Purpose and Content of Lesson:

Tower Garden® seeds are planted in wool cubes, covered with vermiculite, and given only water to germinate. Students will examine soaked bean seeds to identify the embryo within and predict how seeds will grow. Key questions to be answered are:

- What is inside a seed?
- How does soaking a seed in water change its appearance?
- How is the soaking of seeds mirrored in nature? Why do seeds need to get wet to germinate?
- What is the connection between what is inside the seed and how it grows?
- What do seeds need to grow?
- Can seeds germinate without soil?
- Do seeds need light to germinate?

Every seed consists of three main parts:

1. **Embryo** is a tiny plant in the seed that may grow roots, stem, and leaves under proper conditions.
2. **Food supply** (called cotyledon in dicots like beans, endosperm in monocots like corn) surrounds the embryo and is the seed’s only source of nourishment as it pushes through the soil to grow. When leaves grow and manufacture food through photosynthesis, the plant no longer needs the seed’s food supply. The food supply for a bean is used up in about two weeks.  
3. **Seed coat** is a protective covering for the developing embryo. It helps protect the inside of the seed from insects, disease, and damage. Sometimes the seed coat is smooth and paper-thin like that of a kidney bean. A coconut has a thick, hard seed coat and the seed cannot grow until the seed coat is broken.

Common misconceptions about seeds:

Most learners do not know what is inside a seed or that the plant parts that emerge during germination were already within the seed. Even after dissection and examination of the embryo, they do not always make connection between the embryo inside the seed and the germinating sprout. Students will be amazed that many foods are seeds – especially wheat (bread), rice, and corn. Some will argue that beans and nuts are not seeds because they are foods, and only the ones from the seed packs are true seeds. Many believe that seeds need light to grow because they know that plants need light to grow. It is difficult for young students to believe that plants can grow without soil, and growing plants in water, as in the Tower Garden, is a novel idea.

Lesson Objective:

Learners will draw and label the main parts of a seed (seed coat, food source, and embryo) on a diagram, and explain how each contributes to germination. Learners will also identify conditions for seed germination: water and warmth.

This lesson precedes the planting of seeds in the Tower Garden's wool cubes, so students understand that seeds can and do germinate without soil and even without sunlight.

In growing Tower Garden plants students will learn through their plant growing experiences, that once tiny leaves appear, they need sunlight to manufacture food. In addition to water, the new shoot also needs nutrients, typically found in soil, to maintain health and optimal growth. The Tower Garden
plants will receive light and nutrient tonic mixed into the water supply so plants can thrive without soil. There will be many opportunities for students to observe how supplying varying amounts of these resources affects plant growth in the Tower Garden over time.

**ENGAGE**

*Seed classification by properties:*

Have a variety of seeds available for students to observe on trays or plates. Some examples are: wheat berries, brown and wild rice, corn, varieties of beans (especially large lima and kidney beans), lentils, peas, seeds from outdoors, seeds from seed packets, and washed seeds from fruits. Distribute hand lenses and use only dry seeds and beans that have not been seasoned, roasted, split (as with dry peas) or chopped. Do not use peanuts or nuts because of allergies, and be mindful of other allergies students may have when they work with seeds and plants.

Have students work in small groups to separate the seeds into two or three groups by their properties.

Upon completion of this investigation, have each group share their classification criteria and other observations about their seeds. Many misconceptions will be identified in this sharing of ideas, so avoid writing what students say on the board and do dispel misconceptions and substitute with correct conceptions. Typically, students attend to what is written on the board as notes, so only correct concepts should appear in writing. Remind students that all samples they are observing are seeds and contain the same internal seed parts. Some are easier to observe than others because they are larger, and the larger seeds are the ones that will be examined in more detail in the next lab. Collect the seeds but leave each student with one dry kidney bean and lima bean for comparison in the following lab.

**EXPLORE**

*Key questions for Seed Dissection lab:*

1. What is inside a seed?
2. How does soaking a seed in water change its appearance, and how is the soaking of seeds mirrored in nature? Do only wet seeds germinate?
3. What is the connection between what is inside the seed and how it grows?

*Preparation:* Soak large lima beans and red kidney beans prior to teaching. Lima beans need to be soaked for several hours because they fall apart with too much soaking, but kidney beans should be soaked for 24 hours. Soak enough beans so each student receives 2-3 of each type.

Each student will also need a toothpick and hand lens.

*Seed Dissection Lab*

What is inside a seed? Students predict, then discuss their ideas in their groups and have a spokesperson share the group’s ideas.

Each student will receive:

1. a small plate with several large lima and kidney beans that have been soaked,
2. one of each bean type that is not soaked,
3. a toothpick,
4. a hand lens, and
5. a science notebook or handout for labeling and notes.

Upon receiving the materials, have students make observations, without too much manipulation, of the soaked seeds vs. the dry seeds. Have them share their observations. They should note that the soaked seeds are larger and softer. This is an important observation that will be revisited when germination is discussed.

*EXPLORE and EXPLAIN*

*First,* have students describe what they observe on the exterior of the seed. This is the seed coat. Its job is to cover and protect the seed from insects, disease, and damage.

*Second,* direct students to open their seeds as follows:

Take the toothpick and probe along the outer, curved seam between the two halves, and open the seed like a book. Put it flat on the plate with the two halves open wide. Do the same with the other seeds.

Here is an example that can be projected from the Great Plant Escape website that also contains excellent content and vocabulary: [http://extension.illinois.edu/gpe/case1/c1facts2e.html](http://extension.illinois.edu/gpe/case1/c1facts2e.html)
**Third**, while looking at the projected image, have students look for the embryo using the hand lens. They will see these parts: two leaves overlapping (shoot), and a root-like structure underneath. Together, these two parts are called the embryo, or the baby plant. Check that every student can point out this structure with the toothpick to be sure he or she has found both parts of the embryo in at least one of the seeds. Sometimes, with manipulation, the embryo falls out or falls apart, which is why they have extra seeds. How do you think this embryo will grow? (Shoot will grow up towards the sun and root will grow down).

**Ask:** How does soaking a seed in water change its appearance and how is the soaking of seeds mirrored in nature?

**Fourth**, have students point to the solid interior of the seed and explain that this is the food source for the baby plant. Now discuss the importance of soaking the seed. Remind students of their observation that soaking seeds makes them get swollen and softer. In spring, when the temperature is warmer, snow melts, and it also rains. This water drips through the soil and soaks the seeds that are there. Seed swell, and the food source softens, just as we observed. Then the embryo can use that food to gain energy to grow (germinate). In seeds that have two parts (dicots) the food source is called the cotyledon. (Young children can use term food source.) Have students retell this story in their own words to ensure understanding.

**Ask:** What would happen if a seed did not get enough water to soften the food source?

---

**EXPAND**

**Ask:** Will seeds grow if only given water?

Growing seeds on wet paper towels:

There are many ways to have students plant seeds on wet paper towels to observe germination, but this is my favorite because in one or two days students will have germinating seeds to observe.

**Materials:**
- Un-soaked seeds: radish, lentil and lima, 5 of each type for each student.
- A one-quart zip bag for each student.
- Two paper towels folded to fit in the bag end to end and top to bottom in each bag.
- A small, bathroom-sized cup ½ full of water per student.

**Students do the following:**

1. Write their names on the top of the bag with a Sharpie marker.
2. Fold and place the paper towel in the bag.
3. Pour the water a little at a time into the bag with the bag flat on their desks, just lifting the top of the bag. Assure them the water will spread across the paper towel.
4. Plant the three types of seeds on the top of the paper towel, press out the air, and zip it shut.
5. Place bag in a warm location. Bags can be stacked. Do seeds need light to grow? We will find out.
6. Predict which seed will grow first – smallest (radish), medium (lentil), or largest (lima)? In 24 hours or less, they will have their answer.

Another seed planting activity that allows students to observe germination is using two plastic cups with paper towels and seeds between. It is described on following webpage called Seed Hunt: [http://cuip.uchicago.edu/wit/99/teams/pizza/seeds.htm](http://cuip.uchicago.edu/wit/99/teams/pizza/seeds.htm)

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**EXPLAIN**

Students will demonstrate their understanding by completing the following on the attached assessment handout:

1. Draw and label the exterior and interior of one of your seeds (seed coat, food source, embryo shoot, embryo root).

2. Write the term next to its definition:
   - food source ________
   - embryo shoot ________
   - embryo root ________
   - seed coat ________
   - a. protects seed from insects, disease, damage
   - b. will grow down into the ground
   - c. will provide baby plant with energy
   - d. will grow up towards the sun

3. What would happen to the germinating plant if an insect munched on the shoot part of the embryo?

4. What will your seed need to grow other than warmth? ________ Explain.

---

**EVALUATE**

**See Seed Assessment (last page)**

The radish seeds typically sprout in one day and lentils follow shortly after. The lima takes about a week to germinate. Remind students about the food source within the seeds and how water softens this food for the embryo. An excellent critical thinking question can be asked one or two days after this lesson as students are observing their germinating seeds in a bag.

Based on what they have learned about how seeds begin to grow, ask why the smaller seeds grew first. Students can discuss their ideas with others before answering the question.

It is hoped they will see that smaller seeds have 1) less of a food supply so they grow fast to make food, and 2) more of the smaller seed’s surface is exposed to water so the food supply gets wetter and softer for use by the embryo.
Web Resources

1. Facts, terms, and definitions about germination:

2. Vocabulary:
   www.biologyjunction.com/SeedIdentificationDissection-Lab.doc

3. Bean seed embryo image:

4. Plant Structures: Seeds – What’s inside: Great Plant Escape:
   http://extension.illinois.edu/gpe/case1/c1facts2e.html

5. What is a seed? Facts, germination activity, quiz:
   Great Plant Escape:
   http://extension.illinois.edu/gpe/case3/c3m1.html

6. Seed Dissection Lab: Norwood Science Center:

7. Germination movies: Plants-in-motion:
   http://plantsinmotion.bio.indiana.edu/plantmotion/starthere.html

8. Germination, seed parts, text and video: Biology of Plants:
   http://www.mbgnet.net/bioplants/grow.html

9. What is inside a seed handout: Clifford Garden:
   https://cliffordgarden.wordpress.com/2010/12/05/inside-a-seed/

10. Two seed planting activities with wet paper towels: Seeds:
    http://cuip.uchicago.edu/wit/99/teams/pizza/seeds.htm

Additional Applications:

1. See the Great Plant Escape quiz: http://extension.illinois.edu/gpe/case3/c3m1.html that students can do on their own or in class.

2. See also handout on the following page. Go over the germination sequence with students.


4. Students now understand that seeds can grow in water from their paper towel germination activity, so they can plant their Tower Garden seeds in wool cubes soaked in water and cover with vermiculite. Keep in a warm location. When the shoot appears, place trays in the sun or under a plant light.

Appendices:

HANDOUT
https://cliffordgarden.wordpress.com/2010/12/05/inside-a-seed/

SEED LESSON REVIEW

Name ___________________________________________
Date __________________

Write the correct terms from the word box to complete the seed story.

1. We observed the outside of a bean seed and saw a _________. When we opened the seed, we were able to observe the baby plant called the _____________. It consisted of a tiny __________ and a ___________. Most of the inside of the seed is made up of the ________ ________ to nourish the baby plant.

2. Seeds need ____________ and ____________ to germinate (grow).

4. Once they germinate, plants also need ____________ and ____________ to grow.

5. Name some seeds that you know: ____________________________________________

SEED DISSECTION ASSESSMENT

Name____________________________________________
Date__________________

1. Draw and label the exterior and interior of one of your seeds (seed coat, food source, embryo shoot with seed leaves, embryo root).

2. Write the term next to its definition:
   food source __________________________________
   embryo shoot ________________________________
   embryo root _________________________________
   seed coat _________________________________
   a. protects seed from insects, disease, damage
   b. will grow down into the ground
   c. will provide baby plant with energy
   d. will grow up towards the sun

3. Explain what would happen to the germinating plant if an insect munched on the shoot part of the embryo.

4. What will your seed need to grow other than warmth? __________ Explain why.
Seeds and How They Grow

DEVELOPED BY: Debra Zinicola, Ed.D., Seton Hall University, Chair, Department of Educational Studies, and Marian Glenn, Ph.D., Seton Hall University, Professor, Department of Biological Sciences
What is inside a seed?

Turn and Talk:

Explore this question with others in your group. Select one person to share the group’s ideas.

Let’s Explore:

Next, we are going to examine soaked bean seeds to see what is on the outside and inside.

Let’s begin the Seed Dissection Lab.
Seed Dissection Lab

You will receive:

1. a plate with lima and kidney beans that have been soaked in water;
2. one of each bean type that has not been soaked;
3. a toothpick;
4. a hand lens; and
5. a science notebook or handout for labeling and notes.

Let’s Explore:

Look at the seeds on the outside. How are the soaked seeds alike and different than the dry ones?
Let’s Explore:

1. What do you observe on the outside of your seed?
2. What does it look and feel like?

This is the seed coat.

Its job is to cover and protect the seed from insects, disease, and damage.
Seed Dissection Lab

Let’s Explore:

1. Take one soaked seed and your toothpick and probe along the outer, curved seam between the two halves.

2. Carefully open the seed like a book.

3. Put it flat on the plate with the two halves open wide. Do the same with the other seeds.
Let’s Explore:
Use your hand lens to find the **embryo**—the baby plant.
Seed Dissection Lab

Let’s Explore:

1. The **embryo** has a leaf part called the **shoot** (two leaves overlapping, and a **root**).

2. Find them both and point to them with your toothpick.

3. Which part will grow up to the light? ______________

4. Which part will grow down into the soil? ______________
Let’s Explore:

1. Now look at the solid interior of the seed.
   - This is the **food source** for the embryo (cotyledon).
   - It has nutrition the embryo needs to get energy to grow.
   - But the seed has to get wet first to soften the food source.

2. How does this happen in nature?

3. What would happen if a seed did not get enough water to soften the food source? Explain.
Seed Dissection Lab

Let’s Explore:

1. Now that you have seen the inside of a seed, with the **embryo shoot with leaves** and the **embryo root**, how do you think the plant will grow?
2. What does a seed need to grow?
3. What does a plant need to grow?
4. Do you think we can grow seeds in water without soil?
5. Let’s try to grow seeds with only water and see.
Roots

Purpose and Content of Lesson:

Roots will be visible in the Tower Garden® plants because they will not be hidden by soil. Growers of aeroponic plants may be amazed at the abundance of root growth in their plants. Roots are the most overlooked parts of plants, because in nature, we do not see them as we do the stems, leaves, and flowers. Roots comprise about ¼ to ⅓ the total weight of a plant and are essential to its growth and health.

The functions of the roots:
- Anchor the plant in the ground
- Bring water with dissolved minerals into the plant from the ground
- Store products of photosynthesis from the leaves (sugars, starches)

Some roots are called fibrous, branch out in all directions, and are about the same length. Monocots, like grasses, corn, and lilies, have fibrous roots.

Others, called taproots, have a main downward growing root with smaller roots branching off from it. Carrots, radishes, beets, parsnips, and turnips are storage taproots since they hold sugar and starches made in the leaves. Most dicot plants have taproots.

Root hairs are extensions of the root responsible for bringing water into the plant.

Next Generation Science Standards (NGSS):

http://www.nextgenscience.org/search-standards

Disciplinary Core Ideas

LS1.A: Structure and Function
All organisms have external parts. Plants have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (Grades K-2)

Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Grades 3-5)

LS1.D: Information Processing
Plants respond to some external inputs. (Grades K-2)

Common misconceptions about roots:

The idea that water is absorbed into the plant by the leaves is a misconception. Water being absorbed by underground roots in the soil cannot be observed; but droplets on the leaves can be observed, further supporting this misconception.

The notion that nutrients and water that come from the soil are "food" for the plant is another misconception. Fertilizer is called "plant food," and we know that plants need water to grow. Young learners may have difficulty believing, therefore, that leaves make the food for the plant.

Lesson Objective:

Learners will explain the function of roots, recognize two types of roots (fibrous and taproot), and describe how they grow in their science journals.

Developed by: Debra Zinicola, Ed.D., Seton Hall University, Chair, Department of Educational Studies, and Marian Glenn, Ph.D., Seton Hall University, Professor, Department of Biological Sciences
ENGAGE

Living things need water, and plants are living organisms. *How do they get their water?*

Begin with a house plant in a pot.

**Ask:** *If I am going to water this plant, what part do I water? Why? When it rains, how does water get into a tree?*

Identify any misconceptions about watering the leaves and explain that leaves do not bring water into the plant. Tell students that in this lesson you’ll examine the part of the plant that provides water.

Project the following image:

![Plant Roots](http://www.lizzieharper.co.uk/news/article/40/Botanical_Illustration_-_Glorious_grasses_-_June14th_2013)

Talk about the parts of the plant — roots, stem, and leaves and how water gets into the plant through roots via root hairs and travels up the stem to the leaves where the plant's food is made. The xylem and phloem vessels that bring fluids through the root systems are also found in stems. Do not yet talk about the two different types of roots since that is the purpose of the following investigation.

EXPLORE

**Key questions for Seed Dissection lab:**

1. *What do roots look like?*
2. *What is their function?*

**Root investigation:**

Have trays prepared for students to observe in groups with five or less assorted plants having a variety of taproots (dicots) and fibrous roots (monocots). Find plants in season in your yard or at the garden center.

**Say to the students:**

*Different types of roots will be explored today. On your observation tray are several types of plants with visible root systems. Examine each, and with your group members, divide the roots into two categories by some property or characteristic other than the fact that some are edible. Be ready to explain by which property you divided your roots. Also make at least five observations of your roots in your science journal and draw each type. Fill in the chart in the Appendices on page four using names of the plants supplied by the teacher.*

EXPLAIN

Have each group share some of their observations and their characteristics for dividing their roots into two groups. Help them see (if they didn't already) how the taproots (radish, dandelion, carrot) have a main root with smaller roots branching off. Help them also see that the fibrous roots do not have one main root but branch out all over equally.

Discuss how the roots have small hairs that absorb water from the soil and bring it into the root, then it continues to the stem through xylem tubes. Give out hand lenses to see if root hairs are visible, although they are invisible to the naked eye. Also mention that familiar edible roots have more stored sugars and starches (carrot, turnip, beet, radish, yam, horseradish, parsnip, ginger, jicama, rutabaga, Jerusalem artichokes) than other taproots. They are called storage taproots.

Critical thinking questions for groups to discuss then share with the class:

1. *Do you think desert plants (experiencing low rainfall) have deep or shallow roots? Explain.*

If you have cactus plants available, show the students the roots. They are typically shallow to get surface water when it rains. Deep roots would not yield water far into the dry ground unless there was an underground spring or aquifer.

2. *Do you think root vegetables are suitable for growth in a Tower Garden? Explain.*

Storage roots pick up more nutrients from the soil around them and stored sugars and starches from the leaves. Hydroponically grown carrots and other storage roots can get heavy, so they need a growing medium to support them, like vermic-
ulite (a moisture retaining mineral product). A little bit of vermiculite is used to plant seeds in wool cubes in the Tower Garden. Carrots, for example, also take a long time to grow — about three months, while other hydroponically grown plants can grow and be harvested more quickly.

3. Why do you think some plants (like the ones we call “weeds”) sometimes grow back after we pull them out of the ground?

Plants can grow back after you pull up the top growth. Those with long taproots, like dandelion (a foot or more in length), or those roots that spread by sending out rhizomes are especially prone to grow new shoots.

4. How might the function of roots in the Tower Garden be different from roots growing through soil? How might their function be the same?

In the Tower Garden, roots begin in wool cubes, and then extensive root development appears in the interior of the tower and roots hang down, but they do not anchor the plant in the same way as soil. The plants are not subject to effects of strong winds, foot traffic, lawn mowers, or competition for resources. Roots still bring nutrient-rich water into the plant, but the root tip does not have to push through hard ground to grow.

**EXPAND**

Show upper-grade students a cross section slice of a carrot that was soaking in red food dye and water. This way they can see the red portions as xylem; then they will also see the distinctions between phloem and the cortex. They can draw and label in their science notebooks. Show also select images and videos under “Resources.”

**EVALUATE**

Students write the answer to the following questions in their science notebooks:

1. How would the growth of a plant be affected if its roots were cut off? Suggest at least two ways.

2. Watering a plant means to water the soil around the plant. Why is that so?

A summative assessment is included at the end of the lesson on STEMS.

**Web Resources**

1. Plant Structures: Roots [http://www.ext.colostate.edu/mg/gardennotes/132.html](http://www.ext.colostate.edu/mg/gardennotes/132.html)
2. Roots as anchors with images: NGAs Learning Garden [http://assoc.garden.org/courseweb/course1/week1/page8.htm](http://assoc.garden.org/courseweb/course1/week1/page8.htm)
3. Carrot experiments to show function, structure of taproots: World Carrot Museum [http://www.carrotmuseum.co.uk/experiment.html](http://www.carrotmuseum.co.uk/experiment.html)
5. Flowering Plants: Roots [http://leavingbio.net/flowering%20plants.htm](http://leavingbio.net/flowering%20plants.htm)

**Materials for Investigation:**

- Have enough plants with exposed taproots and fibrous roots for students to observe in groups and classify.
- Carrots with leaves and smaller roots attached
- Carrots that have been soaked in dye and sliced
- Other storage taproot vegetables (radishes, turnips, beets)
- Other plants with taproots intact that are not foods (any dicot plant)
- Plants with fibrous roots (lilies, grasses, palms or any monocot plant)
- Computer and projection to show videos and images

**Additional Applications:**

Ask students to share their thoughts in groups on the following questions. After discussion, they can do research to see if their hypotheses are correct and then share findings the following day.

1. What plant part is a sweet potato? ________ a white potato? ________ garlic? ________
   (Sweet potato is a storage root, white potato is a modified stem, and garlic is a root)

2. How do earthworms help plant roots grow?
   (They move through dirt, loosening soil, and deposit waste that is rich in nutrients)

3. How do ants help roots? (They dig tunnels and loosen soil to make space for growth)
<table>
<thead>
<tr>
<th>Type of Plant</th>
<th>Observations (write characteristics)</th>
<th>Plant diagram (draw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>radish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dandelion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>carrot</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Task:** By what property or properties did your group divide your roots into two groups?
All About Roots

DEVELOPED BY: Debra Zinicola, Ed.D., Seton Hall University, Chair, Department of Educational Studies, and Marian Glenn, Ph.D., Seton Hall University, Professor, Department of Biological Sciences
The Roots of a Plant

1. What are the roots of a plant?
2. What do the roots do for the plant?

We don’t often see the plant’s roots, but they are very important.
Roots are organs of a plant that anchor the plant in the ground.

1. Why is that job important?
2. What do you notice about these roots?
In addition to anchoring the plant, roots bring water with dissolved minerals from the ground into the plant.
Root hairs are extensions of the root responsible for bringing water into the plant.

Root hairs are too small to see without magnification.
The Function of Roots

In addition to anchoring the plant and bringing water into the plant, roots also:

Store sugars and starches—products of photosynthesis from the leaves.

Some roots are called storage roots.
Let’s Review:

What do roots do for a plant?

1. _________ the plant.

2. Bring _______ with dissolved minerals from the _________ into the plant.

3. Store _______ and __________________________ made in the leaves through photosynthesis.
The Function of Roots

Were you correct?

What do roots do for a plant?

1. **Anchor** the plant.

2. Bring **water** with dissolved minerals from the **ground** into the plant.

3. Store **sugars** and **carbohydrates** made in the leaves through photosynthesis.
Root Systems

Two kinds of root systems:

1. **Fibrous roots** branch out in all directions and are about the same length.
   
   Grasses, corn and lilies have **fibrous roots**

2. **Taproots** have a main downward growing root with small roots branching off of it.
   
   Carrots, radishes, beets, potatoes and turnips are **storage taproots** since they hold sugar and starches made in the leaves.
Root Systems

1. Which root system is **fibrous**?
2. Which root system is a **taproot** system?
3. Explain.
Questions About Roots

1. What plant part is a sweet potato?
   - A white potato?
   - Garlic?

2. How do earthworms help plant roots grow?

3. How do ants help plant roots grow?
Questions About Roots

1. Do you think desert plants (experiencing low rainfall) have deep or shallow roots? Explain.

2. Do you think root vegetables (such as potatoes) are suitable for growth in a Tower Garden? Explain.

3. Why do you think some plants (like the ones we call “weeds”) grow back after we pull them out of the ground?

4. How might the function of roots in a Tower Garden be different from roots growing in soil? How might their function be the same?
Write your answers to the questions below.

1. How would the growth of a plant be affected if its roots were cut off? Suggest at least two ways.

2. Why does “watering a plant” mean to water the soil around the plant?
LEARNING ABOUT PARTS OF PLANTS

Stems

1. Purpose and Content of Lesson:

   Stems are responsible for fluid transport in plants. They contain vessels that move water from the roots and leaves carrying nutrients, sugars, and carbohydrates throughout the plant, even against the pull of gravity. This lesson allows children to examine real stems and view the transport of dyed water through xylem vessels in celery (actually petioles) and white flowers. They will also examine the cut stems of the flowers, pieces of cactus, and a grape vine to see a wide range of types of stems and feel the fluid inside when they break them. The fluid may even be sticky, which raises further questions about its content. For grades K-2, teach only about xylem (what they will observe) and the first two functions of stems. This lesson directly connects to growing Tower Garden® plants since students can observe how water being pumped past the roots is resulting in growth of plants. When stems wilt or get dry, they can infer there is a problem with the plant’s access to water and make necessary adjustments. From the roots, the stems continue to transport water to the leaves for photosynthesis, growth, and essential cell processes. Students will be able to observe many types of stems depending on what they grow in their Tower Garden®.

   Stems usually grow above the soil surface towards the sunlight and have four main functions:

   1. **Support the plant** and hold leaves, flowers, and fruits above the ground. Stems keep the leaves in the light and enable flowers and fruits to grow.
   2. **Transport fluids** between roots and leaves in the xylem and phloem.

2. Next Generation Science Standards (NGSS):

   http://www.nextgenscience.org/search-standards

   **Disciplinary Core Ideas**

   **LS1.A: Structure and Function**

   All organisms have external parts. Plants have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (Grades K-2)

   Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Grades 3-5)

   **LS1.D: Information Processing**

   Plants respond to some external inputs. (Grades K-2)

3. Common misconceptions about stems:

   Most learners do not realize tree trunks, vines, or cactuses are stems. They believe that stems hold plants upright and reason that vines cannot be stems because they do not hold plants up. That is why teachers should avoid teaching that stems keep plants up, especially since their Tower Garden®

   ![image: Diffen Science](image: Diffen Science)

   **Xylem:** Vessels that transport water in plants from the roots to the leaves.

   **Phloem:** Vessels that move food from the leaves to stem and roots for storage and use.

   ![image: Diffen vessel](image: Diffen vessel)

   ![image: Diffen vessel](image: Diffen vessel)
plants will have stems drooping downward, sideways, and upward. Young learners often say that cactus stems are not thin enough and trees are too big to be stems. It is important to have many samples of stems available, from foods we eat (e.g., asparagus, cauliflower, broccoli stems) to examples of flower stems, vines, and cactus for them to examine. When they are able to cut many types of stems, they will see there is water in them to reinforce that stems transport fluids. Sticky water means stems transport sugars, too.

Trees have vascular bundles of xylem and phloem but they do not appear to be wet like other stems. Showing tree ring slices is sometimes confusing to young learners around this topic because they are dry, hard, and do not clearly show fluid transport. One example related to trees having stems that transport fluids is how sugar maple trees are tapped to collect sap that flows in the phloem to make maple syrup. View video (See Resources) to show students that the sap actually drips out of the tree, reinforcing the concept that trees are, in fact, stems that transport fluids as do the plant stems with which they are familiar.

**Lesson Objective:**

Learners will explain the function of stems and identify xylem and phloem as tubes that transport ground water and plant food from leaves and list several examples of stems on a worksheet.

**Lesson Procedure—**

**THE LEARNING CYCLE: The Five Es**

**ENGAGE**

Review the function and types of the roots from the prior lesson and remind students that the roots lead directly to another plant structure. Hold up a plant with all parts intact for them to see that the stem is next in line (like a section of philodendron with roots and stem — a common houseplant). Ask students to infer the function of the stem. What is it for? Have them think about stems of plants they know.

Without a lot of discussion, but with explicit directions, have students put celery stalks in dyed water. Use food color from the baking aisle, but mix some red into the yellow to make orange because yellow is too pale. Here’s a tried and true formula to get water to rise up the celery xylem in 30 minutes or less:

- Buy firm, fresh celery with leaves on top. Separate the stalks, one for each child prior to the activity. They can put their initials on their own stalk with a Sharpie marker.
- Use room temperature water and glass jars. (Plastic cups tip over).
- Use the entire vial of food dye in 1.5 inches of water for each of the colors. Do not buy the neon colors of dye, just the red, blue, green and yellow pack used for baking. This will make the water a dark color. Do not fill the jar with water – only enough to cover the bottom of the celery. If you are using only one color, make the water dark with that color (25 drops or more).

- Have students snip off the end of the celery to open the tubes and immediately put it in the jar of choice.

You want students to be able to observe the celery near the end of the lesson, so definitely put it in jars at the very beginning. A short discussion can include asking students to make predictions about what they think will happen.

**EXPLAIN**

Students use the data from their stem observation chart to infer the functions of a stem. Use their stem observations to support the functions listed. Project the PowerPoint Presentation titled "STEM LESSON POWERPOINT."

**Key Terms:**

**Xylem:** Vessels that transport water in plants from the roots to the leaves.

**Phloem:** Vessels that that move food from the leaves to stem and roots for storage and use.

**Predict:** What vessels do you think will turn color in the celery, xylem or phloem? Why?
After 30 minutes, have students retrieve their celery stalks from the jars. Supply a paper towel for each student to wipe off the external dye and return to his/her seat with the wrapped celery. Have them put the celery on a clean paper towel and make external observations. Did the dye go to the leaves? What part of the leaves are dyed and why? (Xylem tubes extend into the leaf veins). What can you see at the cut end of the celery (circles of color — the xylem)?

Then model how to break the celery, curved side down, and pull back to reveal the colored vessels. Students can determine if they are xylem or phloem. (The dyed tubes are xylem, phloem are bundled next to them but are not dyed.) They can keep snapping the celery to reveal more tubes all the way to the top of the stalk.

Ask: How did we prove that xylem tubes transport water up the stem?

Students can draw and label their observations of the celery in their science notebooks. Have them also record the functions of the stem.

Celery image [http://www.kiwicrate.com/blog/1966/celery-food-coloring-experiment/]

Content — Stems: Great Plant Escape [http://extension.illinois.edu/gpe/case1/c1facts2b.html]


Background for Teacher: Botany [http://ag.arizona.edu/pubs/garden/mg/botany/plantparts.html]

Diagrams and video: Diffen Science Phloem vs. Xylem: [http://www.diffen.com/difference/Phloem_vs_Xylem]

Tapping Sugar Maple Trees video: [https://www.youtube.com/watch?v=KnOCyLDLHmA]

Materials for Investigation:
- Samples of stems for observation
- Stalks of celery, at least one for each student
- 4 wide-mouth glass jars
- Sharpie marker
- 4 food colors (buy one box, mix some red in with the yellow)
- Paper Towels
- Copies of assessment, one per student
- Science notebooks
- Computer and projection (if available)
- White flowers (small carnations, alstroemeria)

Ask students what they think will happen when white flowers are put into the same dye jars. After listening to their hypotheses, make a fresh cut and place a few white flowers in each of the dye jars left from the celery investigation. Observe the flowers the next day to further reinforce the function of the stem.
### Appendices:
Graphic handout on Stems

<table>
<thead>
<tr>
<th>Stem Type</th>
<th>Similarities to Other Stems</th>
<th>Differences</th>
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**Question:** After examining these stems, what do you think is the job of the stem?
*What is its function?*

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**Date:**

**Name:**
All About Stems

DEVELOPED BY: Debra Zinicola, Ed.D., Seton Hall University, Chair, Department of Educational Studies, and Marian Glenn, Ph.D., Seton Hall University, Professor, Department of Biological Sciences
The Function of Stems

Stems usually grow above the soil surface towards the sunlight.

We know roots bring water with dissolved nutrients into the plant from the soil.

So what do stems do for the plant?
The Function of Stems

Stems:

1. **provide support** for the plant and hold leaves, flowers and fruits above the ground. Stems keep the leaves in the light, and enable flowers and fruits to grow;

2. **transport fluids** between roots and leaves;

3. **store nutrients**; and

4. **produce new living tissue**—stems contain meristematic tissue which generates new tissue. That means they grow!
The Function of Stems

Stem vessels transport fluids:

1. **Xylem**: Vessels that transport nutrition-rich water in plants from the roots to the leaves.

2. **Phloem**: Vessels that move food from the leaves to stem and roots for storage and use.
Examining celery stems:

What vessels do you think will turn color in the celery—xylem or phloem?

Explain.
The Function of Stems

Examining celery stems:
Put the celery on a clean paper towel and make external observations.

1. Where did the dye go?
2. What part of the leaves are dyed and why?
The Function of Stems

Examining celery stems:

1. Break the celery, curved side down and pull back to reveal the colored vessels.

2. How do you know if the colored tubes are xylem or phloem?

3. Keep snapping the celery to reveal more tubes all the way to the top of the stalk.
The Function of Stems

Xylem or phloem?
The Function of Stems

What we learned about stems:

1. How did we prove that xylem tubes transport water up the stem?

2. Draw and label your observations of the celery. Show that xylem vessels transport water up the stem towards the leaves.
The Function of Stems

More about stems:

1. Review using the Great Plant Escape website: [Great Plant Escape](#); and the Tapping Sugar Maple Trees video: [Tapping Sugar Maple Trees](#)

2. Is the liquid dripping out of the Sugar Maple tree from the xylem or phloem? Explain.
Purpose and Content of Lesson:

Angiosperms (flowering plants) are the largest, most successful plant group on Earth. Angiosperms are also the youngest plant group, evolving 125 million years ago. Almost all crop plants are angiosperms.

What is the purpose of a flower?

What is the flower's special job? image

This lesson begins the exploration of how flowers make seeds and develop fruit by focusing on pollination.

Terms and definitions simplified for elementary students:

- pollination: pollen grains on the anther of the stamen land on the stigma of the pistil
- cross-pollination: when pollen is transferred to the stigma of another plant
- self-pollination: when pollen is transferred to the stigma of the same plant
- pollen: microscopic grains formed on a part of the flower called stamens that are needed to make a seed
- pollinators: animals such as bees, wasps, flies, butterflies, bats, and birds that move pollen from anthers to stigmas. Wind also helps pollinate flowers.
- stamen: male flower part that contains an anther with pollen
- anther: part of the stamen that holds pollen
- pistil: female flower part with a stigma on top and an ovary where seeds are formed

Next Generation Science Standards (NGSS):

- LS1.A: Structure and Function
  All organisms have external parts. Plants have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (Grades K-2)
  Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (Grades 3-5)

- LS1.D: Information Processing
  Plants respond to some external inputs. (Grades K-2)

Common misconceptions about stems:

Many children believe the function of flowers is to smell nice and look beautiful. Even after instruction, it is hard for them to think of flowers as being responsible for generating seeds and fruit. Due to the complex vocabulary in the process of pollination and fertilization, younger students can learn about pollination and pollinators with a lesser focus on the process of fertilization. Fertilization will be the topic of the second lesson on flowers.
**Lesson Objective:**

Learners will explain how flowers are pollinated using the terms anther, stamen, pistil, stigma, and pollen and identify at least four types of pollinators on an exit slip.

**EXPLORE**

**Key Questions** — *What is pollination and why is it important? Which flower parts are involved in pollination? How do flowers get pollinated?*

Students use 4-slide view of printed copies of PowerPoint presentation to create skits in groups of 3. They must depict a concept about pollination and incorporate at least three vocabulary words into each skit. Provide about ten minutes for them to prepare their skits and write, on paper, what concept they are enacting and which vocabulary words they are incorporating. After each skit is presented, the class will determine what vocabulary words and definitions apply and summarize what they saw in each skit.

**EXPAND**

**Flower observation:**

Have two or three different flowers for students to observe, draw, and label. If there is any student with a pollen allergy, encase each bloom in a plastic bag that is puffed with air and rubber banded at the stem. Have one of each kind of flower for each group. Daisies, lilies, tulips or whatever seasonal varieties can be found will provide students with the diversity of flower representations to observe key parts: petals, stamens, anthers, pistil, and stigma.

**EVALUATE**

Have all key vocabulary terms written on the board without definitions.

On an exit slip, students will write:

1) What is pollination? (using at least three vocabulary words from the lesson)
2) How does pollination happen in at least two different ways?
3) Four pollinators

**ENGAGE**

Review the function of other parts of plants that have been learned — seeds, roots, and stems. Ask students what they know about flowers and what they do for the plant. Clear up misconceptions and explain that the flower's special job is to make seed(s).

Project this introductory video showing the following pollinators: hummingbirds, bees, butterflies, and bats. (4 min.)


Show the video at the beginning as an introduction, then again at the end of the lesson so at different points it can be stopped for students to describe the process that is occurring using the terms taught in this lesson. Tell them pollen grains grow on stamens and need to get to another flower part called the pistil so the flower can make fruit and seeds. If the pollen does not get to the pistil, no fruit or seeds will be made.

*What will happen to a farmer's tomato plants if the flowers do not get pollinated?*

Pollinators are extremely important; without them, we would not be able to grow plants as food. Honeybees are important pollinators because they visit many flowers, depositing pollen onto many pistils.

**EXPLAIN**

Show PowerPoint slideshow on Pollination. The content and images explain what pollination is and how it happens. (In the “notes” section of each slide are the web addresses of the sources of the content and images.)
6 Web Resources and Materials

1 Grades 6-8 Flower investigation, vocabulary, discussion questions, full lesson plan: Discovery Education http://www.discoveryeducation.com/teachers/free-lesson-plans/plant-pollination.cfm

Image 2 http://pollinator.org/beeissues.htm

Flowers: How seeds are made (process, vocabulary) Great Plant Escape http://extension.illinois.edu/gpe/case4/c4brief.html

Pollination: Diagram, facts, video: Biology of Plants http://www.mbgnet.net/bioplants/pollination.html

Flower Dissection: https://www.desertmuseum.org/center/edu/docs/k-5_DesertGardeners_flowerDissection.pdf

Pollinators images, video: http://www.newtonsapple.org.uk/plant-pollinators/

Materials:
One per group:
- Tray to hold flowers
- Three or four different types of flowers on the tray for students to observe, draw, and label

One for each student:
- Paper plate
- Printout of 4-slide view of PowerPoint presentation
- Hand lens
- Science journals

7 Appendices

PowerPoint slide show titled “POLLINATION”
How flowers make seeds and fruit
Part 1: Pollination
What is Pollen?

Tiny pollen grains are formed on a part of the flower called **stamens** and are needed to make a seed.
Pollination is the first step in the seed making process. In this step, pollen is moved to where it is needed.

Pollen grains on the anther of the stamen need to land on the stigma of the pistil.
What is Pollination?

When pollen is transferred to the stigma of the same plant it is called **self-pollination**.

When pollen is transferred to the stigma of a different plant it is called **cross-pollination**.

Usually plants rely on animals or the wind to pollinate them.

**Question:**

*How would indoor Tower Garden flowers get pollinated?*
Pollination by Insects

Flowers pollinated by insects are colored and scented. Why do you think that is so?

When pollinators suck up nectar in the pistil, they brush against the anthers and get pollen on their bodies.

When they land on a flower, the pollen rubs off their bodies onto the stigma of the pistil.
Pollination by Insects

Cross-pollination:

1. Pollen from stamens sticks to a bee as it visits a flower to collect food.
2. The bee travels to another plant of the same type.
3. Pollen on the bee sticks to a pistil of a flower on the other plant.
Other Pollinators
Wind-pollinated flowers usually have small petals, dull colors and no scent.

**Why do you think this is so?**

Their anthers usually hang out of the flowers so that the pollen grains can be blown by the wind more easily and have a higher chance of landing on a distant, large, feathery stigma.

**Why do the stigmas of wind-pollinated flowers look this way?**
Artificial Pollination

In Tower Garden Cucumbers:

When plants are grown indoors without wind or animal pollinators, the flowers need help to move pollen.

A person needs to transfer the pollen from the anthers onto the stigma of the female flower.
In Tower Garden Cucumbers:

Cucumber plants produce two kinds of flowers.

One kind of flower produces pollen (male). The other kind has a pistil and produces fruit and seeds (female).

Look behind the blossom to see if there is a miniature cucumber. If so, that is the flower with the stigma and pistil.
Artificial Pollination

In Tower Garden Cucumbers:

A cucumber flower being pollinated by hand.
Artificial Pollination

In Tower Garden Cucumbers:

1. Use a small Q-tip to collect pollen from several anthers on the stamens of male flowers.

2. Brush pollen onto the stigmas of the flowers with the miniature cucumbers.

3. Watch the size of the little cucumber for a week after you pollinate the flower. What do you think will happen?
Artificial Pollination

In Tower Garden Cucumbers:
Artificial Pollination

In Tower Garden Tomatoes:

Tomato flowers produce both pollen and a pistil on the same flower.

But the pollen is held in a little cage, and without pollinators, a person is needed to help release it.
Artificial Pollination

In Tower Garden Tomatoes:

So, to pollinate tomatoes, just shake the plants … gently.

*Where do you hope the pollen will land?*

*What will you be able to observe in the next few weeks if you were successful?*
Artificial Pollination

In Tower Garden Tomatoes:
Fertilization

What happens after pollination?

How fertilization takes place

- stigma
- pistil
- pollination
- pollination
- pollen
- pollen
- pollen tube
- pollen tube
- ovule
- embryo sac
- ovary
- egg cell
- vascular system
- style
- filament
- stamen
- anther
- petal
- sepal
Pollination: Terms and Definitions

- **pollination**—pollen grains on the anther of the stamen land on the stigma of the pistil
- **cross-pollination**—when pollen is transferred to the stigma of another plant
- **self-pollination**—when pollen is transferred to the stigma of the same plant
- **pollen**—microscopic grains that are needed to make seeds are formed on a part of the flower called stamens
- **pollinators**—animals such as bees, wasps, flies, butterflies, bats, and birds that move pollen from anthers to stigmas. Wind also helps pollinate flowers.
- **stamen**—male flower part that contains an anther with pollen
- **anther**—part of the stamen that holds pollen
- **pistil**—female flower part with a stigma on top and an ovary on bottom where seeds are formed
- **stigma**—sticky top part of pistil where the pollen from the anthers must land in the seed making process