural Resources	Humans depend on Earth's land, oceans, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.		x	x	x			x				
MS-ESS3.C Human Impacts on Earth Systems	Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.		x	x	x		x	x	x	x	x	
MS-ETS1.A Defining and Delimiting Problems	The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.						x				x	
MS-ETS1.B Developing Possible Solutions	A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.				x		x		x		x	

Glossary

Abiotic: not derived from living organisms.

Acidic: pH less than 7.

Alkaline: pH greater than 7, also known as basic.

Amendment: any material added to soil to make it more productive. Example, fertilizer, mulch, etc.

Anther: male part of flower that holds the pollen.

Arable: land that is capable of producing crops.

Assimilation: the conversion of absorbed nutrients into plant or body structures.

Bacteria: one celled, microscopic organism.

Biodegradable: composed of matter that originated from living organisms and can be decomposed by natural processes.

Biotic: relating to or resulting from living things.

Carbon dioxide: a gas in the air used by plants to make their own food.

Carpel: the female reproductive part of a flower.

Cell: the basic unit of life.

Chlorophyll: the green colored substance in plants that absorbs energy from sunlight.

Chloroplast: organelles inside plant cells where the process of photosynthesis is carried out.

Clay: clay soil is composed mostly of very fine clay particles. It becomes sticky when wet and has poor drainage.

Compost: a mixture made of decaying organic material used to fertilize plants.

Glossary

Conservation: the wise use of resources, to conserve them for use by present and future generations.

Consumer: an organism that eats plants or other animals.

Control: a standard of comparison.

Cotyledon: the part of the seed that stores food for the young plant.

Crop rotation: the successive planting of different crops in the same field over a period of years to maintain or improve soil quality and reduce pest problems.

Decomposer: an organism that recycles nutrients by breaking down waste and the remains of dead plants and animals.

Decomposition: to break down into organic matter; this process is performed by bacteria, fungi, nematodes, earthworms, and others.

Deficiency: a substance that is lacking.

Dicot: type of flowering plant that has two cotyledons to store food for the young plant. Dicots have leaves with netted veins and tap roots.

Dilution: the process of lowering the concentration of a solution by adding a solvent.

Embryo: the tiny plant within the seed.

Endocarp: inner woody layer of the fruit, covering the seed.

Exocarp: outer most layer of a fruit—the skin.

Fertilizer: any substance added to the soil or water that increases the nutrients available to plants.

Filament: the thin stalk that supports the anther.

Flower: the part of the plant that contains reproductive parts and attracts pollinators.

Food chain: the order that animals feed on other plants and animals.

Glossary

Food web: the interconnected food chains of an ecosystem.

Fruit: the part of the plant that holds seeds.

Fungi: organisms that feed on dead and decaying matter. Examples include mushrooms and molds.

Germination: the first growth of a seed when it puts out shoots.

Green manure: vegetation that is plowed into the field to improve soil composition; normally a legume such as beans or alfalfa.

Habitat: the environment where a particular species lives.

Heterogeneous: a heterogeneous mixture is not uniform in composition and components can easily be identified, as there are two or more phases present. “Hetero” is a Greek prefix for “different.”

Homogeneous: homogeneous mixtures are uniform in composition and particles are not typically seen. “Homo” is a Greek prefix for “same.”

Humus: a dark brown or black organic material on top of the soil that is made up of decaying plant or animal matter.

Hydroponics: to grow plants without soil, in a water-nutrient solution.

Hypothesis: an educated guess to explain why something happens. For example: If (you do this) then (this) will happen. A hypothesis must be testable.

Leaf: the flat or needlelike part of a plant where photosynthesis happens.

Loam: soil composed of a relatively equal mixture of sand, silt, and clay particles. Loam soil is good for growing plants.

Legume: usually a plant that has pods whose seeds split in two, often help with nitrogen fixation. Examples include beans and alfalfa.

Macronutrients: Nutrients needed by plants in large quantities.

Glossary

Manure: solid animal waste products used for fertilizer. May contain some straw or other animal bedding material.

Mesocarp: the fleshy part of a fruit that we often eat.

Micronutrients: nutrients needed by plants in small quantities. Examples include boron, copper, and zinc.

Mixture: combination of two or more different substances that are not chemically bonded and can be a solid, liquid, or gas.

Monocot: type of flowering plant that has one cotyledon to store food for the young plant. Monocots have leaves with parallel veins and fibrous roots.

Mutualism: a relationship between two organisms that is beneficial for both.

Nitrogen: an element that naturally exists in air and is needed by plants to produce proteins, chlorophyll, and genetic material.

Nitrogen-fixation: the transformation of atmospheric nitrogen gas into forms available for plant growth (ammonium or nitrates) often performed by Rhizobium bacteria. Nitrogen gas can also be converted to forms that plants can use through the production of commercial fertilizers.

Nodule: a little knot or bump found in roots of legume plants; normally filled with a bacterium (Rhizobium) that performs nitrogen-fixation.

N-P-K: Nitrogen-Phosphorus-Potassium, the three chemical elements that must be represented on a bag of fertilizer.

Nutrients: any element taken in by a plant that is essential to its growth.

Organelle: a specialized structure inside of a cell.

Organic matter: material in soil made from the decomposition of plants or animals. It increases the soil's ability to hold water and air and resist compaction.

Glossary

Organism: another name for a living thing.

Ovule: plant part that contains embryo.

Oxygen: a gas in the air used by humans to breathe. Plants give off oxygen through the process of photosynthesis.

Parts per million (ppm): a unit of measurement commonly used to describe the nutrient concentration in fertilizer solutions; can also be used to analyze contaminants in food, groundwater, air, and more. Compare to one drop of water in a swimming pool.

Petal: the colored segments of a flower.

Phloem: specialized structures that transport water throughout a plant.

Phosphorus: an element required by plants that promotes root growth.

Photosynthesis: the process by which plants make their own food from carbon dioxide, water and sunlight.

Phototropism: a plant's bending and growing toward a light source.

Plant: an organism that produces its own food through photosynthesis. Plants have rigid cell walls and structures to transport nutrients and water.

Pollen: fine powdery material produced by anthers of flowers containing male sex cells of plants.

Pollination: the transfer of male pollen from the male part of a plant to the female reproductive part of a plant.

Potash: a form of potassium that is used to improve soil quality.

Potassium: an element required by all plants for carbohydrate production and the hardening of tissues such as tree trunks.

Primary nutrients: nutrients needed by plants in large amounts; this includes nitrogen, phosphorus, and potassium.

Glossary

Producer: organism that makes its own food using energy from the sun. Plants are producers.

Reproduction: the process by which new living organisms are created.

Root: the part of the plant that grows into the soil to anchor the plant and collect water and nutrients.

Root hairs: tiny hair-like structures that are on the ends of roots and aid in nutrient and water absorption; they increase the surface area of root systems.

Saline: salty.

Sand: the largest size of soil particle. Sand is made up of tiny pieces of rock that have eroded from other rocks.

Secondary nutrients: nutrients needed by plants in medium quantities. Includes calcium, magnesium, and sulfur.

Seed: the small object that will grow into another plant.

Sepal: an individual leaf that makes up the calyx of a flower.

Sidedress: to place plant nutrients on or in the soil near the roots of a growing crop.

Silt: fine sand, clay, or other material carried by running water and deposited as a sediment.

Soil: the top portion of the earth's surface where plants grow.

Soil amendment: any material added to a soil to improve its quality.

Soil horizon: a layer of soil that is parallel to the surface of the land and has different properties than soil layers above and below it.

Soil porosity: the amount of pore spaces between soil particles that are filled with water and gases.

Glossary

Soil profile: soil profiles are made of individual layers of soil called horizons. Soil profiles look different in different areas of the world because they are affected by the climate and other attributes of that area.

Soil texture: the proportions of sand, silt, and clay in a soil.

Solution: a type of homogeneous mixture in which the particles of one or more substances (the solute) are distributed uniformly throughout another substance (the solvent).

Solute: the substance dissolved in a solvent to form a solution.

Solvent: a liquid in which substances (or solutes) are dissolved forming a solution.

Stamen: the male part of the plant containing the pollen, anther, and filament.

Stem: the part of the plant that supports the upper part of the plant and transports nutrients and water.

Stigma: female part of the flower that receives the pollen.

Stomata: a small opening in the epidermis of plant leaves, through which gases are exchanged.

Symbiosis: a close relationship between two organisms, that may or may not benefit each organism.

Sustainable agriculture: an agricultural system that remains viable and environmentally sound over a long period of time.

Transpiration: the passage of water vapor from plant leaves into the atmosphere.

Topsoil: the upper part of soil where plants grow.

Xylem: the specialized cells of plants that transport water and nutrients from the roots to the leaves.

Yield: the amount of crop harvested per unit area over a given amount of time.