

Lesson 3 | Explain

Plant-Soil Interactions

At a Glance

Overview

Students begin the lesson by agreeing or disagreeing with several statements about plant roots. They use a hand lens to examine roots of young seedlings and are given a chance to revise their responses. The diffusion process used by roots to absorb nutrients is modeled. Transport of water through the xylem is demonstrated using pieces of celery stalks and food colouring. Students compare and contrast the plant vascular system to the human circulatory system.



Major Concepts

- Plants remove water and nutrients from the soil through the plant's root system.
- Some nutrients move into root cells from the soil by diffusion and others by an energy-requiring process (active transport).
- The plant vascular system has similarities to the human circulatory system.
- Plants transport water from the roots to the rest of the plant using the xylem.
- Plants transport food from the leaves to the rest of the plant using the phloem.

Objectives

After completing this lesson, students will be able to

- recognize that plants remove nutrients from the soil,
- explain the roles of diffusion and active transport in moving nutrients from the soil to the plant, and
- relate the root and vascular systems of the plant to the human circulatory system.

Teacher Background

Consult the following sections in *Teacher Background*:

4.0 *Plant-Soil Interactions*

5.0 *The Plant Vascular System*



In Advance

Photocopies

Activity 1	Master 3.1, <i>What Do You Know about Roots?</i> (Make 1 copy for each student and prepare an overhead transparency.) Master 3.2, <i>Moving Water and Nutrients into Roots</i> (Make 1 copy for each student.) Master 3.3, <i>Experiments with Roots</i> (Prepare an overhead transparency.)
Activity 2	Master 3.4, <i>The Plant Vascular System</i> (Make 1 copy for each student.) Master 3.5, <i>Getting Water and Nutrients to the Plant</i> (Make 1 copy for each student.)

Materials

Seedling preparation (5 to 6 days in advance)	For each group of 4 students: 1 drinking glass 1 hand lens 6 pinto bean (or other types) seeds 1 cup of water 1 paper towel
Diffusion demonstration (Moving Water and Nutrients into Roots)	For each group of 4 students: 1 paper or Styrofoam cup 1 large container 1 bottle of food colouring Water (enough to fill the large container) 1 sharp pencil
Celery demonstration	For each group of 4 students: 1 paper or Styrofoam cup 1 piece of celery stalk 1 bottle of food colouring

Preparation

Activity 1: Seedling preparation. In Step 4, students are asked to observe the root systems of young seedlings. For this activity, any type of seeds may be used so long as the roots have grown about 1 or 2 cm. Pinto bean seeds are easy to obtain and work well. To germinate the seeds, place several seeds in a row along one side of a paper towel as shown in Figure 3.2a. Carefully roll up the paper towel in the direction of the arrow (from bottom to top). Place the rolled paper towel into a glass of water so that the seeds are at the top and out of the water glass (Figure 3.2a). Water will wick up through the paper towel and keep the seeds moist. Prepare enough seedlings so that each group of 4 students will have a seed to observe. Assume that just $\frac{1}{2}$ of the seeds you prepare will germinate. Set the glasses of seedlings in a location where they will not be disturbed. The seeds will need approximately 5 to 6 days for the roots to grow enough for observation. During the germination period, be careful to replace any water that is lost through evaporation.

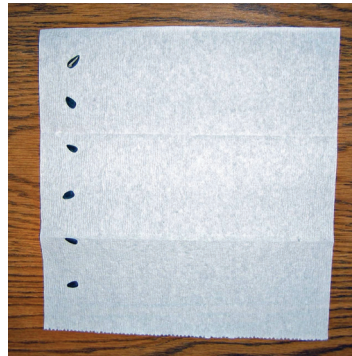
Teacher note

The celery demonstration described in this section is designed to quickly transport water through the xylem. For a more impressive demonstration, you can have carnations take up coloured water and see the edges of the petals take on the colour of the dye. While more dramatic than the celery demonstration, it takes much longer to see the effect; about 2 to 3 hours, as compared with 15 to 20 minutes for the celery demonstration.

Activity 2: Celery demonstration. Use a sharp knife to cut celery stalks into pieces approximately 3 centimetres long. Make sure that the cut surfaces are flat and will allow the celery to rest upright when placed into the paper cups.

Optional Activity 2: Carnation demonstration.

1. Obtain a white carnation and cut the stem diagonally so that the stem is about 9 centimetres long.
2. Add about 3 centimetres of water to a paper cup.
3. Add 6 drops of food colouring (blue works well) to the water and mix.
4. Place the carnation into the coloured water.
5. Within 2 hours, small coloured areas will appear at the edges of the petals.



a



b

Figure 3.2

- a. Seeds are rolled up in a paper towel.
- b. Seeds are placed into a glass of water.

Figure 3.3

- a. Xylem demonstration with celery
- b. Xylem demonstration with carnation.

Procedure

Activity 1: From Soil to Roots

Teacher note

Diffusion and active transport both play roles in moving nutrients from the soil into the plant roots. It is not necessary that middle school students be familiar with the details of these processes. The important things for students to know are

- in diffusion, molecules flow down their concentration gradient (meaning from an area of higher concentration to an area of lower concentration); and
- in active transport, energy is used to move molecules against their concentration gradient (meaning from an area of lower concentration to an area of higher concentration).

1. Remind students that in the previous lesson they learned that air spaces in soil become filled with water and that many nutrients needed by plants are dissolved or suspended in the water. Ask, "How does the plant obtain nutrients from this water?"

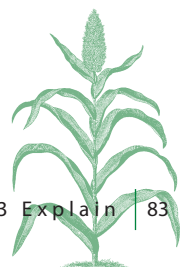
Students' responses will vary. If necessary, guide the discussion to mention the plant's root system.



a



b



2. Display a transparency of Master 3.1, *What Do You Know about Roots?* Cover the transparency with a piece of paper. Reveal the first statement and ask the students to indicate by a show of hands whether they agree or disagree with the statement.

This discussion is designed to help you assess the students' prior knowledge of the topic. If necessary, review for the class the essential features of diffusion and active transport.

Diffusion

- Molecules move randomly due to their kinetic energy.
- This movement causes molecules to intermingle.
- The net movement of molecules is from an area of higher concentration to one of lower concentration.
- The net movement of molecules stops when the concentration of the molecules is the same everywhere.
- The movement of the molecules comes from their kinetic energy and doesn't need additional energy (unlike active transport).

Active Transport

- Active transport is a process used by cells to move molecules from an area of lower concentration to one of higher concentration.
- It requires energy.
- If your students already have been introduced to the energy molecule ATP, you may mention it as the source of energy for active transport.

3. Continue revealing the rest of the statements, one at a time, and asking students whether they agree or disagree with the statements.

After students vote on each statement, ask for 1 or 2 volunteers to explain why they voted as they did. At this time, do not correct wrong answers. The students will come back to these statements later in the lesson. Answers are found and revealed to students in Step 15.

4. Explain that they will now investigate the mechanism by which roots obtain nutrients from the soil. Divide the students into groups of 4. Pass out to each group a young seedling (taken from the paper towel germination) and a hand lens.

This activity refers to the way that most plants obtain their nutrients through the root system. Plants that carry out nitrogen fixation in their roots are a special case and are not dealt with here.

5. Instruct the students to take a minute to observe the seedling's root system with the hand lens and write down their observations on a piece of paper.

The root hairs are white and very fine. Provide a dark background against which the root hairs are more easily visible.



By the end of Grade 7, students should:

- use scientific inquiry/research skills to investigate occurrences (e.g., a forest fire, a drought, an infestation of invasive species such as zebra mussels in a local lake or purple loosestrife in a wetland habitat) that affect the balance within a local ecosystem.

6. After the students have recorded their observations, ask for volunteers to describe what they saw.

Students will report seeing one large root emerging from the seed. They also will describe fine white hairs growing out from the root.

7. Remind students of the first statement from Master 3.1, *What Do You Know about Roots?*: “Plant roots have tiny hairs that absorb water.” Ask, “Why do you think that plants have so many root hairs?”

Student responses will vary. Guide the discussion to bring out that more root hairs mean more surface area with which to contact water and nutrients in the soil.

8. Ask students, “How do nutrients in the soil water get into the root hairs?”

Students’ responses will vary. At this time, accept all answers.

9. Explain that students will now investigate the process by which water enters the root hairs. Keep the class in their groups. Pass out to each group 1 copy of Master 3.2, *Moving Water and Nutrients into Roots*.

10. Ask students to read over the procedure on the handout. Explain that the cup represents the root hair, the larger container represents the water in the soil, and the food colouring represents the nutrients dissolved in the water.

11. After students have completed their investigations, reconvene the class and ask for volunteers to explain what happened when the holes were poked through the cup.

Students will report that the coloured water slowly entered the cup.

By the end of Grade 8, students should:

- test water samples for a variety of chemical characteristics (e.g., pH, salinity, chlorine).
- use scientific inquiry/research skills to investigate local water issues.



12. Ask students:

■ **“Why did the coloured water enter the cup?”**

Students’ responses will vary. Guide the discussion to bring out the fact that although the concentration of water was the same on both sides of the cup, the concentration of the food colouring was higher outside the cup compared with inside the cup.

■ **“What is the process called where a substance moves from an area of higher concentration to an area of lower concentration?”**

The process of diffusion was summarized in Step 2. Students should recall that diffusion involves a net movement of a substance from an area of higher concentration to one of lower concentration.

■ **“Where does the energy come from to drive this process?”**

Students should recall from the discussion in Step 2 that the process is driven by the kinetic energy of the molecules in solution.



- 13. Display a transparency of Master 3.3, *Experiments with Roots*. Cover the transparency with a piece of paper. Reveal the first experiment and read it aloud. Ask the students what this data tells them about how nutrients move from the soil into the roots.**

Since the concentrations of some essential elements move from an area of low concentration to one of higher concentration, this suggests that energy was required for the movement and the process involved was active transport.



By the end of Grade 7, students should:

- use scientific inquiry/research skills to investigate occurrences (e.g., a forest fire, a drought, an infestation of invasive species such as zebra mussels in a local lake or purple loosestrife in a wetland habitat) that affect the balance within a local ecosystem.

By the end of Grade 8, students should:

- use scientific inquiry/research skills to investigate local water issues.

- 14. Reveal the second experiment, read it aloud, and discuss its meaning.**

Students should recognize that a chemical stops energy from being produced. They should reason that the lack of energy will cause the process of active transport to stop. Without active transport, those essential elements that were concentrated in the root hairs during experiment 1 would now be present in lower amounts. If not mentioned by a student, bring out the fact that the transport of other essential elements that move by diffusion would be unaffected.

- 15. Conclude the activity by once again displaying a transparency of Master 3.1, *What Do You Know about Roots?* As before, ask students to indicate by a show of hands whether they agree or disagree with each statement. Ask for volunteers to explain why they changed their minds about their answers.**

Students should be able to respond to the statements about roots as follows:

Answers to Master 3.1, *What Do You Know about Roots?*:

1. Plant roots have tiny hairs that absorb water. (True)

Students were able to observe root hairs using the hand lens. A larger root system contacts and absorbs more water than a smaller one.

2. Plants roots use energy to pump water into the plant. (False)

As shown in the demonstration, water entering the root hairs does so by the passive process of diffusion. When root hairs contact the water, the water flows from a higher concentration in the soil toward a lower concentration in the root cells.

3. Nutrients enter root cells through the process of diffusion. (True)

Water enters the root system by diffusion and takes dissolved nutrients with it.

4. Nutrients enter root cells through the process of active transport. (True)

As shown by the experiments described in Master 3.3, Experiments with Roots, some nutrients are moved by active transport.

5. Plant roots grow until they find water. (False)

Students may believe that roots can sense and grow toward water. This is a misconception. Roots can only grow where water is already present. As the surface of the soil dries out, roots near the surface may die while roots further down are in contact with water and can grow still deeper.

Pass out to each student 1 copy of Master 3.1, *What Do You Know about Roots?* Instruct students to write on their copies of Master 3.1 why each statement is true or false. Students should include specific evidence from the lesson that supports their conclusions.

Activity 2: From Roots to the Plant

1. Explain that getting nutrients into the plant roots is an important first step. Ask students, “How does water, and the nutrients it contains, get from the roots to the rest of the plant?”

Some students may recognize that plants have a vascular system.

2. Explain that students are going to investigate how water moves from the roots to the rest of the plant. As before, divide the class into groups of 4 students.

3. Pass out to each student 1 copy of Master 3.4, *The Plant Vascular System* and 1 copy of Master 3.5, *Getting Water and Nutrients to the Plant*. Instruct students to

- examine the plant vascular system as shown in Master 3.4, *The Plant Vascular System*, and
- conduct the celery demonstration as described in Master 3.5, *Getting Water and Nutrients to the Plant*.

Give students about 15 to 20 minutes to complete their tasks.

4. Reconvene the class and ask for volunteers to report their predictions about the movement of the food colouring in the celery. Ask them if their predictions were correct or incorrect.

Students' predictions will vary. They should report that the food colouring was transported up the celery stalk and was visible as a series of coloured dots along the top of the stalk. Explain that the movement of water took place through the plant's xylem system.

5. Conclude the lesson by reminding students that photosynthesis produces sugars in the leaves. Ask them how the sugars, needed for energy, reach the lower parts of the plant.

Students should recall from Master 3.4, *The Plant Vascular System* that phloem tissue is used to transport sugars downward from the leaves. You can point out that in the case of the celery stalk, the xylem and phloem tissues lie next to each other in structures called vascular bundles.





Optional Homework Assignment

Ask students to write a short paper that describes how the plant vascular system is similar and dissimilar to the human circulatory system.

Students' descriptions should include the following:

Similarities

- Both systems use a series of tube-like structures to transport material throughout the organism.
- Both systems use diffusion to move nutrients and oxygen gas (O_2) into cells.
- Plants have separate systems for moving water up the plant (xylem) and for moving food down the plant (phloem). Humans have a separate system for moving oxygenated blood (arterial system) and non-oxygenated blood (venous system).



Dissimilarities

- The human circulatory system uses the heart to pump blood, while the plant vascular system lacks such an organ.
- Blood in the circulatory system contains cells, while the sap in the plant vascular system does not contain cells.
- Capillaries join the arterial and venous systems, but there are no similar structures in the plant vascular system.

Lesson 3 Organizer		
Activity 1: <i>From Soil to Roots</i> What the Teacher Does		Procedure Reference
Remind students that air spaces in soil become filled with water that contains nutrients. <ul style="list-style-type: none"> Ask, "How does the plant obtain nutrients from this water?" 		Page 83 Step 1
Display a transparency of Master 3.1, <i>What Do You Know about Roots?</i> <ul style="list-style-type: none"> Reveal each statement, one at a time, and ask students to raise their hands if they agree or disagree with each statement. 		Pages 84 Steps 2 and 3
Explain that they will investigate how roots get nutrients from the soil <ul style="list-style-type: none"> Divide the class into groups of 4 students. Give each group a young seedling and a hand lens. Instruct the groups to observe their seedlings with the hand lens and to record their observations. 		Page 84 Steps 4 and 5
Ask for volunteers to share their groups' observations.		Page 85 Step 6
Remind students that plant roots have tiny hairs that absorb water. Ask: <ul style="list-style-type: none"> "Why do you think that plants need so many root hairs?" How do nutrients in the soil water get into the root hairs?" 		Pages 85 Steps 7 and 8
Explain that they will investigate the process by which water enters the root hairs. <ul style="list-style-type: none"> Keep the class in their groups. Give each group 1 copy of Master 3.2, <i>Moving Water and Nutrients into Roots</i>. 		Page 85 Step 9
Ask students to read the procedure. Explain that the cup represents the root hair, the larger container represents the soil water, and the food colouring represents the nutrients.		Page 85 Step 10
After groups have completed their investigations, ask for volunteers to report their results.		Page 85 Step 11
Ask groups: <ul style="list-style-type: none"> "Why did the coloured water enter the cup?" "What is the process called where a substance moves from an area of higher concentration to an area of lower concentration?" "Where does the energy come from that drives this process?" 		Page 85 Step 12
Display a transparency of Master 3.3, <i>Experiments with Roots</i> . <ul style="list-style-type: none"> Reveal the first experiment and read it aloud. Ask the students what the data tell them about how nutrients move from the soil to the roots. 		Page 86 Step 13
Reveal the second experiment, read it aloud, and discuss its meaning.		Page 86 Step 14

M = Involves copying a master
T = Involves making a transparency

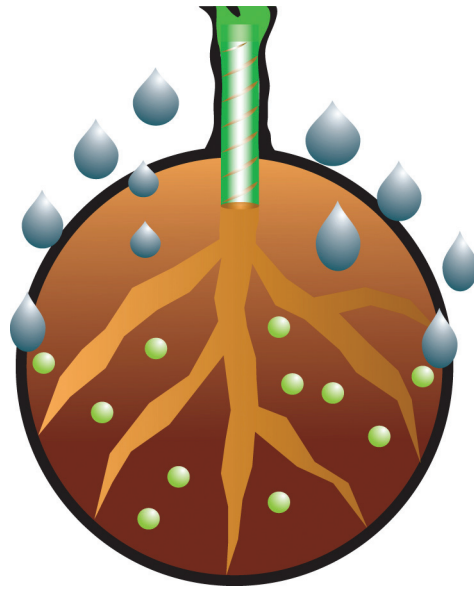


Lesson 3 Organizer <i>continued</i>	
Activity 1: <i>From Soil to Roots</i> What the Teacher Does	Procedure Reference
Again, display Master 3.1, <i>What Do You Know about Roots?</i> <ul style="list-style-type: none"> ■ Ask students to indicate by a show of hands if they agree or disagree with each statement. ■ Ask for volunteers to explain why they changed their minds about some of their answers. 	Page 86 Step 15 
Activity 2: <i>From Roots to the Plant</i> What the Teacher Does	Procedure Reference
Explain that getting nutrients from the soil to the plant roots is the first step. Ask: <ul style="list-style-type: none"> ■ “How does water, and the nutrients it contains, get from the roots to the rest of the plant?” ■ Explain that they are going to investigate this question. ■ Divide the students into groups of 4 students. 	Page 87 Steps 1 and 2
Give each student 1 copy of Master 3.4, <i>The Plant Vascular System</i> and 1 copy of Master 3.5, <i>Getting Water and Nutrients to the Plant</i> . Instruct groups to do the following: <ul style="list-style-type: none"> ■ Examine the diagram on Master 3.4, <i>The Plant Vascular System</i>. ■ Conduct the demonstration described on Master 3.5, <i>Getting Water and Nutrients to the Plant</i>. 	Page 87 Step 3 
Reconvene the class and ask for volunteers to report their predictions and results of the celery activity.	Page 87 Step 4
Remind students about photosynthesis and ask them how sugars are transported to the rest of the plant.	Page 87 Step 5

Master 3.1, *What Do You Know about Roots?*

Name _____

Date _____



1. Plant roots have tiny hairs that absorb water.
2. Plant roots use energy to pump water into the plant.
3. Nutrients enter root cells through the process of diffusion.
4. Nutrients enter root cells through the process of active transport.
5. Plant roots grow until they find water.



Master 3.2, Moving Water and Nutrients into Roots

Name _____

Date _____



Procedure

Step 1. Fill the cup about 1/2 full of water.

Step 2. Place the cup of water into the center of the larger container.

Step 3. Fill the larger container with water until its level is the same as that in the cup.

Step 4. Add several drops of food coloring to the water in the larger container and gently mix the water until the color is evenly distributed through the water. Do not add food coloring to the water in the cup!

Step 5. Using a sharp pencil, poke 2 holes in the cup, opposite each other.

Step 6. Watch the water in the cup for 5 minutes and record your observations in the following space.

Observations





Experiment 1

Scientists know that some essential elements are found in very low amounts in the soil. They found that some of these same elements are present in root hairs at concentrations 100 times higher than those measured in the soil.

What process can move an essential element from a place of low concentration (in the soil) to one of higher concentration (inside the root hairs)?

Experiment 2

The data from *Experiment 1* caused the scientists to believe that active transport was responsible for moving some essential elements from a low concentration in the soil to a higher one inside the root hairs. They know that this process requires energy. The scientists next exposed the living roots to a chemical that stops energy production. Once again, they measured the amounts of essential elements in the soil and inside the root hairs.

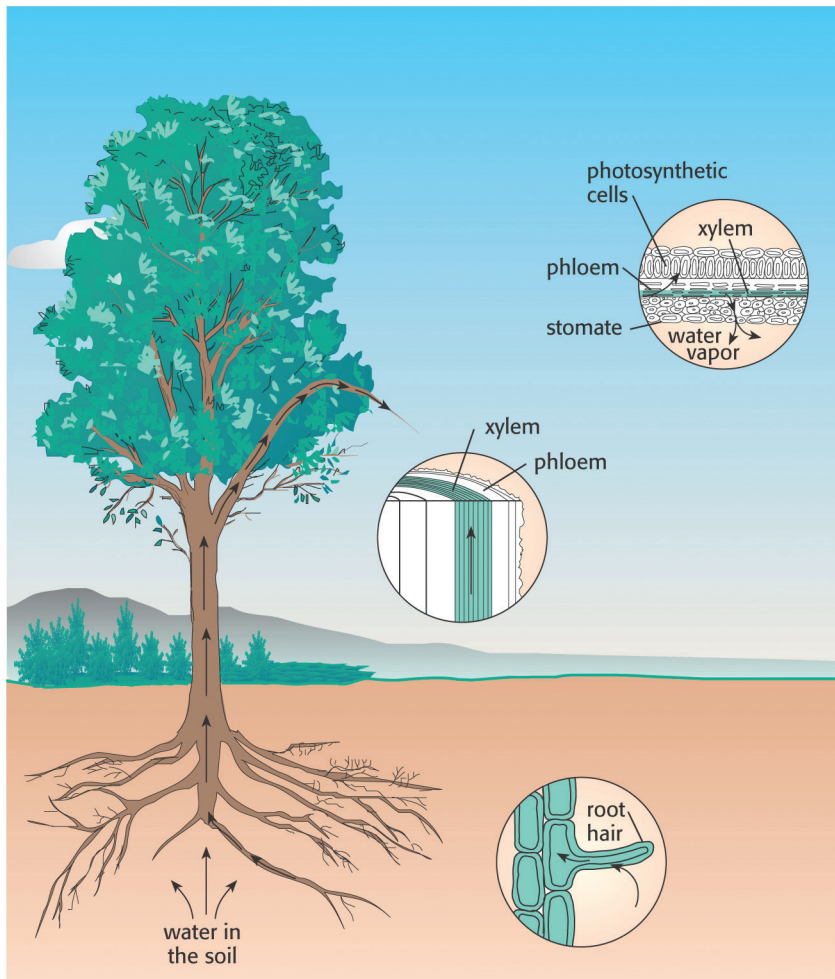
What do you think they observed?



Master 3.4, *The Plant Vascular System*

Name _____

Date _____



1. Xylem transports water up from the roots.
2. Phloem transports sugars produced in the leaves during photosynthesis down the plant.



Master 3.5, Getting Water and Nutrients to the Plant

Name _____

Date _____



Procedure

- Step 1.** Obtain a cup, some food coloring, and a piece of celery stalk.
- Step 2.** Pour food coloring into the cup to a depth of at least 0.5 centimeters.
- Step 3.** Place the piece of celery stalk into the cup of food colouring so that it is resting on its cut surface.
- Step 4.** Predict what you think will happen to the food colouring. Record your prediction in the following space.
- Step 5.** Allow the celery to stand undisturbed for 5 to 10 minutes. Record your observations in the following space.

Prediction

Observations

