# Trees Are for Treasuring…and Measuring

## Grade Level 4-8

## Lesson Overview

Trees are an incredibly important part of the ecosystem of earth. Living for hundreds and even thousands of years and sheltering trillions of living things, trees are essential to earth and the living creatures who inhabit the planet. This lesson will introduce students to several ways to measure trees along with a way to measure their importance to earth's water cycle.

## Student Objectives

1. Estimate, measure, and calculate the height of a tree.
2. Estimate, measure, and calculate the age of a tree.
3. Estimate, measure, and calculate a tree's transpiration.

## Materials

### Worksheets (included in lesson)

- ✓ Build a Clinometer
- ✓ Estimating the Age of a Tree

### Trees Are for Measuring Activities

- clipboards for each student
- one ruler for each pair of students
- one 4 foot stick or dowel rod, for each pair of students
- one 30 foot tape measure for each pair of students
- several hammers for the class to share

### Build A Clinometer Worksheet Materials

- square piece of heavy paper or a protractor, for each pair of students
- drinking straw, for each pair of students
- string, for each pair of students
- one weight (use a washer), for each pair of students
- one 30-foot tape measure
- access to trees outside
- copies of the Build a Clinometer worksheet

### Estimating the Age of a Tree Activity

- tree cookie
- copies of the Estimating the Age of a Tree worksheet

**Determining a Tree's Transpiration**

- plastic bags, one for each group of students
- yarn or thin string, 12" for each group of students
- small containers
- graph paper

## Vocabulary

- **clinometer -** a tool that measures angles of elevation (height) or inclination (slope).
- **transpiration** – the moisture released by a living object.

## Background Information

Trees are a key component of any ecosystem. Trees influence everything around them, including the local weather and the wildlife that lives in the region. Getting to know the trees in your area is a great place to start if you want to appreciate and understand the ecology of your state. This is true not only of rural areas, but also in cities where trees are an important part of the urban ecology.

Students should become familiar with all the parts of a tree. From the bark to the leaves and the cambium to the root hairs, all aspects of trees are interesting and important to the tree's function and survival.

**Basic tree information from the National Wildlife Foundation:**

What Is a Tree?

Trees grow, reproduce, and respond to their environment. Trees, like all plants, manufacture their food through photosynthesis. Trees are in the family of woody plants which have cambium, a special layer of cells that allow the tree to increase in girth and are self-supporting with a single stem. Trees are perennials and can live for many years.

The food for trees is produced through a complex system starting with the leaves. Leaves produce sugar as a result of photosynthesis. A by-product of photosynthesis is oxygen—a vital resource for other living organisms, including humans. The sugar produced during photosynthesis is used to stimulate the growth and development of the tree and stored in the roots to aid the tree in overwintering and assist in its reproduction processes.

The roots gather minerals and water which are needed in the process of photosynthesis and for feeding the tree's growth and development. The tree has one tap root and many lateral roots which help to keep it stable in wind and snow.

## Parts of a Tree

The **crown** of the tree is made up of the leaves and branches.

The **trunk** of the tree supports the crown and serves as a highway for food made in the leaves to travel to the roots and for water and nutrients from the roots to travel to the leaves.

The **heartwood** of the tree develops as the tree gets older. It is old xylem (sapwood) that no longer carries sap (water plus nitrogen and mineral nutrients) and gives the trunk support and stiffness. In many kinds of trees, the heartwood is a darker color than the sapwood, since its water carrying tubes get clogged up.

The **cambium** is a layer or zone of cells, one cell thick, inside the inner bark. The cambium produces both the xylem and phloem cells. This is where diameter growth occurs, and where rings and inner bark are formed. In the xylem (sapwood) layer, tree sap (water plus nitrogen and mineral nutrients) is carried back up from the roots to the leaves. In the phloem (inner bark) layer, sugar that is made in the leaves or needles, is carried down to the branches, trunks, and roots, where it is converted into the food (starch) the tree needs for growth. The bark layer protects the tree from insects and disease, excessive heat and cold, and other injuries.

The **roots** of the tree support the trunk and crown and also anchor the tree in the soil. They serve as a storage facility during the winter for the food produced by the leaves during the growing season. The roots also absorb water and nutrients from the soil for use by the tree.

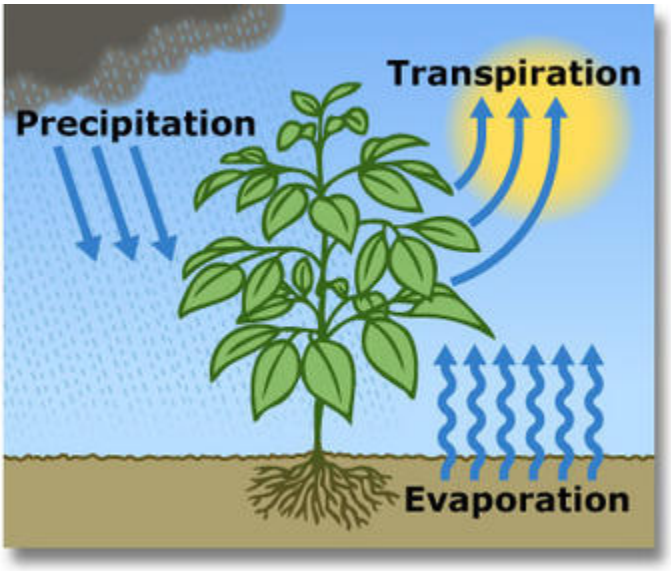
## Tree Types

Trees can be divided into two categories: deciduous and coniferous.

**Deciduous trees** are also known as broadleaf trees because the leaves are generally larger and wider than those of conifers. The larger leaf size means a greater surface area for photosynthesis, but it also means that the leaf is too fragile to withstand winter conditions. Therefore, most deciduous trees drop their leaves in autumn.

**Coniferous trees** keep their leaves/needles throughout the year, shedding only the oldest leaves/needles. Usually these leaves/needles are lower down on the tree or closer to the tree trunk and do not receive as much sunlight as newly developed leaves higher up. Some of the best-known members of the conifer family are pines, spruces, firs, and hemlocks. The cones of the conifers are its flowers.

## What is evapotranspiration?




Evapotranspiration is the sum of evaporation from the land surface plus transpiration from plants.

The typical plant, including any found in a landscape, absorbs water from the soil through its roots. That water is then used for metabolic and physiologic functions. The water eventually is released to the atmosphere as vapor via the plant's stomata — tiny, closeable, pore-like structures on the surfaces of leaves. Overall, this uptake of water at the roots, transport of water through plant tissues, and release of vapor by leaves is known as transpiration.

Water also evaporates directly into the atmosphere from soil in the vicinity of the plant. Any dew or droplets of water present on stems and leaves of the plant eventually evaporates as well. Scientists refer to the combination of evaporation and transpiration as evapotranspiration.

The transpiration aspect of evapotranspiration is essentially evaporation of water from plant leaves. Studies have revealed that transpiration accounts for about 10 percent of the moisture in the atmosphere, with oceans, seas, and other bodies of water (lakes, rivers, streams) providing nearly 90 percent, and a tiny amount coming from sublimation (ice changing into water vapor without first becoming liquid).

## Transpiration: The release of water from plant leaves

Just as you release water vapor when you breathe, plants do, too – although the term "transpire" is more appropriate than "breathe." The picture in this lesson shows water vapor transpired from plant leaves after a plastic bag has been tied around the stem for about an hour. If the bag had been wrapped around the soil below it, too, then even more water vapor would have been released, as water also evaporates from the soil.

Plants put down roots into the soil to draw water and nutrients up into the stems and leaves. Some of this water is returned to the air by transpiration. Transpiration rates vary widely depending on weather conditions, such as temperature, humidity, sunlight availability and intensity, precipitation, soil type and saturation, wind, and land slope. During dry periods, transpiration can contribute to the loss of moisture in the upper soil zone, which can have an effect on vegetation and food-crop fields.

Plant transpiration is pretty much an invisible process. Since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathing". Just because you can't see the water doesn't mean it is not being put into the air, though. One way to visualize transpiration is to put a plastic bag around some plant leaves. As this picture shows, transpired water will condense on the inside of the bag. During a growing season, a leaf will transpire many times more water than its own weight. An acre of corn gives off about 3,000-4,000 gallons (11,400-15,100 liters) of water each day, and a large oak tree can transpire 40,000 gallons (151,000 liters) per year.

## Atmospheric factors affecting transpiration

The amount of water that plants transpire varies greatly geographically and over time. There are a number of factors that determine transpiration rates:

**Temperature**: Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close.

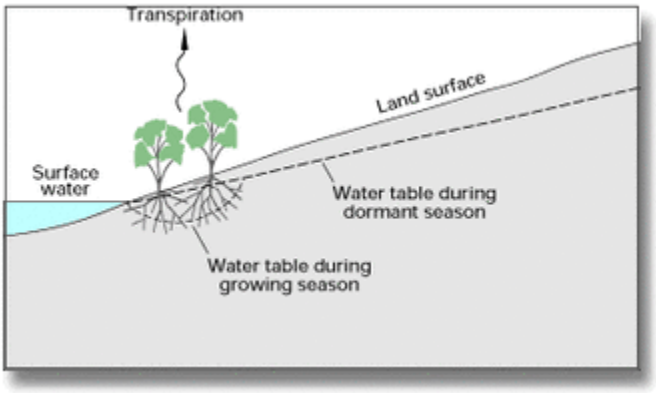
**Relative humidity**: As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.

**Wind and air movement**: Increased movement of the air around a plant will result in a higher transpiration rate. Wind will move the air around, with the result that the more saturated air close to the leaf is replaced by drier air.

**Soil-moisture availability**: When moisture is lacking, plants can begin to senesce (premature aging, which can result in leaf loss) and transpire less water.

**Type of plant**: Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants.

**Transpiration and groundwater**




In many places, the top layer of the soil where plant roots are located is above the water table and thus is often wet to some extent, but is not totally saturated, as is soil below the water table. The soil above the water table gets wet when it rains as water infiltrates into it from the surface, But, it will dry out without additional precipitation. Since the water table is usually below the depth of the plant roots, the plants are dependent on water supplied by precipitation. As this diagram shows, in places where the water table is near the land surface, such as next to lakes and oceans, plant roots can penetrate into the saturated zone below the water table, allowing the plants to transpire water directly from the groundwater system. Here, transpiration of groundwater commonly results in a drawdown of the water table much like the effect of a pumped well (cone of depression—the dotted line surrounding the plant roots in the diagram).

*Sources and more information*

- Evapotranspiration and Droughts, USGS, U.S. Global Change Research Program
- The Water Cycle, NASA Earth Observatory

## Procedure

1. Instruct students on the background information about trees and transpiration in any manner you find to work for your classroom.
2. Use the following activities about measuring trees to get your students out into nature to see, touch, explore, and investigate this lesson topic.

### Trees Are for Measuring

1. Explain to students that they will be measuring a tree outside the classroom using several methods. Divide the class into pairs.

    a. The Ruler Method: While standing at the base of a tree, a student holds a ruler straight out in front, vertically. With one eye closed, back away from the tree until you reach the point at which the ruler and the tree appear to be the same size. Ask your partner to measure the distance between the tree and the ruler, using the measuring tape. The total measurement is the approximate height of the tree.

    b. The Shadow Method: On a sunny day, pound a stick or dowel into the ground, near a tree, but not shaded by trees or other vegetation. Measure the length of the stick above the ground, then measure its shadow. Then measure the shadow of the tree. The following algebraic format may be used to calculate the approximate height of the tree:

$$\frac{\text{length of the stick above the ground}}{\text{x (unknown height of the tree)}} = \frac{\text{shadow of the stick}}{\text{shadow of the tree}}$$

For example, if your 4-foot stick (remember, approximately one foot has been pounded into the ground) casts a shadow of 2 feet, and your tree shadow is 10 feet, then:

$$\frac{3}{x} = \frac{2}{10}$$

Cross multiply (3x10 = 2x; 30 = 2x; 15 = x)

The tree is approximately 15 feet tall.

c. Building a Clinometer Method: Using a square piece of paper, a drinking straw, a string and a weight (washer), direct each pair of students to follow the instructions to build a clinometer following the directions on the ***Build a Clinometer*** worksheet.

2. Summarize the efforts of each pair of students. Encourage students to determine which measurement method is most accurate, and explain why.

**Estimating the Age of the Tree**

1. Some tree ages can be measured by measuring the distance around the trunk of the tree at a point five feet off the ground. If the tree's girth at that point measures 24 inches, the tree is approximately 24 years old. This method cannot be used for all trees. For additional information, refer to the Extension Activities at the end of this lesson.

2. Using a tree cookie (a horizontal cross cut section from a tree), direct students to count tree rings to determine the age of the tree. Have the students complete the ***Estimating the Age of a Tree*** worksheet.

**Determining a Tree's Transpiration**

1. Divide students into groups, help students tie plastic bags over groupings of leaves on live branches of several different trees. After 24 hours, students will carefully remove the bags from the branches and measure the amount of moisture in the bags. Measure and record the transpiration amounts from the different types of trees and chart the data. Discuss what causes transpiration rates to differ (sun, size of trees, number of branches and/or leaves, etc.)

## Extension Activities

1. Calculate the age of a tree using this alternative method:

    - Determine the species of your tree.
    - With tape measure, find the circumference of the tree (in inches) 4 1/2 feet above ground.
    - Determine the diameter of the tree: Diameter = Circumference divided by 3.14 (pi).
    - Calculate the age of the tree: Diameter times the growth factor (below) of the tree species.

    Growth factors:

| | | | | | |
|---|---|---|---|---|---|
| Red maple | 4.5 | Silver maple | 3.0 | Sugar maple | 5.0 |
| River Birch | 3.5 | White Birch | 5.0 | Green Ash | 4.0 |
| Black Walnut | 4.5 | Black Cherry | 5.0 | White Oak | 5.0 |
| Red Oak | 4.0 | Pin Oak | 3.0 | Cottonwood | 2.0 |
| Amer. Elm | 4.0 | Ironwood | 7.0 | Dogwood | 7.0 |
| Redbud | 7.0 | Aspen | 2.0 | Shagbark Hickory | 7.5 |
| Linden or Basswood | 3.0 | | | | |

2. Determine liters of water transpired per day (also pounds, etc. - there are 2.2 pounds per liter of water.)
3. Calculate yearly water loss of the tree through transpiration (if deciduous, use number of months the tree has leaves.)

## Additional Resources

- https://www.fs.usda.gov/
- https://www.americanforests.org/
- https://www.arborday.org/
- https://www.isa-arbor.com/
- https://www.usgs.gov/special-topic/water-science-school/science/evapotranspiration-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects
- Illinois Agriculture in the Classroom interactive Tree Ag Mag http://www.agintheclassroom.org/TeacherResources/AgMags/Tree%20Ag%20Mag%20for%20Smartboard.pdf
- Illinois Big Trees and Illinois Big Tree Registry https://extension.illinois.edu/forestry

## Standards

### *Illinois Mathematics Standard*

CC.8.EE.7 Analyze and solve linear equations and pairs of simultaneous linear equations. Solve linear equations in one variable.

### *Illinois English Language Arts Standard*

ELA.L.5. Demonstrate understanding of figurative language, word relationships, and nuances in word meanings.

The **M**ultidisciplinary **AG**ricultural **I**ntegrated **C**urriculum (mAGic) was created in 2004 under the leadership of the Illinois State Board of Education (ISBE) and the Facilitating Coordination in Agricultural Education Project (FCAE). Funding was made available through the FCAE grant budget from the agricultural education line item of the ISBE budget. This revision, as printed, was developed in January 2021.

These mAGic lessons are designed to bring agriculture to life in your classroom. They address the Illinois Learning Standards in math, science, English language arts and social studies.

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Name _____

# Build a Clinometer

A *clinometer* is a tool that measures angles of elevation (height) or inclination (slope). You will use the clinometer you make in this activity to measure a tree.

Gather all materials:

one square piece of heavy paper for each team or group
one drinking straw
one piece of string, approximately 12 inches long
one washer (this will be your weight)
one 30-foot tape measure

1. Fold the square of paper to form a triangle (since the paper is square, it will form a right isosceles triangle, with 2 sides of equal length, a 90 degree angle, and two 45 degree angles).
2. Tape the drinking straw along the long edge of the triangle (the angled edge). This will be used as a sight.
3. At the upper end of the long fold, attach the string. Tie the weight to the other end of the string (the other end that is hanging down), making it long enough so that the weight dangles a few inches below the corner of the triangle. You will look through the straw from the bottom up to sight the tree top.
4. To use the clinometer, one person looks up through the straw to sight the top of the tree, while the other makes sure the clinometer string is hanging straight down. It will be necessary for the student with the clinometer to move away from, or toward, the tree. The string should be parallel to the vertical edge of the triangle. When the student with the clinometer is the correct distance from the tree, mark the ground. Measure the distance from the mark to the base of the tree. Do the following calculation:

Distance from the mark to the base of the tree: _____ (feet? inches?)

\+

Height from the student's eyes to the ground _____ (feet? inches?)

=

Height of the tree _____ (feet? inches?)

This method of measuring tree height is called the isosceles-right triangle method. Why?

Name _____

# Estimating the Age of a Tree

Using the tree cookie provided, answer the following questions.

1. How old was this tree when it was cut down? (Hint: count each ring.) ____years old.

2. Assume the tree was cut down in 2006. What year did it begin to grow? (Hint: Count the rings and subtract that number from 2006.)

3. All of the rings are not the same distance from each other. Find two rings that are much farther apart than any other two. What could account for the larger space between the rings?

4. Find two rings that are much closer together than any other two. What could account for the smaller space between the rings?

5. Pick a ring near the outside edge of the tree. Think of something that happened that year and record it here.
   Year:_____ What happened that year?_____

6. Are there any scars on the bark of the tree? If so, what could have happened to the tree?

7. Can you identify any growing conditions that would have changed the sizes of the spaces between the rings? Remember, trees need sunlight, water and space to grow well.

8. Is the tree cookie completely round? If not, why?

9. Is the tree an evergreen (keeps its needles throughout the year in Illinois), or deciduous (loses its leaves in the fall, or spring)? (Answer in a complete sentence.)

10. What tree do you think you have? What makes you think this? List logical reasons for your answer.

# Estimating the Age of a Tree

## ANSWER KEY

Using the tree cookie provided, answer the following questions.

1. How old was this tree when it was cut down? **number of rings** years old.

2. Assume the tree was cut down in 2006. What year did it begin to grow? **i.e. 2006-97 rings = 1909**

3. All of the rings are not the same distance from each other. Find two rings that are much farther apart than any other two. What could account for the larger space between the rings? **A good growing year with enough moisture and sunlight**

4. Find two rings that are much closer together than any other two. What could account for the smaller space between the rings? **Less growth could be caused by lack of moisture, sunlight, or excessive temperatures**

5. Pick a ring near the outside edge of the tree. Think of something that happened that year and record it here.
   Year: **1900** What happened that year? **the beginning of a new century**

6. Are there any scars on the bark of the tree? If so, what could have happened to the tree? **Fire, lightning, human causes, animal damage**

7. Can you identify any growing conditions that would have changed the sizes of the spaces between the rings? Remember, trees need sunlight, water and space to grow well. **Other trees growing and got in the way, buildings, roots don't have enough room due to other plants**

8. Is the tree cookie completely round? If not, why? **Roots don't have enough room, tree was damaged**

9. Is the tree an evergreen (keeps its needles throughout the year in Illinois), or deciduous (loses its leaves in the fall, or spring)? (Answer in a complete sentence.)
   **Answers vary, according to cookie each group of students has.**

10. What tree do you think you have? What makes you think this? List logical reasons for your answer.
    **Type of bark, sap present, hardness of wood, insect damage**