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

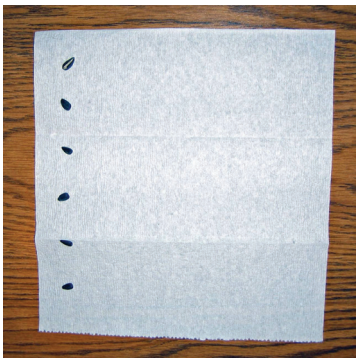
Preparation

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 3.2b). 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 ½ 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 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.



a

b

Figure 3.2
a. Seeds are rolled up in a paper towel. b. Seeds are placed into a glass of water.

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.

Procedure

Activity 1: From Soil to Roots

a

b

Figure 3.3
a. Xylem demonstration with celery b. Xylem demonstration with carnation.

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.

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.

Expectations:

Students will:

- select appropriate instruments (e.g., sampling instruments, laboratory glassware, magnifying lenses, an electroscope) and materials (e.g., ebonite rods, star charts, a ball and spring apparatus, pH paper) for particular inquiries.
- conduct inquiries, controlling some variables, adapting or extending procedures as required, and using standard equipment and materials safely, accurately, and effectively, to collect observations and data.

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.

Expectations:

Students will:

- investigate the effect of various qualitative factors (e.g., temperature) on the rate of diffusion of molecules across a plasma membrane.

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.

Expectations:

Students will:

- synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error.

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

Students should recognize that since the chemical halts ATP synthesis there will not be energy available to support active transport. Those essential elements that depend on active transport to reach high concentrations will exhibit much lower concentrations in the root hairs as compared with the first experiment. Other essential elements that are transported by diffusion will be expected to have their concentrations unchanged.

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

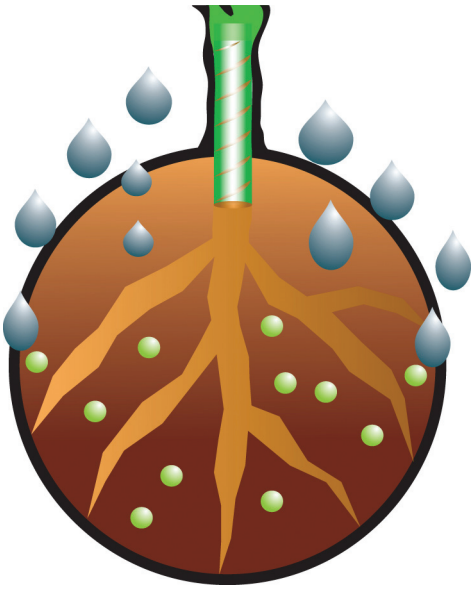
M = Involves copying a master

T = Involves making a transparency

Lesson 3 Organizer	
Activity 1: *From Soil to Roots* **What the Teacher Does**	**Procedure Reference**
Remind students that air spaces in soil become filled with water that contains nutrients. ■ Ask, "How does the plant obtain nutrients from this water?"	Page 81 Step 1
Display a transparency of Master 3.1, *What Do You Know about Roots?* ■ Reveal each statement, one at a time, and ask students to raise their hands if they agree or disagree with each statement.	Page 81 Step 2 Page 82 Step 3
Explain that they will investigate how roots get nutrients from the soil. ■ 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 82 Steps 4 and 5
Ask for volunteers to share their groups' observations.	Page 82 Step 6
Remind students that plant roots have tiny hairs that absorb water. Ask: ■ "Why do you think that plants need so many root hairs?" ■ How do nutrients in the soil water get into the root hairs?"	Pages 83 Steps 7 and 8
Explain that they will investigate the process by which water enters the root hairs. ■ Keep the class in their groups. ■ Give each group 1 copy of Master 3.2, *Moving Water and Nutrients into Roots.*	Page 83 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 coloring represents the nutrients.	Page 83 Step 10
After groups have completed their investigations, ask for volunteers to report their results.	Page 83 Step 11
Ask groups: ■ "Why did the colored 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 83 Step 12
Display a transparency of Master 3.3, *Experiments with Roots.* ■ 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 83 Step 13
Reveal the second experiment, read it aloud, and discuss its meaning.	Page 84 Step 14

Lesson 3 Organizer *continued*	
Activity 1: *From Soil to Roots* **What the Teacher Does**	**Procedure Reference**
Again, display Master 3.1, *What Do You Know about Roots?* ■ 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 84 Step 15
Activity 2: *From Roots to the Plant* **What the Teacher Does**	**Procedure Reference**
Explain that getting nutrients from the soil to the plant roots is the first step. Ask: ■ "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 85 Steps 1 and 2
Give 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 groups to do the following: ■ Examine the diagram on Master 3.4, *The Plant Vascular System.* ■ Conduct the demonstration described on Master 3.5, *Getting Water and Nutrients to the Plant.*	Page 85 Step 3
Reconvene the class and ask for volunteers to report their predictions and results of the celery activity.	Page 85 Step 4
Remind students about photosynthesis and ask them how sugars are transported to the rest of the plant.	Page 85 Step 5

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.

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

Name
Date

Experiment 1

Scientists measured the concentrations of various essential elements in the soil and inside the root hairs. They found that some essential elements had concentrations up to 100 times greater inside the root hairs as compared with the soil.

What process can move a substance against its concentration gradient?

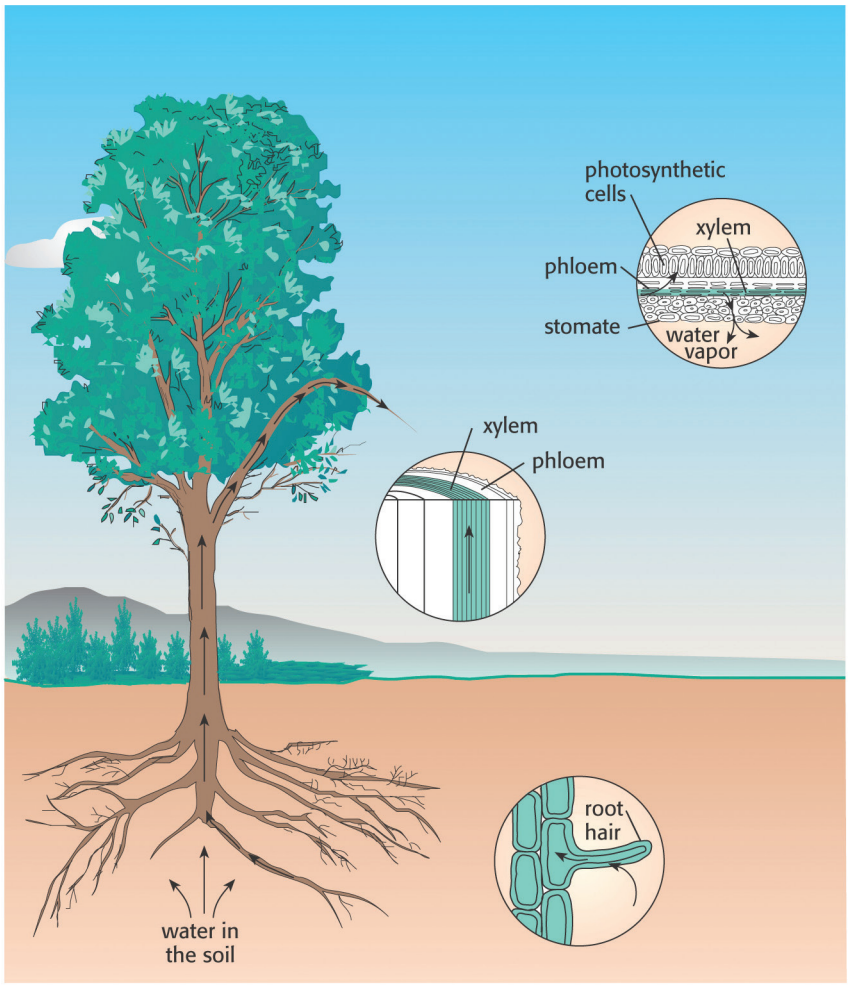
Experiment 2

The data from *Experiment 1* caused the scientists to suspect that active transport was responsible for concentrating some essential elements in the root hairs. They next exposed the living roots to a chemical that stops the synthesis of ATP. Once again, they measured concentrations of essential elements in the soil and inside the root hairs.

What do you think they observed?

Name

Date



1. Xylem transports water up from the roots.

2. Phloem transports sugars produced in the leaves during photosynthesis down 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 coloring so that it is resting on its cut surface.

Step 4. Predict what you think will happen to the food coloring. 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