Plant Piping

Description: Students build models to learn about the special cells and structures that plants use to move water from their roots up through the stems and leaves.

Learning Objectives: Students learn that plants have systems that move water as part of the water cycle.

SCIENCE TOPICS	PROCESS SKILLS	GRADE LEVELS
Botany Evaporation Water Cycle Transfer of Energy	Observation Modeling Making Predictions Hypothesizing	5

TIME REQUIRED

Day 1

Advance Preparation	Set Up	Activity	Clean Up
30 minutes	**15 minutes**	**60 minutes**	**20 minutes**

Day 2

Advance Preparation	Set Up	Activity	Clean Up
None	**None**	**45 minutes**	**20 minutes**

SUPPLIES

- Canning or mayonnaise-type jars (3) per class
- Clear drinking straws (1 per student)
- Paper plates (1 per student, 2 per teacher)
- Clear plastic 8–10 oz drinking cups (1 per student)

- Plastic knives (1 per student)
- Leaves from your house, neighborhood, or schoolyard
- 2 bunches of celery
- 1 houseplant with medium to large sized leaves
- Non-sealable sandwich bags (2 to 5)
- Scotch tape
- Paper towels
- Red food coloring (blue also works)
- Magnifying lenses
- 2 plastic lunch trays
- 2 dish towels
- Plastic wrap
- Scissors (1 per student)
- Knife
- 3 gallons of water
- Permanent markers (1 per group of 2 students)
- Chalkboard, overhead, or chart pack and writing implements
- Materials to photocopy: Science Background and Student Procedure

ADVANCE PREPARATION

At least 24 hours in advance:

- Fill the 3 canning jars half full with water and add approximately 30 drops of red food coloring to each jar. The darker the water, the easier it will be for students to see results.
- Cut the bottom ends off of one bunch of celery, leaving the leaves on.
- Separate these celery stalks into three batches and put them in the jars with colored water. Leave the celery in the water for at least 24 hours. The other bunch of celery should remain uncut until the next day.
- Using the sandwich bags, place a bag over a leaf on the houseplant. With the tape, seal the bag around the stem at the base of the leaf. The bag should cover the leaf.
- Repeat with 3 more leaves.

Day of the activity:

- Remove the celery from the colored water and dry off the stems. Cut both the colored and plain celery into 2 3-inch pieces, making sure there are enough pieces for each student.
- Label one paper plate “A” and another one “B.” Put the colored celery pieces on plate “A” and the plain celery pieces onto plate “B.”
- Label two clear cups “Control.”
- Fill the two cups with water and add at least 10 drops of food coloring per cup. Carefully swirl to mix.
- Mark the water level on the control cups with a permanent marker.

- Cover the top of one cup with plastic wrap. Leave the other control cup open to the air.
- Get the dishtowels wet and place them on the plastic lunch trays. Students will use these to get their paper towels wet.

SET UP

- Place the two control cups in the area selected to set out the experiment.
- Gather the following supplies and put them in a central location in the classroom: plates, celery, plastic knives, clear drinking cups, straws, paper towels, water jugs, plastic lunch trays with wet towels, plastic wrap, scissors, and markers.

INTRODUCING THE ACTIVITY

Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

What do you know about plants?
Students' answers will vary but encourage all ideas.

Has anyone ever received a colored carnation on St. Patrick's Day? How do you think they do that?
Someone adds food coloring to the water and it turns the flowers colors.

How about trees—who can tell me something about trees that makes them different from other plants?
Trees can be taller, trees have bark, birds live in trees, houses and paper are made from trees, etc.

We know that plants and trees come in all shapes and sizes. The smallest plant in the world is a type of duckweed called water meal (*Wolffia globosa*). When it is fully grown, it is not much larger than a period at the end of a sentence in a book. The tallest plant in the world is a type of Eucalyptus from Australia that has been recorded at 326 feet tall. That's tall, especially for a plant, but trees get even taller! The two tallest trees in the world, the Douglas fir (329 feet tall) and coastal redwood (367 feet tall), are found on the West Coast. The Douglas fir is found in a very large range that includes Oregon, Washington, Idaho, and Montana. The coastal redwood is only found in California and Oregon. (http://www.bbg.org/gar2/topics/botany/parts_grouping.html) Exactly how tall is the tallest coastal redwood? Well, if you took a person who is 5 feet tall, you would need to stack

73.5 copies of that person, head to toe, to reach the same height, 367 feet, of the redwood tree.

Even though there is a lot of variety among plants and trees, they still have a few things in common—plants and trees need sunlight, nutrients, and water to survive. For the rest of this activity, we are going to focus on water.

If a tree can get to be 367 feet tall, how does the water reach the top of the tree?
Let students give suggestions on how this works. Encourage suggestions of either the pushing or pulling of water.

I can think of two possible ways that water could get to the top of the tree. One way would be something like a pump that moves water from the roots to the leaves. A second way could be something that pulls the water, kind of like a vacuum.

Which of these two ideas do you think would work the best?
Take a hand vote of the whole class.
For those of you who guessed a pump—you are right. For those of you who guessed something that pulls the water—you are also right. To move water through a plant or tree, it takes both actions. When water moves into the roots, it works like a pump, and water is actively moved into the plant. However, the force that pulls water through the plant and out the leaves is even stronger than the pumping. This pulling force is called **evaporation** (write this word on a board so students can see it).

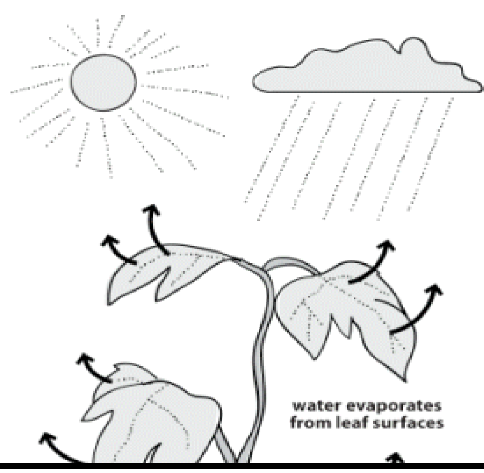
Who knows what evaporation is and can give an example?
Evaporation is the process of water changing from a liquid into a gas. Examples: sweat cooling off a person, a sidewalk drying after a rainstorm, etc.
When we are talking about plants, the loss of water from a plant is called **transpiration** (write this word on the board next to evaporation).

SCIENCE BACKGROUND

Background information can be found at the end of the activity. Print on a separate page for students to read before doing the activity.

The Pipes of Plants

Plants are amazing! They get all their food, energy, and water without moving. They are stuck in the ground, on a rock, or even on another plant (like ivy on a tree). Different plants have different ways of surviving. These special differences are called **adaptations**. They have adapted to get nutrients and water through their roots.



Plants get energy from the sun through a process called **photosynthesis**. A special chemical called **chlorophyll** is produced in the leaves and stems of plants. Chlorophyll absorbs energy from the light of the sun. In photosynthesis, plants use this energy to make sugar. They also use water from the ground and **carbon dioxide** from the air to make their sugar. When photosynthesis is done, **oxygen** is left over. So plants put oxygen back into the air. (This is the opposite of people and animals. We breathe in oxygen and breathe out carbon dioxide.)

TEACHER DEMONSTRATION

Now last night, I set up a little experiment. I wanted to find out for myself if water actually evaporates from the leaves of a plant. For my experiment, I used only the following three items: my plant, plastic sandwich bags, and clear tape.

Does anyone have any ideas on how I could test my question?
Let students give suggestions and help them come to the answer.

Here is what I tried: I sealed some plastic bags over a few leaves to collect any water that might have evaporated off the leaves. Let's come over and take a closer look at what happened. **What do you see?**
The bag over the leaves has water collected inside.

Where did the water in the bag come from? The water came out of the leaf during a process called transpiration.

OK, now we know that water moves from the roots of a plant to the leaves. What does the water use to travel through the plant?

Let students offer suggestions.
Water travels through plants in a series of tubes. These tubes are called **xylem** (write this on the board).

Let's say you want to move a lot of water up through a plant. Do you think it would work better if we had one xylem with a very large diameter or a lot of them with small diameters?
Students may not have much frame of reference for this question but allow them to make suggestions and explain why they think so.

Has anyone ever seen air bubbles in a straw? That is a common problem for big tubes. If the xylem in a plant gets air bubbles in it, then it can no longer move water and that piece of xylem is destroyed. That leaves us with small xylem. By using lots of small tubes, even a big tree can get all the water it needs up to its top.

Remember our discussion of green colored flowers? To create them, people put food coloring into the water, and, as the water moves through the xylem, the color is pulled throughout the plant. Yesterday, I put some celery in a jar with colored water, and this morning I cut them into small pieces. We are going to take a closer look at what happens to celery that has been in colored water. Up here on this table are the supplies we are going to need. I want everyone to come up and grab a plate, one piece of celery from plate "A," one piece of celery from plate "B," and a plastic knife.

On these plates, you have sections from a piece of celery that I let sit in colored water last night and one that has been in normal water only.

What differences do you notice between the two pieces of celery?
Students should see colored spots on the ends of the dyed celery.

Using your knife carefully, dissect the pieces of celery and tell me what you find.

Did anyone discover that the colored spots are actually long stringy things? What part of the plant do you think this is?
This is the xylem of the plant!

OK, so we know that water moves up plants in special tubes called xylem. We also know that water exits the plant by evaporating out of the leaves—remember my leaf experiment—pulling the water through the plant. This movement of water through a plant is called **transpiration**.

When I was thinking about plants and transpiration, a question I had was: "How does the size of the leaf affect how much water moves through the plant?"

We are going to conduct an experiment to test your ideas about how different sizes of leaves affect transpiration.

CLASSROOM ACTIVITY

Students should work in groups of 2 to 4. Each group follows the directions on the Student Procedures page.

This activity begins with the teacher guiding students through the process of creating a hypothesis. The sections in bold represent questions and statements the teacher could use in this process.

Student Procedure for Plant Piping

1 **Collect the following supplies:**

- Two cups
- Two straws
- Two paper towels
- Two small pieces of plastic wrap
- Marker
- Scissors

2 **Make the xylem for the experiment.**

- Take one paper towel and cut it lengthwise into approximately 2-inch strips.
- Take the strips to the cafeteria tray. Gently press the strips into the wet towel until they are completely wet. Water should not be dripping on the floor.
- Twist the wet paper towel strips into a rope and gently push them into each straw. When you are done, the straw should have paper towel all the way through it with no gaps.

Does anyone have any ideas about how leaf size might affect transpiration?
The size of the leaf will either speed up or slow down the process.
Write all the students' ideas on the board.

If the leaf is larger, do you think the transpiration will be faster or slower?
Poll students and go with what the majority of the class predicts.

The experiment will test either of the two hypotheses. Remember, it is OK if the class thinks smaller is faster—this is what doing an experiment is all about. The important thing is guiding the students through the process.

OK, here is our hypothesis: **The _______ the leaf, the faster the rate of transpiration**. **Now let's test it!**

Tell students that to test this hypothesis, they are going to work in pairs to create their own model of a plant and its water transportation system. They will be using the clear straws to represent the xylem of the plant. The paper towels will be the leaves.

Have students break into pairs for this part of the activity. Students should follow the instructions on the "Student Procedures" handout. The teacher may wish to demonstrate for the entire class a technique students can use to twist the wet paper towel into a leaf, though students may enjoy experimenting with this process.

More importantly, the teacher may wish to demonstrate the correct way to cut the paper towels in order to make two leaves of the correct sizes.

As students are completing their experimental setups, try to check each one and make sure that there are no gaps in paper towels within their straws. Any open space will prevent water from transpiring through the tube.

It is not essential for the plastic wrap to be tight around the base of the straws. Students may make a hole that is slightly too large. This will not significantly affect the results of the experiment.

Data Collection Note:
This Expedition Northwest activity has a math extension designed for use in conjunction with it. The math extension includes tools teachers can use to help students collect more detailed information about their leaf sizes and rates of transpiration.

CLASS DISCUSSION

Ask for student observations. Let students guide the discussion and present their hypotheses before discussing explanations.

Was our class hypothesis supported by the results of our experiment?
Let students share their results and discuss whether they think the hypothesis was supported or not.

Was anyone surprised by the results of our experiment?
Let the students talk this out.

If you collected any unexpected data, can you think of any explanations? What could have caused this?
Have students speculate on causes such as: differences in water level at the beginning, large holes ripped in the plastic wrap, paper towel was not well connected inside of the straw, etc.

Can you think of a place in the world where having large leaves would be a disadvantage? How about small leaves?
Students may realize that large leaves could be a disadvantage in the desert, that small leaves might be an advantage in a dry climate, or that large leaves require a lot of water.

Does anyone know some adaptations plants have to help them survive in extreme climates?
Desert plants might have a waxy cuticle or small leaves, tropical plants have drip tips to help with so much water, boreal forest trees have needles for leaves, etc.

EXPLANATION

In-depth background information for teachers and interested students.

One of the driving forces of transpiration is evaporation. The larger the leaf, the more surface area there is. The increased surface area allows for water to evaporate more quickly. When the water evaporates, it leaves behind the blue food coloring. Other factors that control the rate of transpiration are the relative humidity, wind, and temperature surrounding the plant. Plants that are adapted to live in very arid, or dry, environments are called **xerophytes**. To help slow down transpiration and reduce water loss, these plants may have small, thick leaves, a thick leathery cuticle, stomata only on the bottom of the leaf, or they may even shed their leaves during the hot, dry months. One of the most famous arid environment plants is the cactus. These plants are able to store and then use water when none is available.

OPTIONAL EXTENSIONS

Extension A—Further Experiment Extensions
Repeat the experiment using different variables including wind levels (a fan on low speed will produce remarkably noticeable results), heat (a lamp or controlled environment), leaf thickness, saltwater, etc.

Extension B—Additional Math Component
Use the **Expedition Northwest Math Extension** for this activity.

Extension C—Create a Graph
- Have students measure the water in 10 mL increments, labeling each new water level as they fill their cup up to 100 mL.
- Record water levels at set time intervals.
- Graph the data.

Extension D—How Tall Is a Redwood in Humans?
- Calculate the total height for the teacher and everyone in the class. How many times taller would the tallest tree be? How about the heights of a northwest NBA team or WNBA team?

Extension E—Leaf Stomata
Purchase a plant or use the one from the demonstration and have students use microscopes to take a closer look at the stomata.

CROSS-CURRICULAR CONNECTIONS

SUBJECT	Activity
LANGUAGE ARTS	Write a story describing life from the point of view of a plant. Explain what it's like to not be able to move.
SOCIAL STUDIES	Look up the amounts of water needed by a variety of important food plants. Discuss how important it has been for cultures to get water to their crops throughout modern history. Investigate methods they used to accomplish this.
ART	Have students create carnation or celery stalk art using their new knowledge of transpiration. Make carnations of different colors. Can they get different colors of dye to travel up through the plant partway by removing the stalk from the water at the right time? See what happens to these plants if the stalks are split at the bottom and each end is put into different colored water.

RESOURCES

http://www.cornwallwildlifetrust.org.uk/educate/kids/photsyn.htm
Cornwall Wildlife Trust: Information about photosynthesis and transpiration.

http://www.mbgnet.net/bioplants/main.html
Missouri Botanical Gardens: Biology of plants including adaptations in biomes.

http://www.fairchildgarden.org/EduProfDev/Leaf_anatomy.html
Fairchild Tropical Botanic Garden: Biology of plants.

GLOSSARY

Adaptations: A special characteristic that helps a plant or animal survive.

Carbon dioxide: A gas in the Earth's atmosphere. Plants use it to make sugar. Animals exhale it (breathe it out).

Chlorophyll: A special chemical found only in plants that lets them absorb energy from the sun.

Evaporation: The process of water changing from a liquid to a gas.

Oxygen: A gas in the Earth's atmosphere. Animals need to breathe it in to survive. Plants expel it as they conduct photosynthesis.

Photosynthesis: The process that plants use to make sugar from water, carbon dioxide, and sunlight.

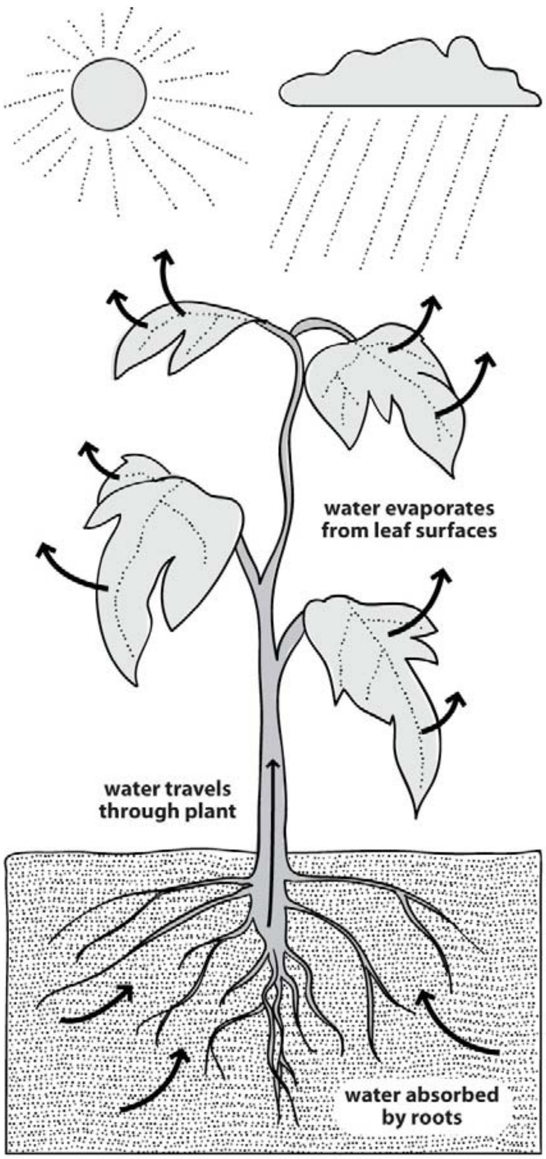
Stomata: Microscopic holes in leaves through which water evaporates.

Transpiration: The movement of water through a plant.

Xylem: The tube-shaped tissue in plants that moves water and nutrients from the roots to the leaves in a plant.

The Pipes of Plants

Plants are amazing! They get all of their food, energy, and water without moving. They are stuck in the ground, on a rock, or even on another plant (like ivy on a tree). Different plants have different ways of surviving. These special differences are called **adaptations**. They have adapted to get nutrients and water through their roots.



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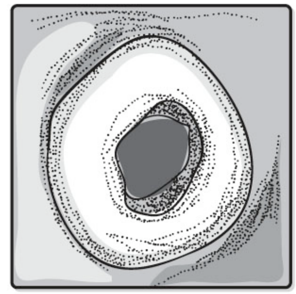
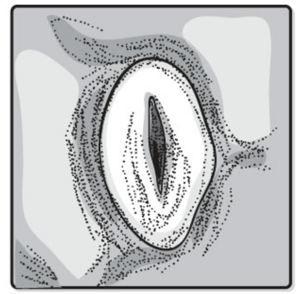
Photosynthesis mostly happens in the leaves of plants. But how do plants and trees get water all the way up to their leaves? Plants use their roots to pull water and nutrients from the ground and into the plant. However, the roots can only push water and food to the base of the plant. Since gravity is pushing down on the water, how do plants get the water to move up? The water is actually pulled up and through the plant. When water is pulled through a plant, it moves in a series of pipes called **xylem** (z-eye-lem). Water can move through the xylem as fast as 75 cm (29 inches) per minute!

On the outside of plant leaves, there are holes called **stomata** (a single hole is called a stomate). These holes are so small that you need a microscope to see them. Around each stomate there are two cells called guard cells. These guard cells expand and shrink to control the size of the stomate. This controls how much water can leave a leaf. This is very similar to how your eyes work. The iris (or colored part) of your eye expands and shrinks to change the size of your pupil and control how much light enters your eye.



open stomata



closed stomata

As the water leaves the stomata, it evaporates off of the leaf. As it evaporates, more water is pulled to the opening of the stomata, continuing the cycle. This process is called **transpiration**. Over the course of a day, a leaf can transpire more than its weight in water! Imagine sweating more than your own weight!

Student Procedure:
Plant Piping

1

Collect the following supplies (per student or per group):
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- Two straws
- Two paper towels
- Two small pieces of plastic wrap
- Marker
- Scissors

2

Make the xylem for the experiment.
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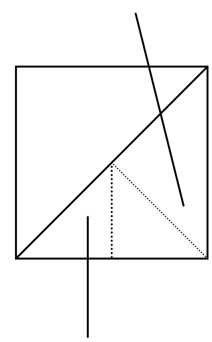
- Take the strips to the cafeteria tray. Gently press the strips into the wet towel until they are completely wet. Water should not be dripping on the floor.
- Twist the wet paper towel strips into a rope and gently push them into each straw. When you are done, the straw should have paper towel all the way through it with no gaps.

3

Make the leaves—one per straw.
- Cut the remaining paper towel in half diagonally.
- Cut one half of the paper towel in half again diagonally. One of these pieces will represent the large leaf.
- Cut the remaining small piece in half diagonally. This small triangle will represent the small leaf.
- Get the leaves wet using the same process as in step 2.
- Twist the base of the leaf and insert it into the straw far enough that it won't fall out.



4

Put the experiment together.
- With the marker, label one cup "Large Leaf" and one cup "Small Leaf." Be sure to put your name and the date on the cups.
- Bring the two cups to the jug of water. Fill the cups half way with water. Make sure that the cups have the same amount of water in them. Mark the water level on the cups with a marker. Add ten drops of blue or red food coloring to each cup and carefully swirl the jars to mix. Use the same food coloring in both cups.
- Bring the cups back to your desk.
- Tightly cover the top of each cup with plastic wrap and rubber band or tape. Be careful not to tip them over.
- Using a ballpoint pen or pencil, carefully poke a small hole in the middle of the plastic wrap.

- Carefully put each prepared straw (xylem) into the hole—one per cup. Make sure the leaves are still attached.
- Place your cups in the area of the classroom designated by your teacher. The cups will remain there overnight.
- Return to your desks and clean up.

Day 2

5 **Collect data.**

- Use a marker to put a line on the cup showing the new water level.
- Observe the two cups. What do you see happening?

6 **Analyze data.**

- Compare the amount of water each leaf was able to move through the straw. Which leaf had a faster rate of transpiration?

7 **Form a conclusion.**

- Was your class hypothesis supported? Why or why not?