# *Biology in a Box*

**A science education outreach program brought to you by a partnership between The University of Tennessee and the National Institute for Mathematical and Biological Synthesis**

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UNIT 9 - FORESTRY

# Homepage

**Click on underlined text to  information and exercises!**



**Clicking the icon on other slides will bring you back to this page!**

# Materials

**Exercise 1**

Tree Parts poster
Trunk Parts poster
Set of “Missing Parts” cards
Tree trunk puzzle
Tape measure
Tree cookie wedges from 2 species
Laminated leaves (labeled A-N)
Sealed containers with seed cases (labeled 1-14)

**Exercise 2**

12 wood chips labeled with species
12 mystery wood chips (labeled A-L)
Wood density cubes (3 species)
6” ruler
Kitchen scale or spring scale
Magnifying glass
Wood porosity samples (2)
Magnifying glass

**Exercise 3**

Container of wood products
Set of “Wood Products” cards

**Exercise 4**

Forest habitat poster
15 Critter cards
15 Habitat cards

**Exercise 5**

Succession game board
Deck of 27 “External Forces” cards
Container of paper clips

**Exercise 6**

Sample of damage by Southern Pine Beetle (*Dendroctonus frontalis*)
Game board depicting monotypic stand
Game board depicting mixed stand
Blank game board

# Introduction

- **Forestry** is the science and practice of studying and managing forests and their natural resources.
- **Wood is among Tennessee's top five agricultural crops**
  - **Tennessee produces more hardwood flooring and pencils than any other state.**
  - **Tennessee is the second largest producer of hardwood lumber.**
- **Thus, we need to keep our forests healthy and replace trees that are removed to make forest products. This is called forest regeneration.**
- **To keep our forests healthy, we must understand the biology of trees and the ecology of forest systems.**

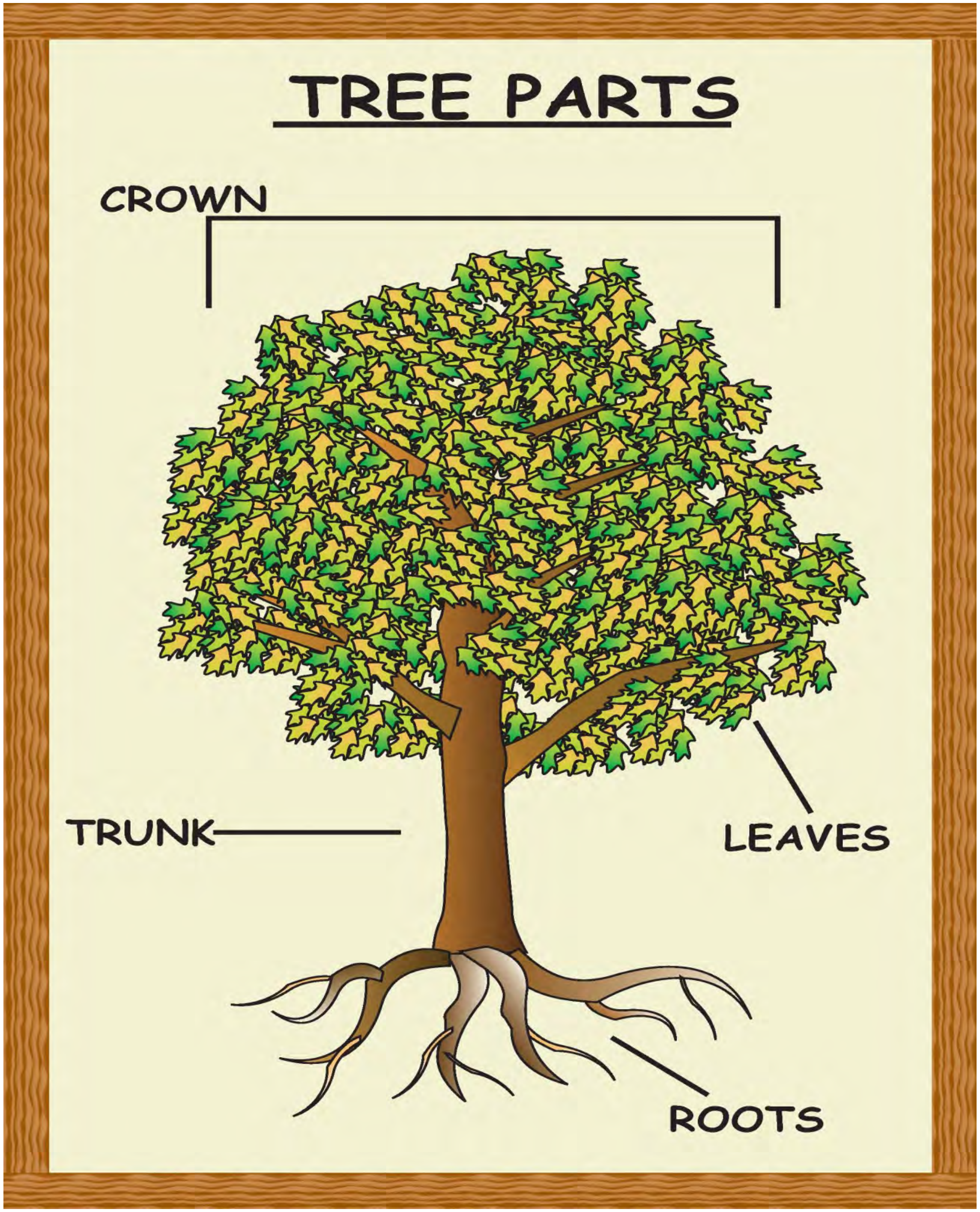
# Exercise 1. Dendrology: The Study of Trees

- What do trees need to grow?
- They need sunlight, water, and minerals that are contained in soil and ground water.
- Different parts of the tree help in providing for its growth.
  - Roots act as an anchor in the soil, and also collect minerals and water from the soil.
  - Leaves undergo photosynthesis, using energy from sunlight to turn water and carbon dioxide into food for the tree.
    - This food is used for growth and the production of seeds.
    - As part of the process of photosynthesis, the leaves release oxygen into the air.
    - The oxygen released into the environment supports the great diversity of animals on earth today.
  - The trunk of the tree is helps get the leaves above obstacles so they can absorb the sun's rays.

**Trees have three main sections:**

- **the crown**
- **the trunk**
- **the roots**

- **Each is made up of smaller parts that all serve important functions.**
- **You will learn more about each of these parts in the following exercises.**



# Exercise 1. Dendrology: The Study of Trees

- **Click one of the underlined exercise names below to go to that exercise.**

- **In <u>Exercise 1a. Tree Trunks</u>, students will examine tree trunks, including their parts and functions.**

- **In <u>Exercise 1b. Forest Measurements</u>, students will learn about the types of measurements that forests actually use in the field.**

- **In <u>Exercise 1c. Leaves & Seed Cases</u>, students will learn about the important structures of trees involved in making the food and reproduction.**

# Exercise 1a. Tree Trunks

- **Click one of the underlined exercise names below to go to that exercise.**

- **In Exercise 1a.1. Parts of a Tree Trunk, students in grades K-12 will learn about the parts of a tree trunk, and their functions.**

- **In Exercise 1a.2. Trunks Tell Tales: Tree Rings and Tree Cookies, students in grades 3-12 will learn about dendrochronology, or the study of the history recorded within a tree!**

- **Click the button to the right to go back to the main menu for Exercise 1.**

# Exercise 1a.1. Parts of a Tree Trunk

- A tree's trunk supports its crown of leaves and serves as a plumbing system, carrying water and minerals up from the roots and food (sugars) down from the leaves where they are needed.

- The tissues that carry water and food in a tree are important, and have special names:
  - xylem – carries water
  - phloem – carries food

- In addition to these two types of important tissue, a tree's trunk is composed of various layers, which have also been given special names.

# Exercise 1a.1 Parts of a tree trunk

- **Moving from the outside of a tree towards its center, the main layers of a tree trunk are as follows:**
  - **Bark - composed of two main layers**
    - **Outer bark – formed from dead phloem cells**
    - **Inner bark – formed from live phloem cells**

**FUN FACT:** The cork oak (*Quercus suber*, which is native to southwest Europe and northwest Africa) has bark so thick and spongy it can be peeled off in one thick layer without killing the tree. This bark is used to make the corks that seal bottles, as well as bulletin boards, sandals, and other products.

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# Exercise 1a.1 Parts of a tree trunk

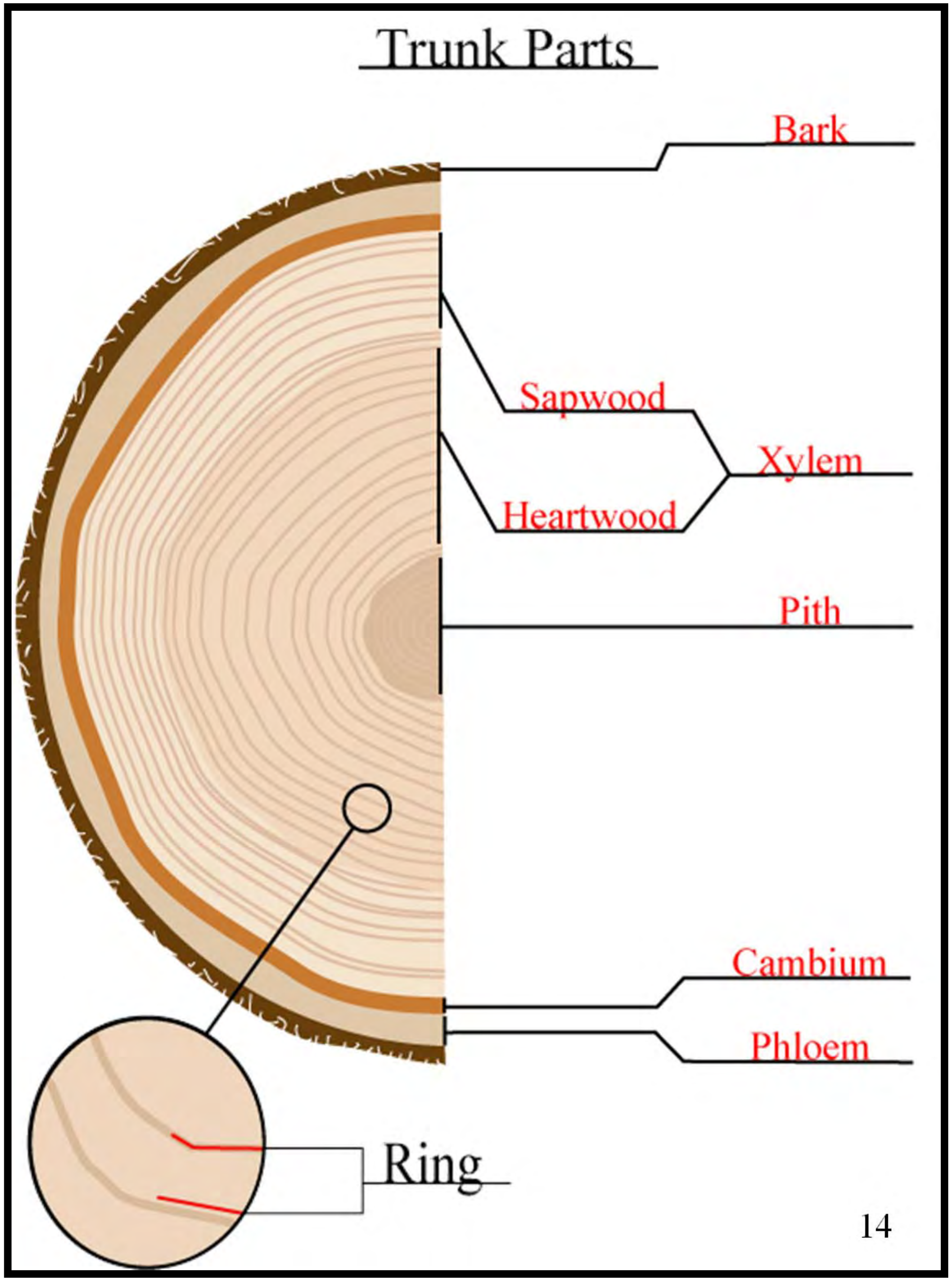
- **Continuing to move inwards from the bark of a tree towards its center, the main layers of a tree trunk are as follows:**
  - **Cambium – produces new bark to the outside, and new sapwood to the inside**
  - **Wood - composed of two main layers**
    - **Sapwood – living xylem that transports water through the tree; usually lighter in color**
    - **Heartwood – dead xylem that provides structural support to the tree; usually darker in color**
  - **Pith – central core of the trunk; stores sugars & wastes**
    - In older trees the pith is crushed by the xylem's woody tissue, and wastes are deposited in heartwood cells near the center of the trunk.

# Directions

- Lay out the pieces of the "trunk puzzle"on a table at the front of the room.
- Select a student to find the pith and place it in the center of the table.
- Select another student to locate the heartwood puzzle piece and insert this piece next to the central pith.
- Continue until all components of the tree trunk are in their proper position
- Check your finished puzzle against the figure of a tree cookie (cross-section) on the next slide
- Have a short discussion trying to recall what job each part performs for the tree.

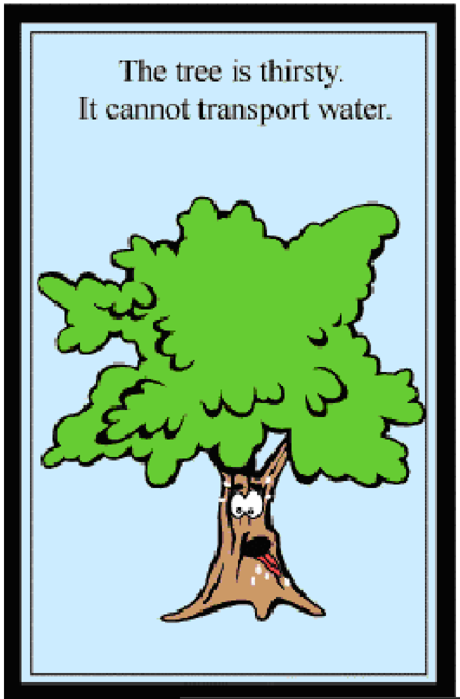
**Fig. 1. Cross section of a tree trunk or half of a ‘tree cookie’ showing parts described on previous slide.**

**Continue on to the “Missing Parts” game:**



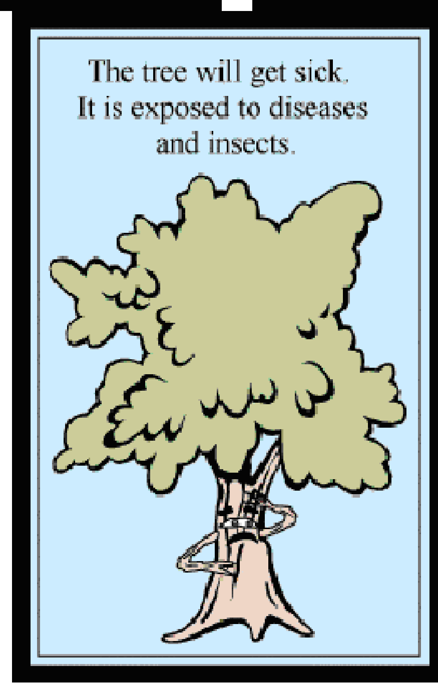
# Missing Parts Game

- **After you have learned the function of each part, test your memory by completing the Missing Parts Game**
- **Read the question on the following slides**
- **The first student to raise their hand gets to select the picture or pictures that answers each question.**
- **Answers follow the question slides.**





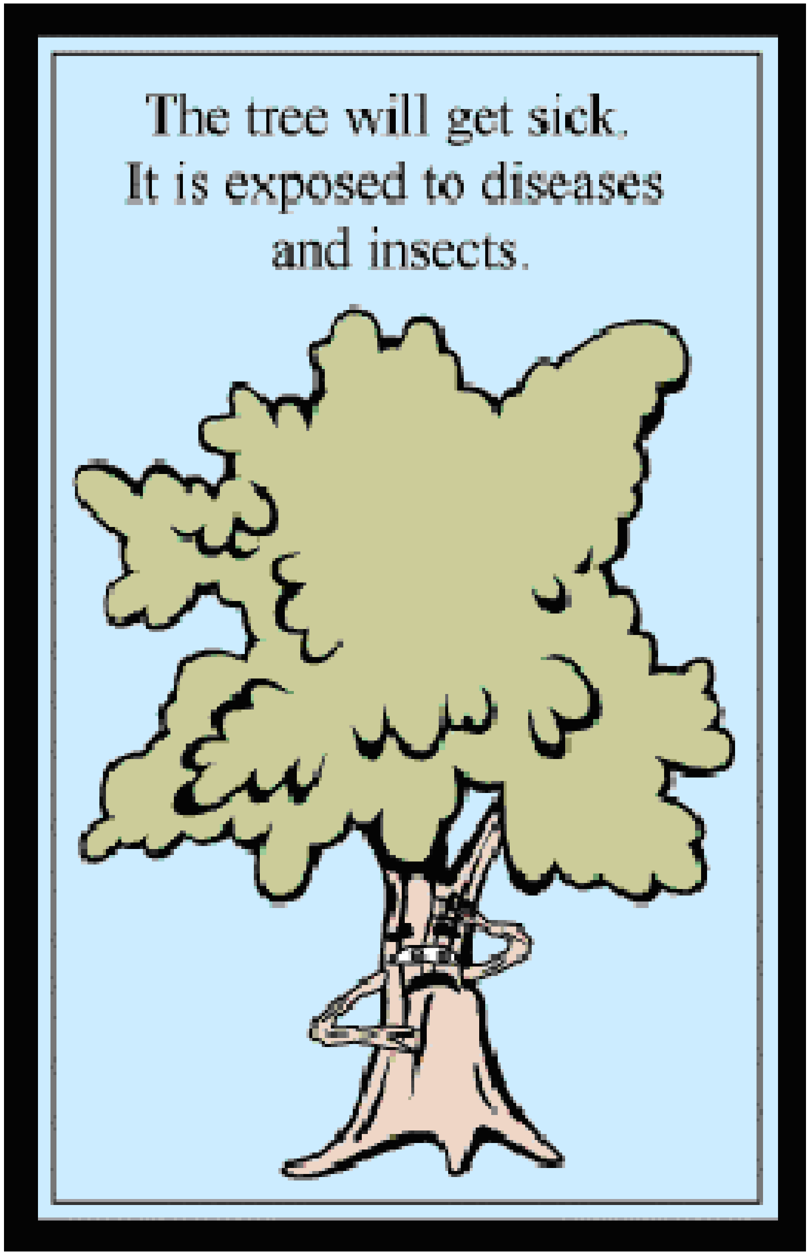


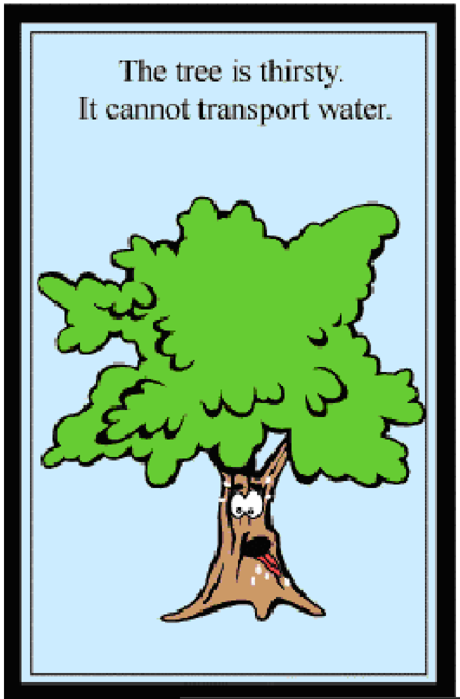



**What would happen to a tree if it lost its bark?**

**Time to check your answer!**

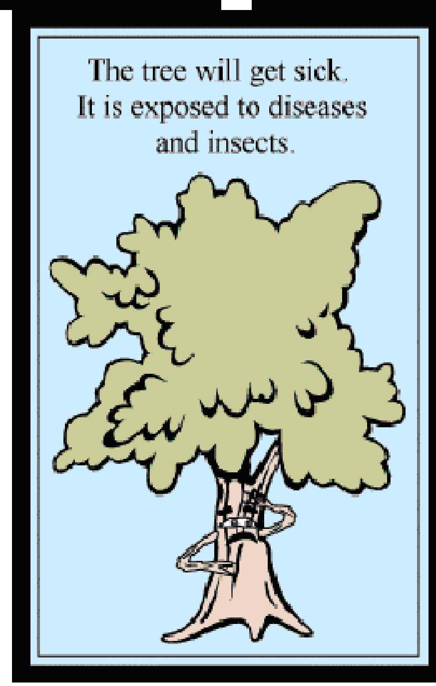
## If it loses its bark,







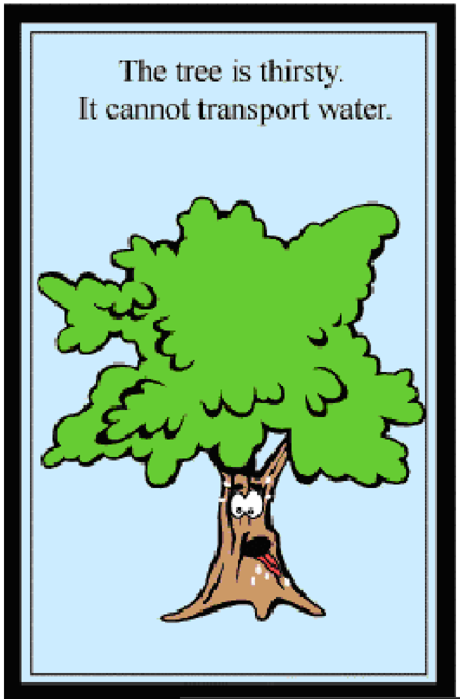





**What would happen to a tree if the phloem cells stopped working?**

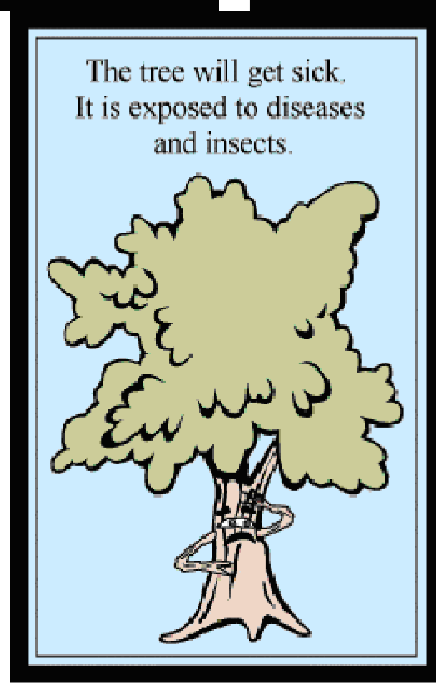
Time to check your answer!

# If the phloem cells stopped working,





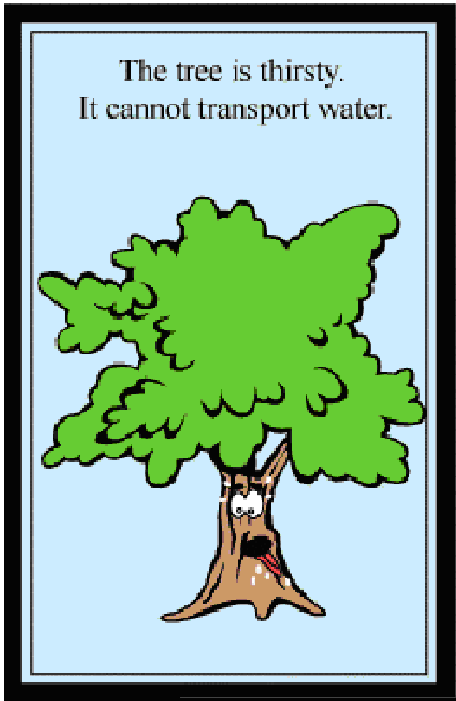





**What would happen to a tree if the heartwood rotted away?**

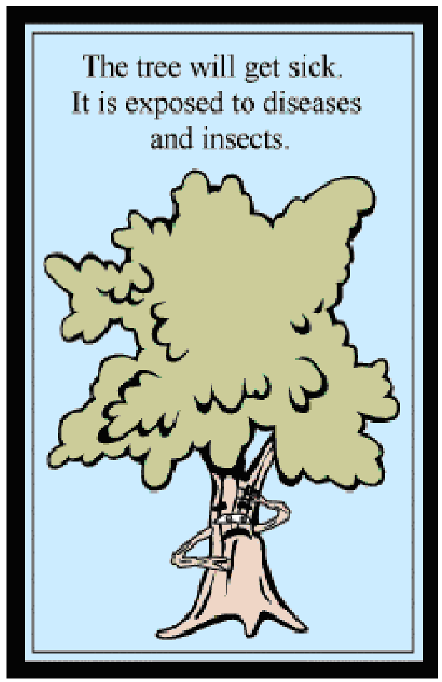
**Time to Check Your Answer!**

## If the heartwood rotted away,





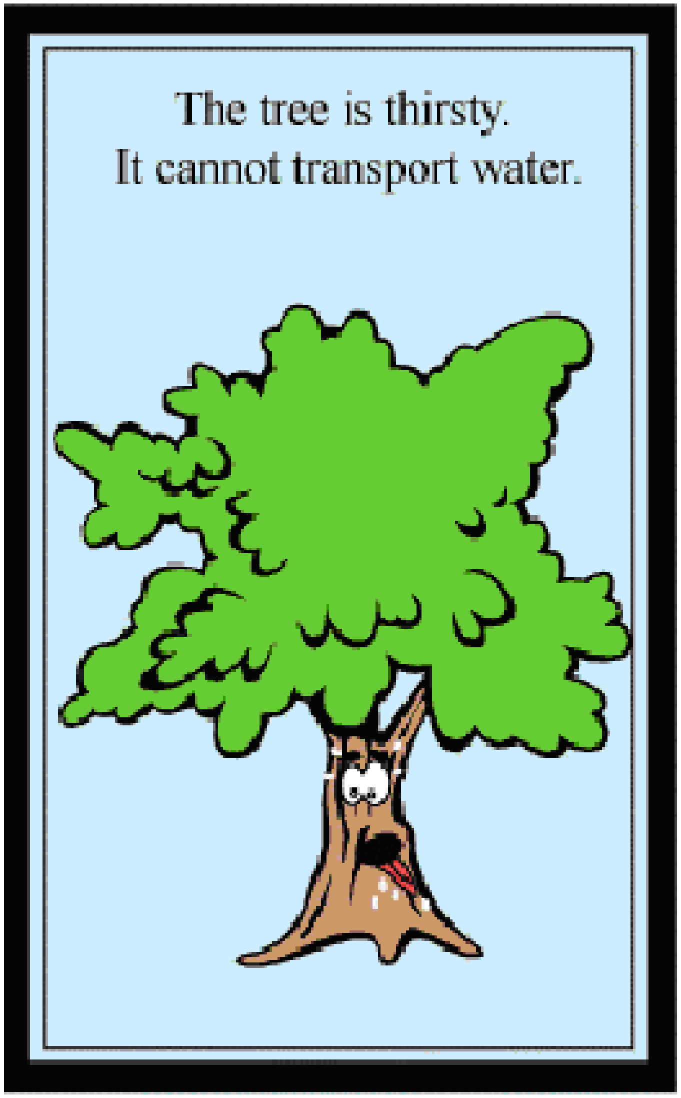


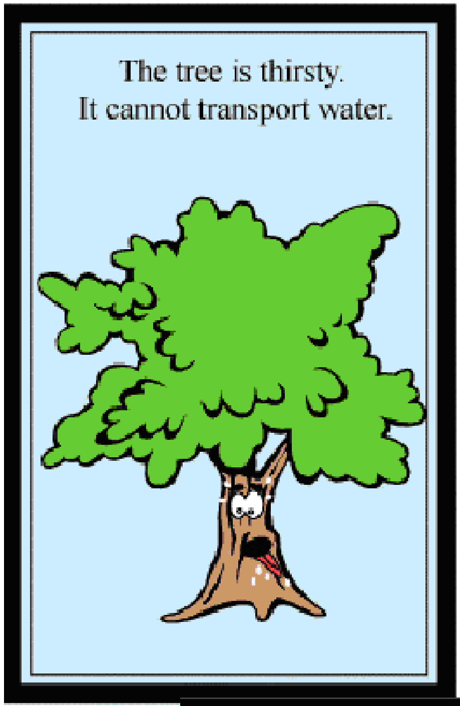


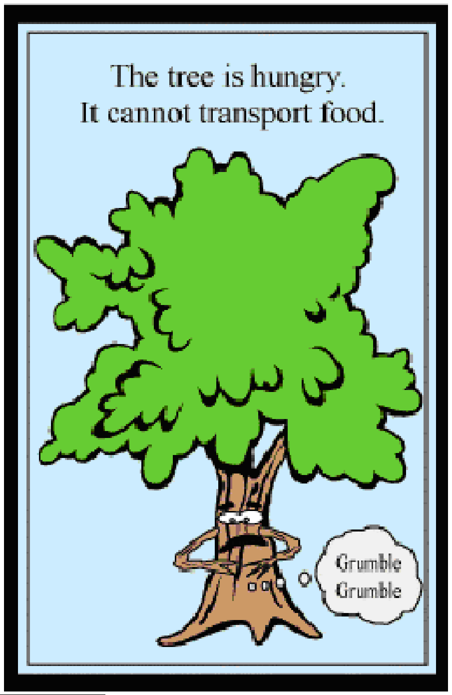

**What would happen to a tree if the sapwood vessels stopped working?**

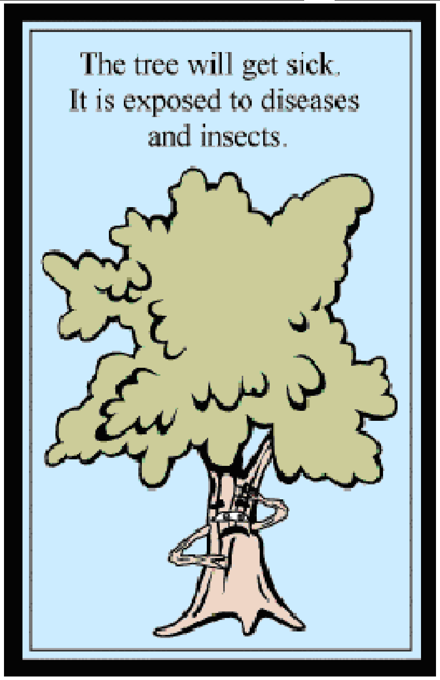
**Time to Check Your Answer!**

## If the sapwood vessels stopped working,





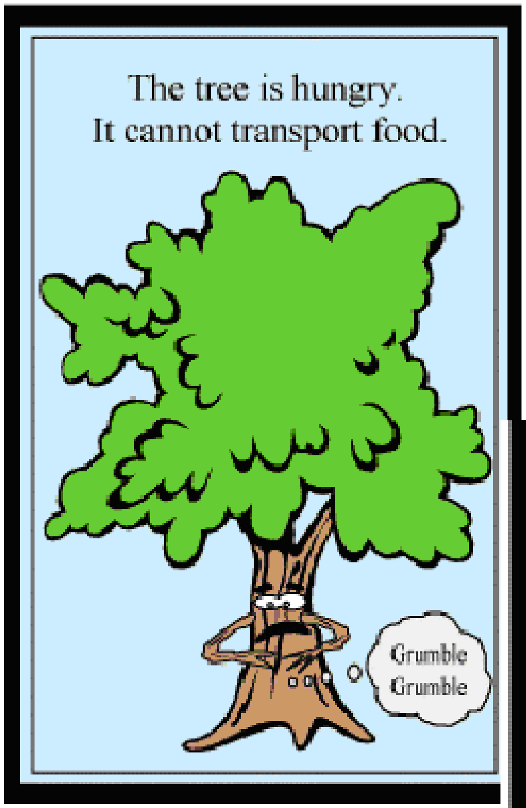


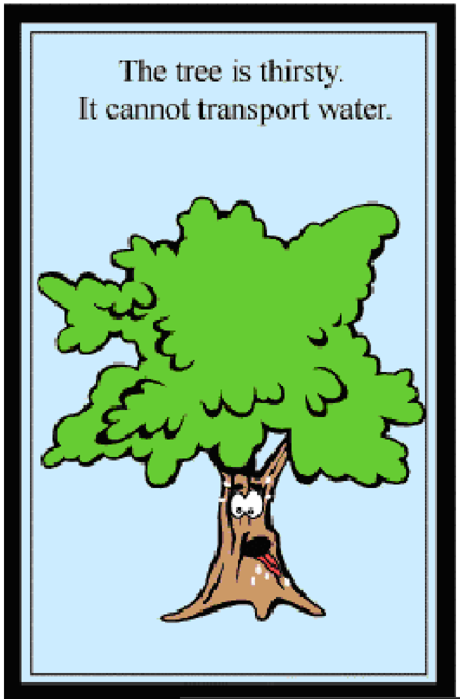



**What would happen to a tree if it lost all of its leaves in the spring?**

**Time to Check Your Answer!**

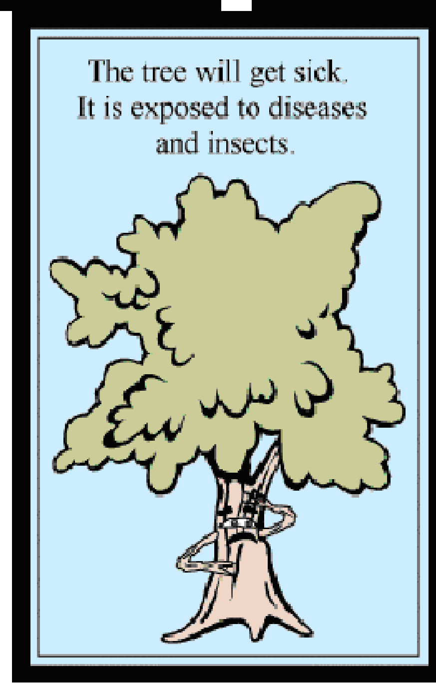
## If it lost all of its leaves in the spring,





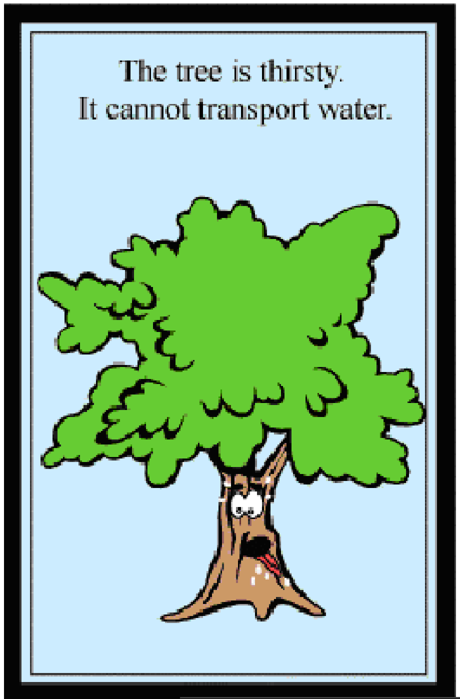





**What would happen to a tree if its cambium layer were missing?**

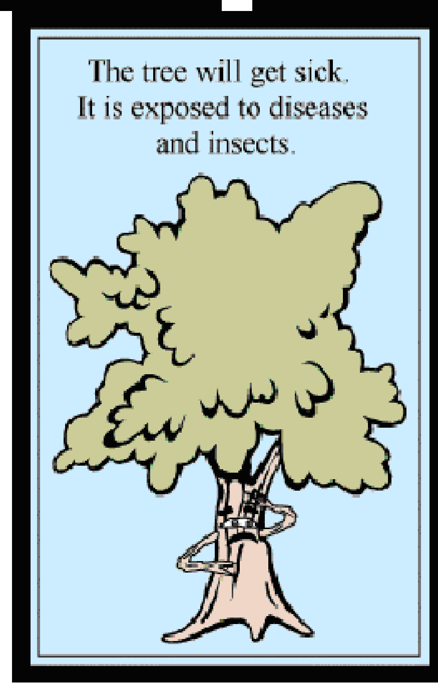
**Time to Check Your Answer!**

## If its cambium layer were missing,





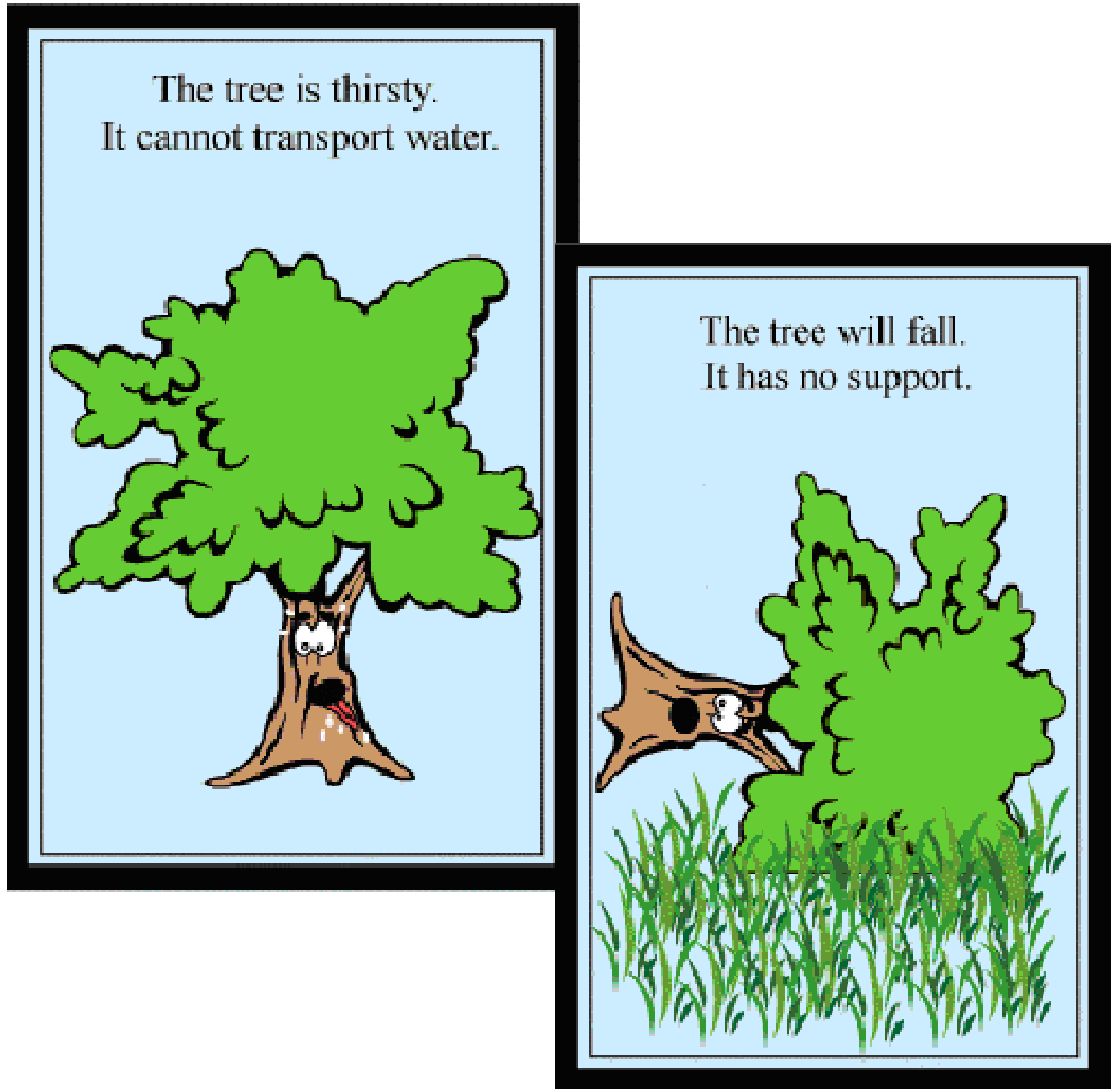





**What would happen to a tree if its roots were cut and carried away?**

**Time to Check Your Answer!**

## If its roots were cut and carried away,



# Exercise 1a.2. Tree rings and tree cookies

- **Often you can tell a lot about a tree's history by looking at a slice or cross section of its trunk.**
- **As the tree grows, it lays down two tissue layers.**
  - **The early wood forms during the wet spring season, which is when the tree grows most rapidly.**
  - **In the drier period from summer to winter, the late wood forms.**
- **In the winter the tree stops growing and becomes dormant, or inactive.**
- **As a result, the colors and density of these two layers are different from each other and the wood of the tree develops what look like rings.**
  - **Early wood occurs in wider rings (more/faster growth), and is usually lighter in color.**
  - **Late wood is represented by thinner, darker rings.**
  - **Each pair of early wood and late wood rings represents 1 full year of growth!**

# Exercise 1a.2. Tree rings and tree cookies

**We can learn a lot about a tree's history by looking at its growth rings and tree cookie/cross-section:**

- **A wide ring means that the tree grew a lot during a given season: fast growth**
- **A narrow ring means that it did not grow much: slow growth.**
- **A curled/wavy ring means the tree was injured by something during that time period.**
  - **Perhaps it was struck by lightning or hit by a car**
- **Holes in the tree cookie show that insects bored into the tree at some point.**
- **Charcoal on the tree cookie is a sign that a fire burned through the area where it was growing.**
- **Knots on the tree cookie indicate presence of branches.**

**How old is the tree represented in the picture to the left? Also, do you note anything in the tree rings that can tell you something about events in the tree's history?**

# Click for the answers!

**The tree from which the tree cookie at left was taken was about 13 years old.**

**The knot in the lower part of the cookie is where a branch grew.**

**The outer and inner bark, as well as the outer year of wood growth also appears to have some insect damage.**

## Exercise 1a.2. Tree rings and tree cookies

**Often, exciting things can be learned from tree rings:**

- **For example, in examining tree ring patterns in Virginia, scientists found that there was a severe drought from 1587 to 1589.**
- **This explained the mysterious disappearance of people from what has been called the ‘Lost Colony’.**
- **Scientists suggest that this severe drought caused the death of the people of this colony.**
- **The tree rings became a record of history!**

# Directions

- Look at the wedges of the two tree cookies supplied for you.  Each should be labeled with its species, and the year that it fell (and thus stopped growing!)
- The goal is to determine the age at death (felling) of the two trees.
- Divide the class into groups of two students, where:
  - one counts the rings
  - the second places a finger on the previous ring counted to keep their place as the count proceeds.
- The groups can rotate their visits to the tree cookies as the rest of the class is engaged in some other assignment.
- NOTE: Each group should decide whether they will count just the dark-colored rings or just the light-colored rings.  (Remember, one pair of rings = 1 year!)
- NOTE:  Do not count the pith or the bark in determining a tree’s age through a ring count.

# Directions

**Now try to answer the following questions:**

1. **How old were each of the trees when they fell?**
2. **Which tree was older?**
3. **In which years each tree grow the most? What do you think the environmental conditions were that year?**
4. **When did the trees have slow growth? What could have happened in those years to keep the trees from growing?**
5. **Does either of the trees show wounds like holes or knots? What could cause these?**
6. **Were there any major event that happened in the trees' lives during the year of your birth?**

# Exercise 1b. Forest Measurements

- **Foresters regularly need to measure the trees they manage**
  - to know how well they are growing,
  - what they might need to grow at a faster rate,
  - which ones should be harvested (cut for use or to make more room for other trees).

- **The measurements the forester makes include such things as**
  - trunk diameter
  - tree height
  - crown size
  - general tree health as indicated, for instance, by leaf color.

# Exercise 1b. Forest Measurements

- Click one of the underlined exercise names below to go to that exercise.

- In Exercise 1b.1. Measuring Trees, students in grades 3-12 will learn how foresters take basic measurements of trees.

- In Exercise 1b.2. Measuring and Comparing Forests, students in grades 5-12 will learn how foresters compare different forests.

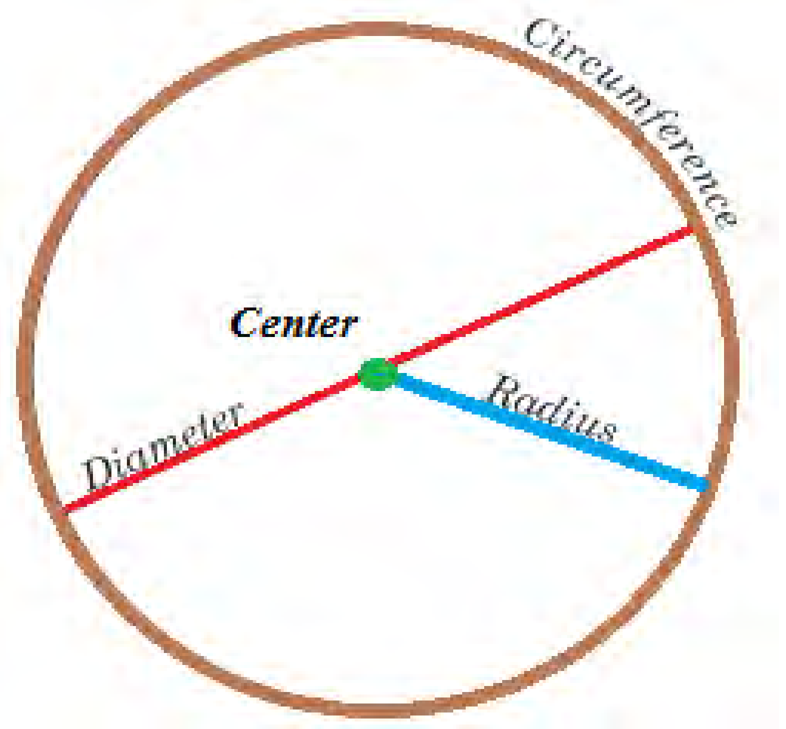
- In Exercise 1b.3. Using Histograms, students in grades 5-12 will learn how to use histograms to visualize data.

- In Exercise 1b.4. From Trees to Houses, students in grades 5-12 will learn about how math and forestry are directly related, using the building of a home as an example.

- Exercise 1b.5. Foresters for a Day, is an open-ended exploration for students in grades 3-12.

# Exercise 1b.1. Measuring Trees

- Since trees' trunks are circular, foresters need to know a little bit about circles when measuring trees.
- For example, foresters need to know about the relationships between a trunk's
  - **diameter** – the length of a line passing from one edge of the trunk to the other through its center
  - **radius** – the distance from the center of the trunk to one edge (equal to half the diameter)
  - **circumference** – the distance around the trunk



# Exercise 1b.1. Measuring Trees

- Divide into teams of two to three students.
- Look around your classroom and find several circular objects of which you might measure the circumference using the tape measure your teacher provides to each team. Some examples could include jar lids, cups, circular manipulatives, a clock on the wall, etc.
- Each team should measure these items and record the values they obtain in a table that resembles the one shown below. You should measure your objects to the nearest *millimeter* (mm). It is important to be as careful as possible so that you get an accurate measurement. Measure to the nearest millimeter and record that length in the column labeled "*Circumference (C)*" in the table.

| **Item Measured** | **Circumference in mm (C)** | **Diameter in mm (D)** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

# Exercise 1b.1. Measuring Trees

- Compare the circumference values between groups for each object the class chooses to measure. Did every group get the same circumference value?
- Discuss why variable results might have been obtained.
- In order to account somewhat for inter-observer differences, scientists often have more than one person take the same measurement. They compute a **mean** or *average value* of these measurements. The mean value refers to central tendency. The formula for calculating the mean for the circumference of any object your teams might have measured is:

$$\boldsymbol{C_{mean} = \frac{\sum x}{n}}$$

- In the previous equation, **S** indicates a sum, ***x*** = each of the measurements teams 1, 2, 3… have taken for that object, and ***n*** = the total number of measurements made (3 teams measured the circumference of item ***x*** in this example).

# Exercise 1b.1. Measuring Trees

- If the three measurements of circumference of a clock were 19.5, 19.8 and 20.1cm respectively, $C_{mean} = (19.5 + 19.8 + 20.1)/3$ or $C_{mean} = 19.8$ cm for that clock.
- Compute the mean of your measurements for some of the circular objects in your room that more than one team has measured.

- For an exercise on discovering pi, click **HERE**.
- Otherwise, click **HERE** to move on.

# Exercise 1b.1. Measuring Trees

- **Trunk diameter is one measure of tree size.**
- **Since tree trunks are circular, diameter is the length of a line that passes from one side of the tree through the center of the tree to the other side.**
- **It would be time-consuming and destructive to the tree to drill a hole through its trunk to measure this.**
- Luckily, there is a relationship between diameter and circumference that turns out to be very useful for us.
- Use the table you already constructed, and add some additional columns as shown below:

| Item Measured | Circumference in cm (C) | Diameter in cm (D) | C + D | C – D | C × D | C ÷ D |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

# Exercise 1b.1. Measuring Trees

- Use the numbers you have recorded in the columns representing the circumference (C) and the diameter (D) of the items you measured to find the ***sum*** (+), ***difference*** (-), ***product*** (×), and ***quotient*** (÷) of those numbers.
- Record your answers in the appropriate columns.
- Compare the answers in each *column*.
- In what ways are they different? Are they similar in any way? Discuss these differences and similarities with your classmates.
- Your teacher will collect all the measurement data for the class and list each of the four calculation column findings for the collection of items.
- Do you see any patterns in any of the columns (sum, difference, product, or quotient)?
- Describe and discuss any patterns you discover.

# Exercise 1b.1. Measuring Trees

- If your data have been collected properly, you should notice that the list of quotients of the circumferences divided by the diameters ($C \div D$) of the items produces a consistent outcome.
- Every one of the quotients will have resulted in a number very close to 3.14, which is the number used to represent ***pi*** or the Greek letter **$\pi$**.
- The quotient of the circumference of every circle divided by its diameter results in *pi* ($\pi$), or the number 3.141592653589793...
- Since this value is a non-repeating, non-terminating decimal number (or ***irrational*** number), we often just use $\pi \approx 3.14$ ($\approx$ means *approximately*) when we need to use the value of *pi* in our work or activities.
- This relationship is true for every circle no matter if it is very small or very large.
- By completing this activity, you have *discovered* **$\pi$**!

# Exercise 1b.1. Measuring Trees

- For all perfect circles, the relationship between circumference and diameter can be written as follows:

$$C = \pi D$$

- The same equation may be written another way:

$$D = C/\pi$$

- In these equations, $C$ = Circumference, $\pi \approx 3.14$, and $D$ = Diameter.
- You may be familiar with a more common representation of the equation, $C=2\pi R$, where $R$ is the **radius** of the circle.
- The radius is the distance from the exact center of the circle to any edge, or half of the diameter ($D=2R$).

# Exercise 1b.1. Measuring Trees

**Trunk diameter is one measure of tree size.**

- **Since tree trunks are circular, diameter is the length of a line that passes from one side of the tree through the center of the tree to the other side.**

- **It would be time-consuming and destructive to the tree to drill a hole through its trunk to measure this.**

- **Instead, foresters use a relationship that is known for circles: the diameter of a circle is equal to its circumference (distance around the outer edge) divided by a constant conversion factor $\pi$(pi, pronounced "pie"), which is approximately equal to 3.14.**

$$D = C/\pi$$

# Exercise 1b.1. Measuring Trees

- To find the diameter of a tree trunk, foresters use a special kind of measuring tape called a DBH tape, or Diameter at Breast Height tape.
- "Diameter at Breast Height" is the average height at mid-chest on an adult man, and is taken to be 4.5 feet from the ground.
- This method provides a shortcut to using the previous equation as a DBH tape is calibrated to directly measure the diameter of the tree trunk by placing the tape around the trunk's circumference and reading the value where the tape meets.
- If you were trying to measure anything other than a circle's diameter (by wrapping the tape around its circumference) with a DBH tape, your answer would be wrong!
- Even if you don't have a DBH tape you can still find the diameter using the earlier equation:

$$D = C/\pi$$

# Exercise 1b.1. Measuring Trees

- Given each of the following, use a calculator to find the missing measurements.

  a. D = 2.5, C = ?
  b. D = 6, C = ?
  c. C = 9, D = ?
  d. C = 0.32, D = ?
  e. R = 3, D = ?
  f. D = 8, R = ?
  g. R = 5, C = ?

- Click to go to the next slide to check your answers!

# Exercise 1b.1. Measuring Trees

- **Below are the answers you should have obtained to the previous questions (with non-integer answers rounded to one decimal place):**

  a. D = 2.5, C = 7.9
  b. D = 6, C = 18.8
  c. C = 9, D = 2.9
  d. C = 0.32, D = 0.1
  e. R = 3, D = 6.0
  f. D = 8, R = 4.0
  g. R = 5, C = 31.4

# Exercise 1b.1. Measuring Trees

- Take the class outside to the school yard to measure the circumference of a number of trees.
- Divide the class into groups of two students and one student or the teacher can serve as scribe.
- Each group will find a tree in the schoolyard and use the cloth tape measure included in the box to obtain the circumference of a tree trunk.
- Stretch the tape around the tree and read the number of inches where the two parts meet. This is the tree's circumference.
- The unit of measurement is inches.
- While most scientists use the metric system (centimeters and meters), foresters use inches and feet (English units), Perhaps this is because they work so closely with the logging industry, which uses English units.

# Exercise 1b.1. Measuring Trees

- **Working in teams of two, with one person measuring, and one person recording the data, find a tree in your schoolyard and use the provided tape measure to find the circumference of the trunk. Write this number down.**
- **Continue on to the next tree and a new measuring team.**
- **Back in the classroom, the list of tree circumferences will be put on the board, so that each student can copy them and use the equation presented earlier to obtain tree diameter from the measurement of its circumference.**
- **Back in the classroom, the list of tree circumferences will be put on the board, so that each student can copy them and use the equation presented earlier to obtain tree diameter from the measurement of its circumference.**

# Exercise 1b.1. Measuring Trees

- Since you have measured a number of trees in your school yard, you might want to summarize your 'tree lot' as to the mean or average size of tree present.
- Use the following equation to do this:

*Mean tree diameter = Sum (Diameter)/N*

- Where *N* = the number of trees measured.
- Using the equation presented earlier (and below to remind you), calculate the diameter of each tree's trunk.

$$D = C/\pi$$

  - Although you measured your trees in English units, just like foresters regularly do, it is still important to know how to convert these to metric units.
  - Since other scientists that study trees in other countries may use metric units, knowing how to convert data from one system of units to another is important to better understand the data.

**HINT: 1 inch = 2.54 cm**

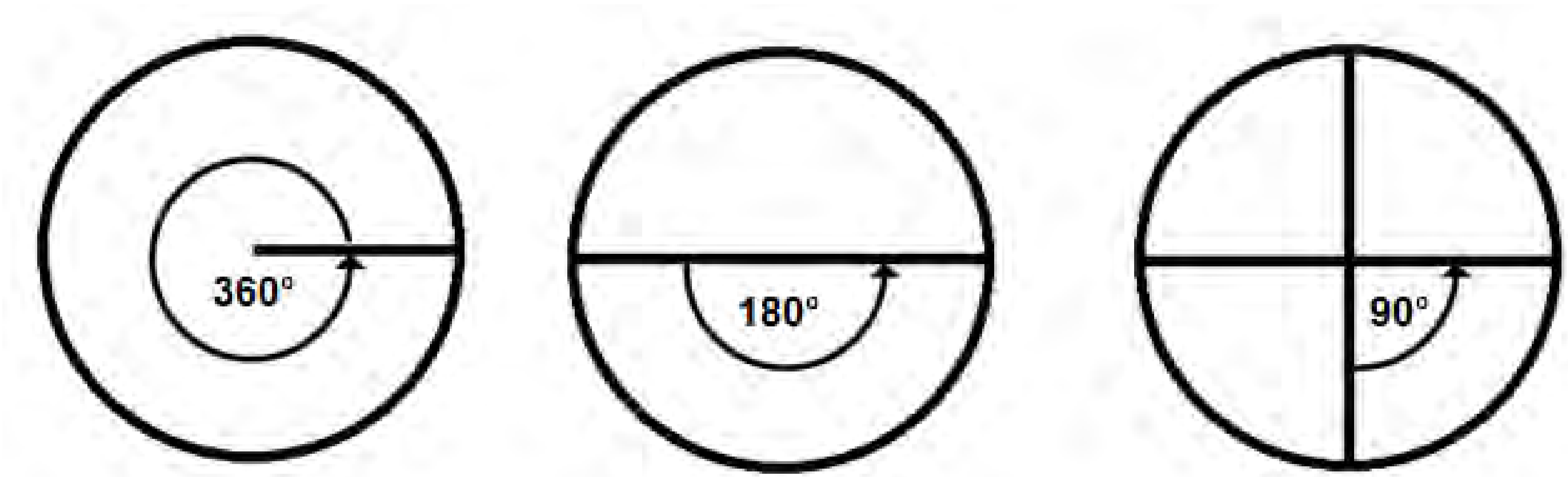
- Now convert all your measurements to metric units.

# Exercise 1b.1. Measuring Trees

- If you don't have trees you can measure in your schoolyard, examine the tree cookies or tree cookie wedges provided.
- Measure either the circumference or the diameter of the tree cookies provided in this unit. If you measure diameter, use calculate the circumference. If you measure the circumference, calculate the diameter.
- You may only have a wedge of a tree cookie, making measurement of the entire circumference or diameter impossible.
- However, you should still be able to measure the radius of the tree cookie.
- You can estimate how large the circumference of the tree cookie would be if it were an entire cross section by figuring out what **proportion** of an entire circle that your tree cookie represents.
- How can you determine what proportion of an entire circle your tree cookie (if not an entire cross section) represents?

# Exercise 1b.1. Measuring Trees

- One way to do this is to think about another property of circles.
- All perfect circles consist of 360 degrees.
- A half-circle, then, consists of 180 degrees.
- In other words, the straight edge of a half circle forms an angle of 180 degrees (a straight line)
- A quarter circle (one fourth of a circle) has two straight edges that form a 90 degree angle. See the image below for an illustration:



# Exercise 1b.1. Measuring Trees

- By measuring the angle formed by the straight edges of your portion of a tree cookie, you can determine what **fraction** of a circle your tree cookie piece represents, and thus also what fraction of the circumference the curved edge of your tree cookie represents by using the equation below:

$$\frac{(Angle\ formed\ by\ cut\ edges)^{\circ}}{360^{\circ}} = \frac{Distance\ around\ curved\ edge}{Circumference}$$

- You can then solve for an estimate of what the circumference of the entire tree cookie would be by dividing both sides by the number of degrees formed by the tree cookie portion's straight edges:

$$Estimated\ Circumference = \frac{Distance\ around\ curved\ edge \times 360^{\circ}}{(Angle\ formed\ by\ cut\ edges)^{\circ}}$$

# Exercise 1b.1. Measuring Trees

- If you have a full tree cookie, take actual measurements of the diameter and circumference of it, and compare these values to your calculated value.
- If you only have a portion (wedge) of a tree cookie, calculate the circumference from your measured diameter (or radius), and compare this value to the "*Estimated Circumference*" value, as calculated on the previous slide.
- Discuss the following questions with your classmates.
- Were your actual measured values of diameter and/or circumference of your tree cookies close to your calculated values?
- If there was a fairly substantial difference between the calculated and measured values, why do you think this might be the case?

# Exercise 1b.1. Measuring Trees

- Now answer the following questions:

- Would it be practical to measure tree diameters in meters? Why or why not?

CLICK FOR THE ANSWER!

It would be pretty impractical to measure tree diameters in meters. Unless a tree was very large, it would not likely have a diameter that is even one meter.

- Would it be practical to measure tree heights in centimeters? Why or why not?

CLICK FOR THE ANSWER!

It would not be practical to measure tree heights in centimeters, either. Unless a tree is a small sapling, it would be likely be very many centimeters tall. It would just be simpler to report tree heights in meters.

# Exercise 1b.2. Measuring & Comparing Forests

- **Even though foresters measure lots of individual trees, one reason that they do so is to compare different forests stands.**
- **Forests may be very different from one to the next, so being able to describe these differences with numbers is important.**
- **One reason is because it is of interest to know the amount (and value) of the wood in a particular forest stand.**
- **A few measures that foresters often use to compare stands are:**
  - **Stand density – the number of trees per unit area**
  - **Basal area – the total amount of area contained in the cross sections of the tree trunks in a stand**
  - **Volume – total amount of wood present in a stand**

# Exercise 1b.2. Measuring & Comparing Forests

- Again, stand density is the number of trees per unit area.
- Stand density is important because trees that grow closely packed tend to grow more slowly, because of more intense competition for light.
- If a stand is too dense, a forester might want to remove some of the smaller trees.
- To calculate stand density, all a forester needs to know is the number of trees in the stand, and the area of the stand.

**Stand density = # trees/area of stand**

- Foresters usually measure stand areas in acres.
  - 1 acre = 43,560 $ft^2$
- A metric unit often used for large areas is the hectare.
  - 1 hectare = 10,000 $m^2$
- To help with converting between these, 1 meter = 3.28 ft.
- Answer the questions on the following slide.

# Exercise 1b.2. Measuring & Comparing Forests

- How many acres are in a hectare?

- A forest stand has an area of 2.35 hectares. What is this in acres, $ft^2$, and $m^2$?

- If a 1 acre plot is perfectly square, what is the length (in feet) of each side of the plot?

- If a 1 hectare plot is perfectly square, what is the length (in meters) of each side of the plot?

- Again, to help you figure these out, the following conversions might be handy:
  - 1 acre = 43,560 $ft^2$
  - 1 hectare = 10,000 $m^2$
  - 1 meter = 3.28 ft
- Go to the next slide to check your answers.

## Exercise 1b.2. Measuring & Comparing Forests

**How many acres are in a hectare?**

**1 hectare = 2.47 acres**

**A forest stand has an area of 2.35 hectares. What is this in acres, $ft^2$, and $m^2$?**

**2.35 hectares = 5.81 acres = 252,951.90 $ft^2$ = 23,500 $m^2$**

**If a 1 acre plot is perfectly square, what is the length (in feet) of each side of the plot?**

**208.71 feet on each side**

**If a 1 hectare plot is perfectly square, what is the length (in meters) of each side of the plot?**

**100 m on each side**

- **Now lets actually calculate some stand densities.**

## Exercise 1b.2. Measuring & Comparing Forests

- **Now lets actually calculate some stand densities.**
- **Two hypothetical forest stands are 0.025 acres in area each.**
  - **Stand A has a total of 12 trees.**
  - **Stand B has a total of 23 trees.**
- **What is the stand density of each stand?**
- **Calculate the stand density of each stand, and click to see the answers below.**

**Stand A density = 12 trees/0.025 acres = 480 trees/acre**
**Stand B density = 23 trees/0.025 acres = 920 trees/acre**

# Exercise 1b.2. Measuring & Comparing Forests

- The basal area of a stand is equal to the sum of the basal areas of all trees in the stand.
- Since tree trunks are circular, the basal area of a single tree is equal to the area of the circle formed by the cross section of the tree:

$$A = \pi R^2$$

- In the equation, A is the basal area of a tree, $\pi$ (pi) ≈ 3.14, and R is the radius (remember, this is half of the diameter, measured as DBH in trees), so we could write this as:

$$\text{Basal area of tree} = \pi(\text{DBH}/2)^2$$

- To get the basal area of a stand containing n trees, you would just calculate the basal area of each tree in the stand, and add them all up:

**Stand basal area =**

**Basal area of tree 1 + Basal area of tree 2 + … Basal area of tree n**

- Calculate the basal areas (in $in^2$) for each tree and the total basal areas of the stands on the following slide.

## Stand A

| DBH (in) | Height (ft) | Basal Area ($in^2$) |
|---|---|---|
| 45 | 35 | |
| 27 | 30 | |
| 37 | 37 | |
| 21 | 21 | |
| 14 | 14 | |
| 9 | 9 | |
| 26 | 26 | |
| 50 | 50 | |
| 36 | 36 | |
| 27 | 27 | |
| 26 | 26 | |
| 39 | 39 | |

## Stand B

| DBH (in) | Height (ft) | Basal Area ($in^2$) |
|---|---|---|
| 5 | 8 | |
| 11 | 16 | |
| 4 | 7 | |
| 8 | 14 | |
| 7 | 20 | |
| 9 | 14 | |
| 6 | 11 | |
| 8 | 22 | |
| 6 | 12 | |
| 2 | 10 | |
| 4 | 8 | |
| 4 | 14 | |
| 6 | 20 | |
| 3 | 15 | |
| 10 | 14 | |
| 5 | 16 | |
| 6 | 18 | |
| 1 | 10 | |
| 7 | 14 | |
| 9 | 19 | |
| 9 | 20 | |
| 6 | 7 | |
| 15 | 34 | |

**Go to the next slide to see if you calculated the basal area of each tree and the total basal area of each stand properly.**

**Stand A**

| DBH (in) | Height (ft) | Basal Area (in²) |
|---|---|---|
| 45 | 35 | 1590 |
| 27 | 30 | 573 |
| 37 | 37 | 1075 |
| 21 | 21 | 346 |
| 14 | 14 | 154 |
| 9 | 9 | 64 |
| 26 | 26 | 531 |
| 50 | 50 | 1963 |
| 36 | 36 | 1018 |
| 27 | 27 | 573 |
| 26 | 26 | 531 |
| 39 | 39 | 1195 |

**Stand B**

| DBH (in) | Height (ft) | Basal Area (in²) |
|---|---|---|
| 5 | 8 | 20 |
| 11 | 16 | 95 |
| 4 | 7 | 13 |
| 8 | 14 | 50 |
| 7 | 20 | 38 |
| 9 | 14 | 64 |
| 6 | 11 | 28 |
| 8 | 22 | 50 |
| 6 | 12 | 28 |
| 2 | 10 | 3 |
| 4 | 8 | 13 |
| 4 | 14 | 13 |
| 6 | 20 | 28 |
| 3 | 15 | 7 |
| 10 | 14 | 79 |
| 5 | 16 | 20 |
| 6 | 18 | 28 |
| 1 | 10 | 1 |
| 7 | 14 | 38 |
| 9 | 19 | 64 |
| 9 | 20 | 64 |
| 6 | 7 | 28 |
| 15 | 34 | 177 |

# Did you get all of these correct?

# Exercise 1b.2. Measuring & Comparing Forests

- Now that you have calculated basal areas for all of the trees in each stand, it is easy to calculate the basal area for each stand.
- To do this, just add up all the basal areas of each tree in a stand. For example, the basal area (in $in^2$) for stand A would be equal to

$$(1590in^2 + 573in^2 + 1075in^2 + 346in^2 + 154in^2 + 64in^2 + 531in^2 + 1963in^2 + 1018in^2 + 573in^2 + 531in^2 + 1195in^2) = 9613\ in^2$$

- Since this is a large area, square feet, rather than square inches would be a better unit to use, but how do we convert this?
- Remember, 1 foot is equal to 12 inches. So, a square foot would have a total of 12 × 12 square inches. Therefore:

$$1\ ft^2 = 144\ in^2$$

- So, to get the stand's basal area in $ft^2$, simply divide by 144:

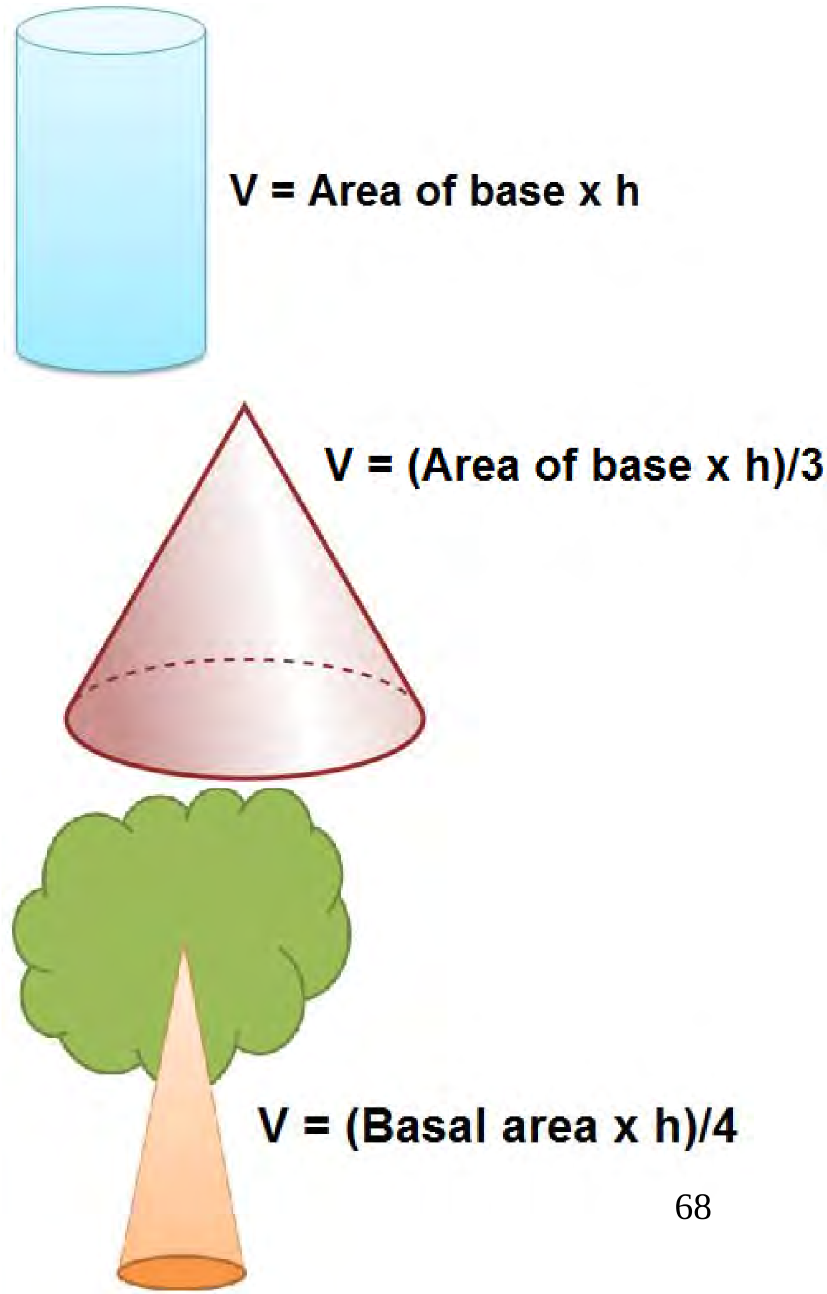
$$\text{Basal area of stand A} = 9613\ in^2/144 = 66.76\ ft^2$$

- Calculate the basal area of stand B. Click for the answer.

$$\text{Basal area of stand B} = 6.56\ ft^2$$

# Exercise 1b.2. Measuring & Comparing Forests

- One measure of interest to foresters is the total volume of wood available in a forest stand.
- This is simply calculated as the total volume of the trunks of all of the trees in the stand.
- You might think of trunks as cylinders.  There is a standard formula for volume of a cylinder (see figure at right).
- However trees taper from the base to the crown, so you might instead think of a cone.
- However, trees are less than perfectly conical.  Also, the bark of a tree is not used, so foresters use a volume formula that incorporates a correction factor:



# Exercise 1b.2. Measuring & Comparing Forests

- ❑ Now you should calculate the volume of the available wood in each of the example stands from earlier.
- ❑ However, when calculating volume, all of the units must agree. In other words, you CANNOT mix inches and feet.
- ❑ In calculating the volume of a tree, let's use cubic feet ($ft^3$) as our units.
- ❑ Luckily, height data for all of our trees are all in feet.
- ❑ However, we just calculated basal areas in square inches, so to find volume in cubic feet, we will need to have our basal areas in square feet.
- ❑ However, this is pretty easy. Remember:

$$1\ ft^2 = 144\ in^2$$

- ❑ Now extend your tables that you filled out earlier, adding extra columns for each stand. You should add a new column for each of the following to the table for each stand, and calculate these values for each tree:
  - ❑ Basal area ($ft^2$)
  - ❑ Volume ($ft^3$)
- ❑ Click to the next slide for the answers!

# Exercise 1b.2. Measuring & Comparing Forests

- Now you should calculate the volume of the available wood in each of the example stands from earlier.
- However, when calculating volume, all of the units must agree. In other words, you CANNOT mix inches and feet.
- In calculating the volume of a tree, let's use cubic feet ($ft^3$) as our units.
- Luckily, height data for all of our trees are all in feet.
- However, we just calculated basal areas in square inches, so to find volume in cubic feet, we will need to have our basal areas in square feet.
- However, this is pretty easy. Remember:

$$1\ ft^2 = 144\ in^2$$

- Now extend your tables that you filled out earlier, adding extra columns for each stand. You should add a new column for each of the following to the table for each stand, and calculate these values for each tree:
  - Basal area ($ft^2$)
  - Volume ($ft^3$)
- Click to the next slide for the answers!

## Stand A

| DBH (in) | Height (ft) | Basal Area ($in^2$) | Basal Area ($ft^2$) | Tree Volume ($ft^3$) |
|---|---|---|---|---|
| 45 | 35 | 1590 | 11.04 | 96.60 |
| 27 | 30 | 573 | 3.98 | 29.85 |
| 37 | 37 | 1075 | 7.47 | 69.10 |
| 21 | 21 | 346 | 2.40 | 12.60 |
| 14 | 14 | 154 | 1.07 | 3.75 |
| 9 | 9 | 64 | 0.44 | 0.99 |
| 26 | 26 | 531 | 3.69 | 23.99 |
| 50 | 50 | 1963 | 13.63 | 170.38 |
| 36 | 36 | 1018 | 7.07 | 63.63 |
| 27 | 27 | 573 | 3.98 | 26.87 |
| 26 | 26 | 531 | 3.69 | 23.99 |
| 39 | 39 | 1195 | 8.30 | 80.93 |

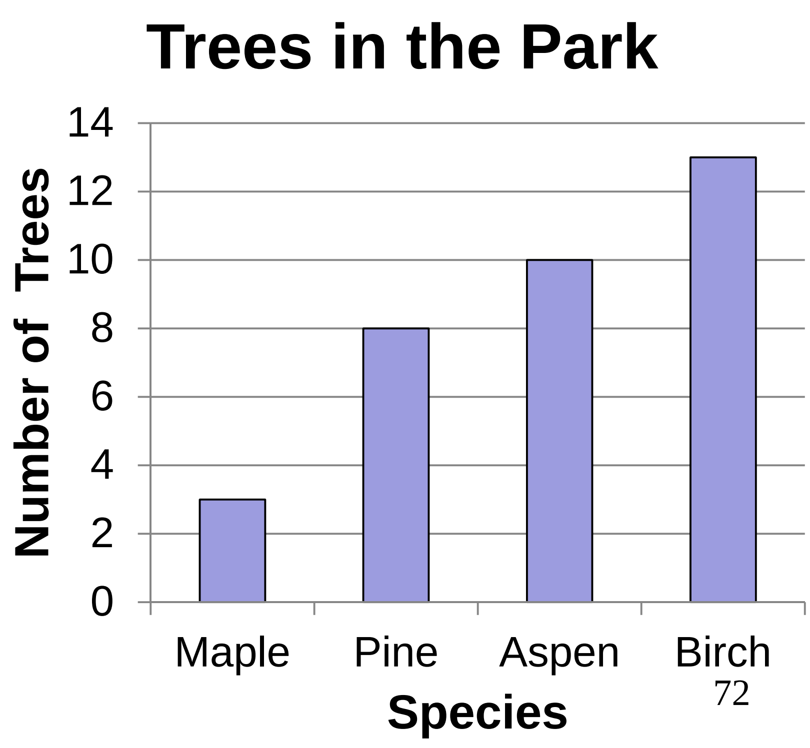
## Stand B

| DBH (in) | Height (ft) | Basal Area ($in^2$) | Basal Area ($ft^2$) | Tree Volume ($ft^3$) |
|---|---|---|---|---|
| 5 | 8 | 20 | 0.14 | 0.28 |
| 11 | 16 | 95 | 0.66 | 2.64 |
| 4 | 7 | 13 | 0.09 | 0.16 |
| 8 | 14 | 50 | 0.35 | 1.23 |
| 7 | 20 | 38 | 0.26 | 1.30 |
| 9 | 14 | 64 | 0.44 | 1.54 |
| 6 | 11 | 28 | 0.19 | 0.52 |
| 8 | 22 | 50 | 0.35 | 1.93 |
| 6 | 12 | 28 | 0.19 | 0.57 |
| 2 | 10 | 3 | 0.02 | 0.05 |
| 4 | 8 | 13 | 0.09 | 0.18 |
| 4 | 14 | 13 | 0.09 | 0.32 |
| 6 | 20 | 28 | 0.19 | 0.95 |
| 3 | 15 | 7 | 0.05 | 0.19 |
| 10 | 14 | 79 | 0.55 | 1.93 |
| 5 | 16 | 20 | 0.14 | 0.56 |
| 6 | 18 | 28 | 0.19 | 0.86 |
| 1 | 10 | 1 | 0.01 | 0.03 |
| 7 | 14 | 38 | 0.26 | 0.91 |
| 9 | 19 | 64 | 0.44 | 2.09 |
| 9 | 20 | 64 | 0.44 | 2.20 |
| 6 | 7 | 28 | 0.19 | 0.33 |
| 15 | 34 | 177 | 1.23 | 10.46 |

# Exercise 1b.3. Using Histograms

- Displaying data graphically helps examine patterns.
- Some data, such as the species of trees in a park, are categorical, meaning each data point belongs to a discrete class (in this case species).
- Categorical data can be easily displayed using a bar chart.
- However, what if data are numerical?

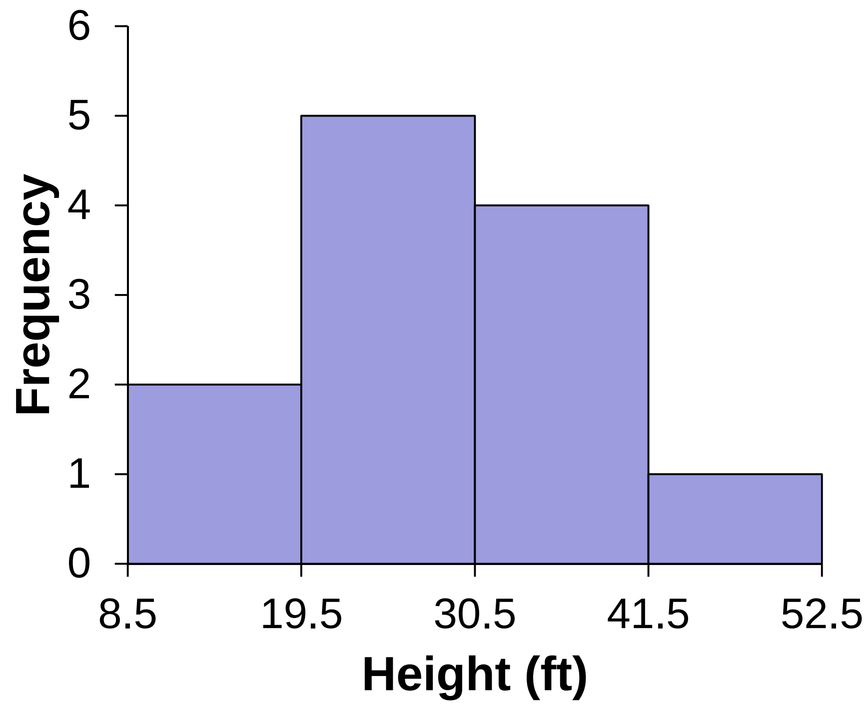
| Tree Species | Number of Trees |
|---|---|
| Maple | 3 |
| Pine | 8 |
| Aspen | 10 |
| Birch | 13 |



# Exercise 1b.3. Using Histograms

- Numerical data that vary continuously can be summarized in a **frequency table**.
- In such tables, data can be further divided into **classes**, each representing a range of values.
- The frequency table shows the **number of data points within each class**.
- This type of data is best displayed in a **histogram**.
- Histograms appear similar to bar chart, but are somewhat different.
- The data from the right are from the heights of the trees in Stand A.

| Height in Feet | Number of Trees |
|---|---|
| 8.5-19.5 | 2 |
| 19.5-30.5 | 5 |
| 30.5-41.5 | 4 |
| 41.5-52.5 | 1 |



# Exercise 1b.3. Using Histograms

- To display histograms, the data should be divided into any number of classes. For our example, we used four classes.
- After determining the number of classes, the class width should be determined. Classes should be of equal width.
- One easy way to do this is to take the range of the data (highest value – lowest value), and divide by the number of classes. In our case, this = (52 – 9)/4 = 10.75.
- Often we want our classes to be nice numbers, so we could round this up to 11 to have classes of a width of 11.
- Next, we want to determine the boundary points for our classes (where each class starts and ends).
- We don't want any data points to fall exactly on a boundary point, so boundary points are often defined with an extra decimal place beyond that in the actual data. Example: Our lowest value was 9, so our first boundary point was 8.5.
- Add the class width to a boundary point to find the next boundary point: 8.5, 19.5, 30.5, 41.5, 52.5

# Exercise 1b.3. Using Histograms

- After determining the boundary points, now our classes are defined. In our case, our classes become: 8.5-19.5, 19.5-30.5, 30.5-41.5, 41.5-52.5
- Next, we just determine the frequency of each class, or the number of data points falling within each class.
- To make the histogram, the data of interest is plotted on the x-axis, and the frequency is plotted on the y-axis.
- NOTE: It is perfectly fine to have empty classes (with no data points in them)!
- NOTE: When defining classes, choosing a good number of classes is somewhat important.
  - With fewer classes the overall shape of the histogram is clearer, but you lose detail.
  - With too many classes, you will end up with lots of empty classes, and many other classes of equal frequency.
- Construct a frequency table and histogram of the height data for Stand B with four classes, and compare it to the one for Stand A. Then answer the questions on the following slides.

# Exercise 1b.3. Using Histograms

**What general comparison can you make about the two stands in terms of height?**

**Click for the answer!**

**Stand A consists of trees that are taller on average than those in Stand B.**

**Were the two histograms easy to compare? Why or why not?**

**Click for the answer!**

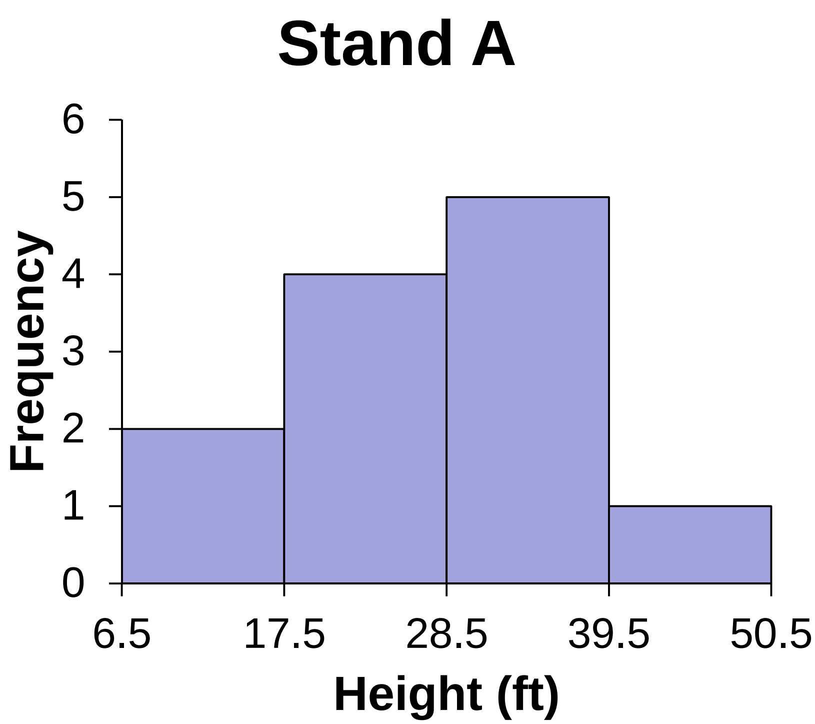
**Most of the trees in Stand A are between 19.5-30.5 feet tall. Most of the trees in Stand B are between 13.5-20.5 feet tall. These ranges overlap somewhat, so comparing these directly *could* be potentially misleading.**

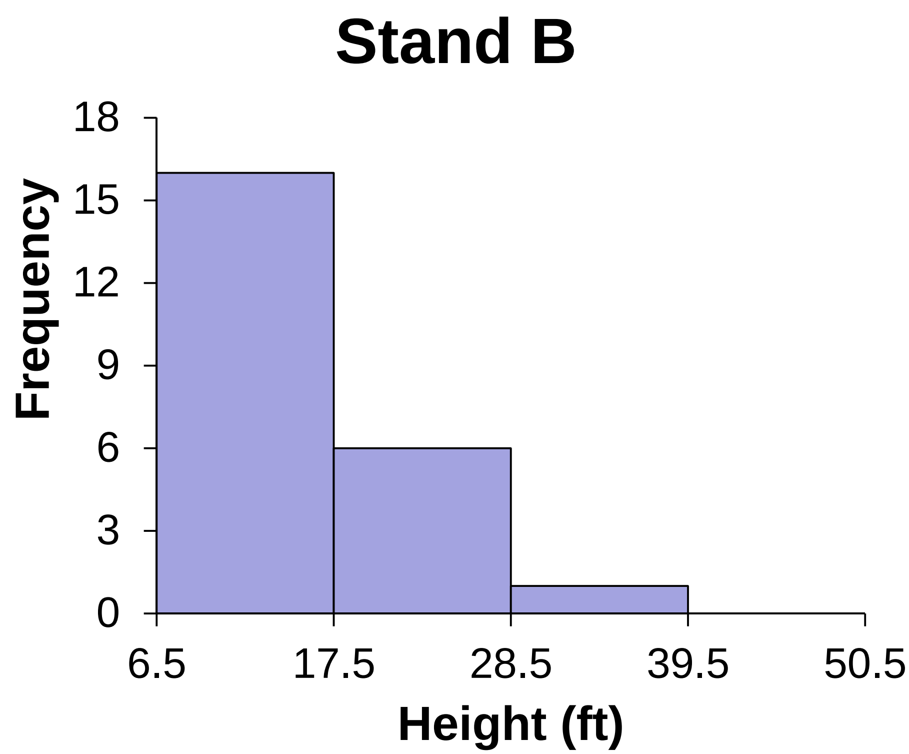
**Can you think of a way to make the two histograms easier to compare? If so, make new histograms of the height data for comparison.**

**The answer can be found on the following slide.**

# Exercise 1b.3. Using Histograms

**Below are histograms of the height data of each stand using the same class widths and boundary points, constructed using the *overall* maximum and minimum tree heights:**



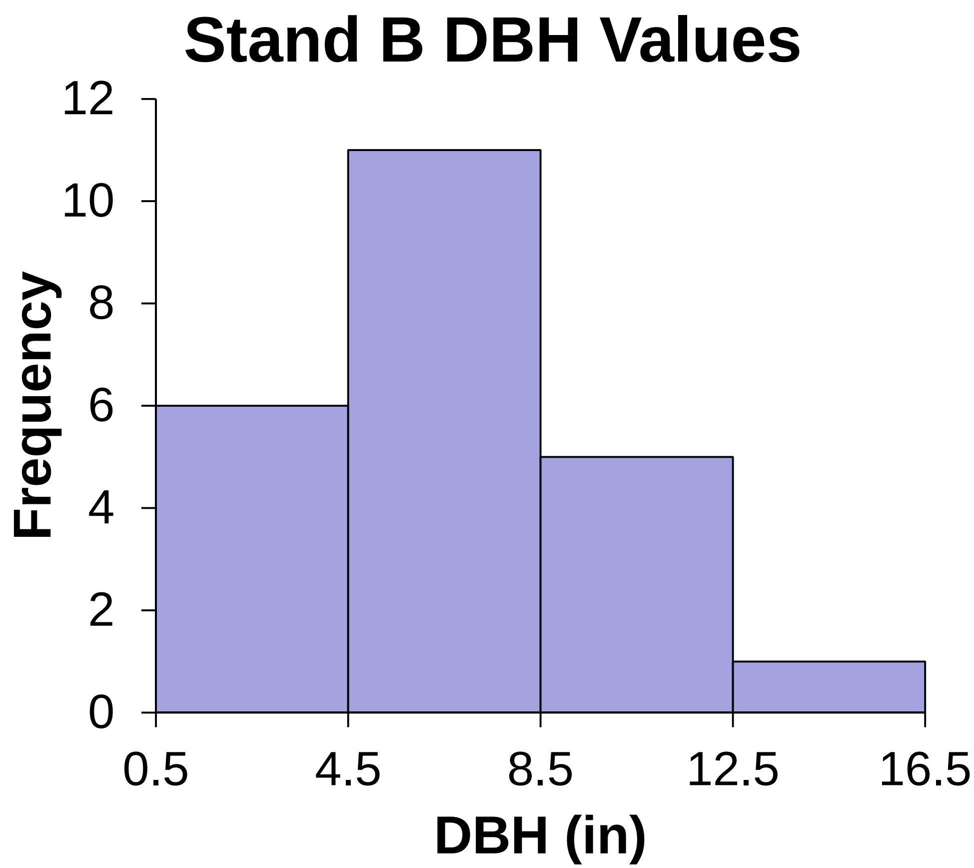

**In using the same class intervals and boundary points make it even more clear that the distribution of tree heights tends towards taller trees in Stand A.**

# Exercise 1b.3. Using Histograms

**Now make a frequency table and histogram of the DBH data for Stand B.**

**Click for the answer!**

| DBH (in) | Frequency |
|---|---|
| 0.5 – 4.5 | 6 |
| 4.5 – 8.5 | 11 |
| 8.5 – 12.5 | 5 |
| 12.5 – 16.5 | 1 |



# Exercise 1b.3. Using Histograms

- Answer the following questions:

If you counted the number of different species of birds in a forest, are your data categorical or quantitative? Would you display these with a bar graph or a histogram?

Click for the answer!

The data are categorical. The categories are bird species. You would use a bar graph.

If you measured the rate of photosynthesis in several leaves on random leaves on trees in the same forest, are your data categorical or quantitative? Would you display these with a bar graph or a histogram?

Click for the answer!

The data are quantitative. You would use a histogram.

# Exercise 1b.4. From Trees to a House

- Logging companies use board feet as a measure of wood volume.
- A board foot is equal to a piece of wood one foot long, one foot wide, and one inch thick.


- Using board feet, you can determine how much wood to harvest to make particular objects.
- For example, a small (1000 square feet) house with three bedrooms requires about 3000 board feet.
- How many trees (on average) from stand A would you have to cut to build such a house?
- the next slide to see how you might calculate this.

# Exercise 1b.4. From Trees to a House

- Find the total wood volume in the stand by adding together the volume of each tree.
- Total wood volume of Stand A = 603 $ft^3$.
- Now we can find the average wood volume for a tree in the stand by dividing total volume by the number of trees.
- 603 $ft^3$/12 trees = 50.3 $ft^3$ per tree
- Now we need convert this volume to board feet.
- Remember the definition of a board foot. Since a board foot is 1 foot x 1 foot x 1 inch, it would take 12 board feet to equal 1 $ft^3$.
- So, the average tree in Stand A consists of 50.3 x 12 board feet, or a total of 603.6 board feet.
- We need a total of 3000 board feet for the house. Since the average tree in the stand is 603.6 board feet, we can just divide 3000/603.6 to find out how many trees (on average) we would need to cut to build the house.
- It would take approximately 5 trees from Stand A to build the house.

# Exercise 1b.4. From Trees to a House

**Now calculate how many trees from Stand B, on average, it would take to build the same house (requiring 3000 board feet). Click for the answer!**

$$\frac{\text{total wood volume stand } B}{\text{total number of } trees} = \frac{31.23 \text{ ft}^3}{23 \; trees} = 1.36 \text{ f}t^3 \text{ per tree}$$

$$1.36 \text{ f}t^3 \text{per tree} \times \frac{12 \text{ board } feet}{1 \text{ f}t^3} = 16.32 \text{ board feet per tree}$$

$$\frac{3000 \; board \; feet}{one \; house} \times \frac{tree}{16.32 \; board \; feet} \approx 184 \; trees$$

**You would need 184 average-sized trees from Stand B to build the house. There are not enough trees in the stand!**

# Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- ❑ Identify one or more plots of forest habitat near your school or your home.
- ❑ Naturally, if the forest plot is rather large, you will not realistically be able to measure all the trees in the plot, unless you do this as a long-term project.
- ❑ Because of this, you could divide your class into teams of 3-4 students and each team would sample a plot (scientists call these plots ***quadrats***) of trees in the forest.
- ❑ You can use the ***random walk method*** to locate each plot.
- ❑ To do so, you will use a random numbers table like the one below.

| | | | | | |
|---|---|---|---|---|---|
| 8 0 9 4 | 2 5 2 5 | 6 2 4 7 | 1 3 4 7 | 7 4 3 3 | 3 6 2 0 |
| 3 5 6 3 | 2 1 9 8 | 8 2 1 1 | 9 0 4 5 | 2 6 1 8 | 2 7 5 1 |
| 1 3 3 0 | 6 3 3 1 | 3 7 5 3 | 9 6 9 3 | 8 7 3 8 | 6 8 1 5 |
| 3 5 6 5 | 0 0 1 6 | 2 2 4 3 | 6 4 3 2 | 4 7 9 6 | 6 0 9 5 |
| 7 8 5 0 | 5 9 2 5 | 5 5 8 8 | 7 3 1 1 | 2 1 9 2 | 4 5 4 5 |
| 4 4 9 0 | 5 4 1 7 | 9 7 2 7 | 6 1 5 3 | 5 9 0 1 | 4 8 7 8 |
| 6 5 4 5 | 9 1 0 4 | 9 3 1 8 | 8 8 1 9 | 7 5 3 7 | 2 7 8 5 |
| 3 6 2 6 | 5 9 9 5 | 1 2 1 5 | 9 7 5 3 | 9 2 2 3 | 5 6 5 8 |
| 4 8 6 5 | 4 8 2 0 | 7 5 5 4 | 0 6 1 2 | 9 6 8 3 | 4 2 5 1 |
| 6 4 9 8 | 7 5 1 9 | 0 4 7 4 | 7 8 1 8 | 6 8 3 2 | 9 6 8 3 |
| 6 7 2 2 | 9 8 6 9 | 9 3 6 1 | 7 8 7 5 | 4 8 8 3 | 1 3 1 5 |
| 9 7 4 8 | 5 9 3 2 | 5 1 1 5 | 2 7 2 1 | 0 0 3 3 | 9 3 0 3 |
| 5 6 4 1 | 1 4 1 7 | 1 4 1 9 | 7 4 3 4 | 8 1 6 5 | 7 3 6 8 |
| 7 4 4 4 | 9 2 0 0 | 8 8 4 0 | 5 8 8 2 | 4 3 9 8 | 3 9 0 4 |
| 8 2 7 9 | 3 0 1 9 | 4 6 7 2 | 3 7 4 3 | 3 9 7 9 | 4 6 8 9 |
| 0 1 6 1 | 7 6 1 7 | 1 0 2 4 | 2 3 8 7 | 2 8 9 1 | 6 6 7 7 |
| 7 3 8 8 | 9 7 5 9 | 7 5 5 5 | 6 6 2 4 | 9 9 7 7 | 2 0 0 8 |
| 7 8 3 0 | 4 7 1 4 | 3 6 9 5 | 2 9 1 9 | 1 8 0 4 | 4 0 4 4 |
| 9 8 8 7 | 4 2 1 6 | 6 5 2 6 | 4 5 3 5 | 8 4 3 0 | 5 2 7 0 |
| 1 2 6 1 | 2 5 1 6 | 8 5 6 9 | 2 3 1 0 | 3 9 3 9 | 8 7 0 3 |

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- First, one of the team members should close his/her eyes and place a finger on some point on the random numbers table.
- Open them and record the first five numbers that fall to the right of your finger on that line. Let's say, for example, the number string is 8 2 4 7 1.
- Starting at the edge of the forest, you will walk forward into it the number of paces (large steps) indicated by the first number (8 in this case).
- If the next number is an odd number (1,3,5,7, or 9), you will turn to the left for your next steps.
- If the number is even (2,4,6, or 8), you will turn to the right.
- Since our next number in the string is 2 in our example, you would turn to your right.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- The third number indicates how many paces you would take in this direction, 4 in our example.
- Repeat the process for the remaining two numbers: in our example a turn to the left and 1 pace. This is where team 1 will establish the plot they will sample.
- Team 2 will continue from this point using their unique set of numbers from the table below to establish their quadrat location and so on.
- If the forest is quite large, we recommend that you add 10 paces to the prescribed distances.
- Thus for team 1 in our example, the initial move into the woods would be 18 paces, right turn 14 paces, left turn 10 paces.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

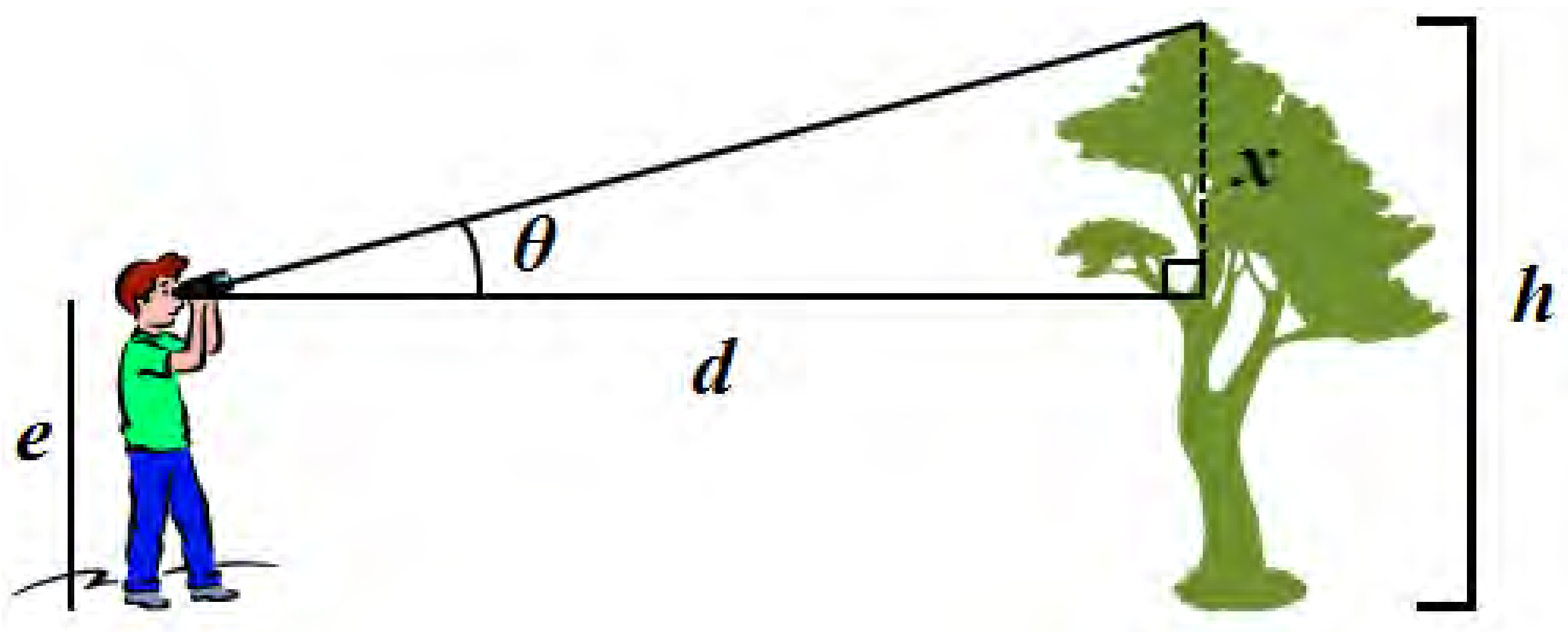
- Once each team has established their plot’s location, use a measuring tape to determine the plot's boundary, which you can mark with pieces of cloth, paper plates etc.
- Scientists prefer that sample plots be circular for measuring trees.
- Also the plots should be quite large, say have a radius of at least 5 meters.
- Have a team member stand in the center of the plot and another student stretch out a string that is 5 meters long (or use a meter tape) to locate points along the circle's boundary to place markers.
- Next take some measurements (such as DBH and height, which can be measured using the provided clinometer and the information provided later) of all of the trees in your sample plot.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

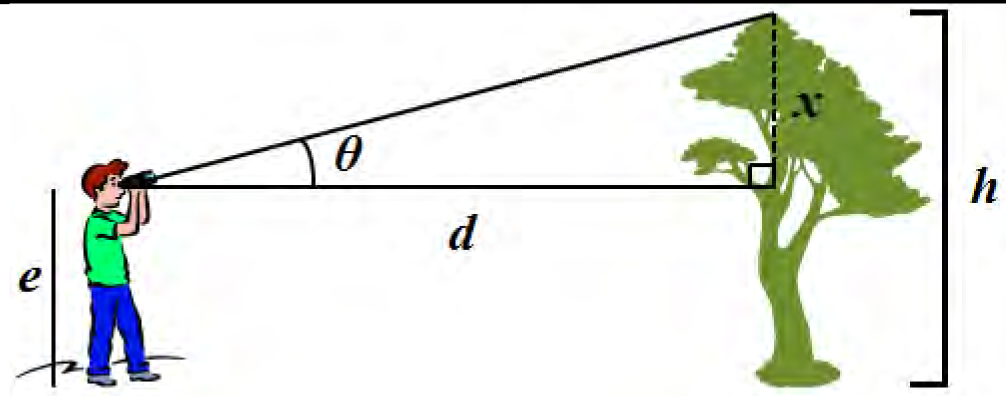
- ❑ You should place a mark (e.g. a piece of tape or pin a piece of paper) on each tree sampled, so that you do not measure the same tree more than once.
- ❑ You may also use a field guide to identify the species of trees in your plot, so that the measurements might be compared among the different tree types.
- ❑ **Be sure to remove all plot and tree markers when you are finished and carry this trash out of the woods.**
- ❑ Back in your classroom, determine the basal stand area for your plot.
- ❑ Use the gathered data from your forest plot to determine how many trees it would take to build a 1000 square foot house.
- ❑ Compare the results among teams for class discussion.
- ❑ Discuss potential factors that might create any observed variation in your plot, and in forests in general.
- ❑ Go to the next slide to see how to measure the heights of trees.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- To easily find the height of a tree when standing on ground level with its base, one can use a tool called a **clinometer**.
- This tool applies **trigonometry**, the branch of mathematics dealing with the relationships among the sides and angles of triangles.
- In the figure below, the unknown height (***h***) of a tree is of interest.

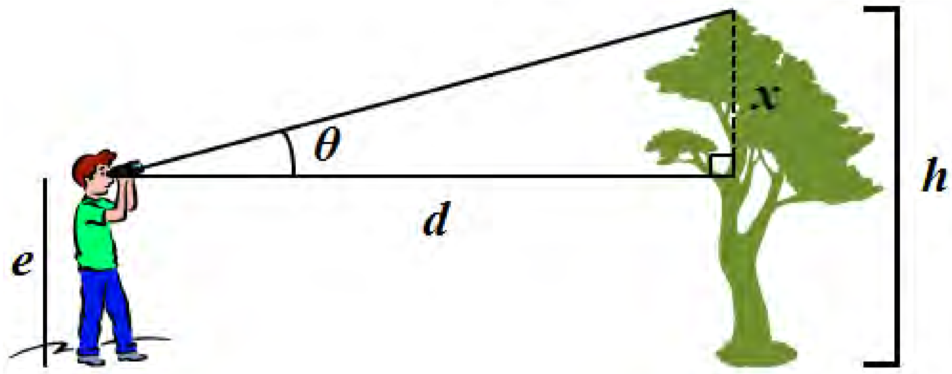


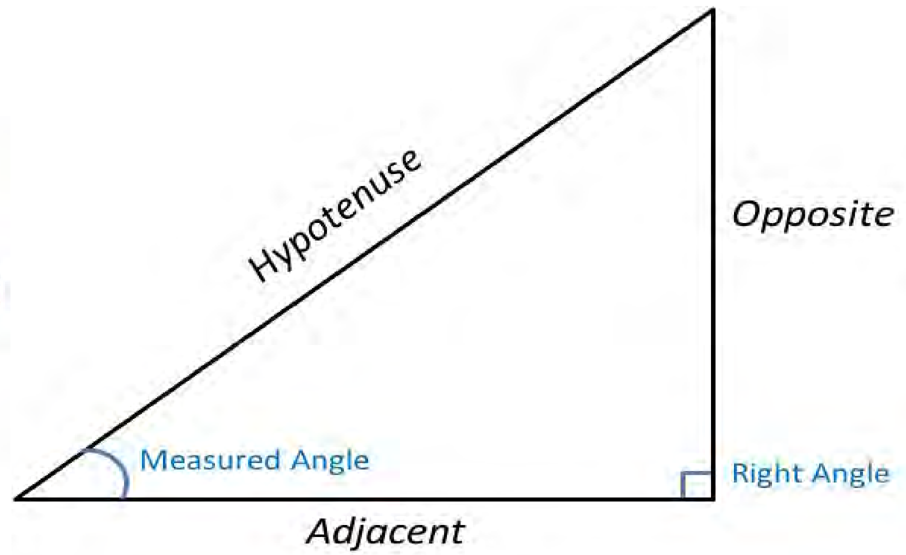
## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)




- ***e*** represents the height of the observer's eye.
- ***d*** is the distance of the observer's eye from the tree.
- The angle, ***θ***, from the observer's eye to the top of the tree, is measured by using a clinometer.
- From these values, ***x***, the height of the tree *above* the observer's eye level, is calculated from a simple trigonometric relationship.
- Since the observer is standing on level ground with the base of the tree, the angle formed by ***d*** and ***x*** is a right angle.

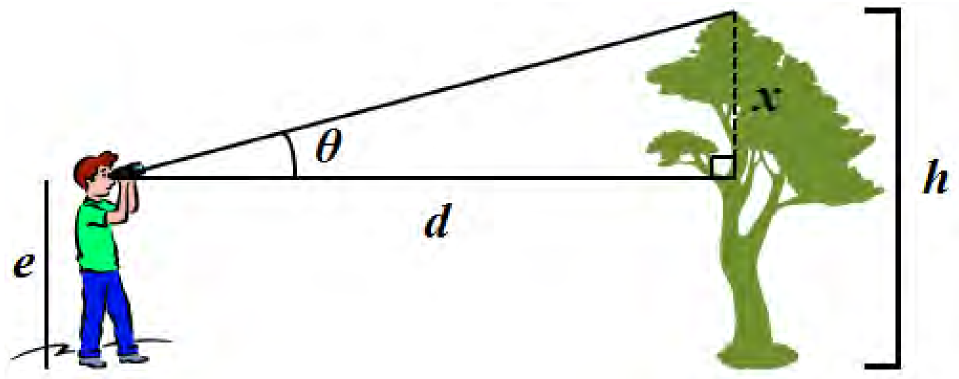
## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

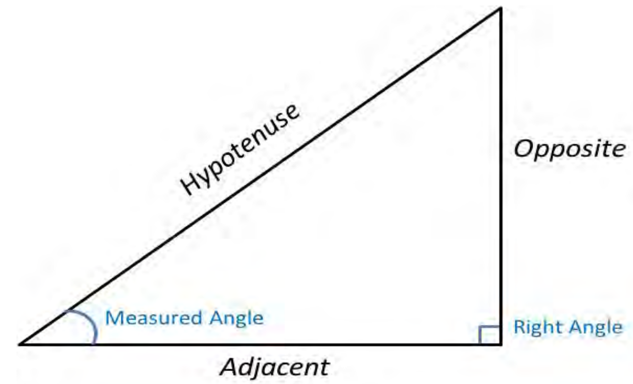



- Since the angle formed by ***d*** and ***x*** is a right angle, the relationship between ***d***, ***x*** and ***θ*** is known from a trigonometric ratio known as the **tangent**.
- In a right triangle, the tangent is defined as ***the value resulting from the division of the length of the side of a right triangle opposite the angle is divided by the length of the side of the triangle adjacent to the angle*** (not the hypotenuse, which is the side opposite the right angle).

# Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)




- Using the variables from the figures above, and the definition of the tangent ($\tan\theta = \frac{Opposite}{Adjacent}$), we can see that

$$\tan\theta = \frac{x}{d}$$

- From this equation, solve for the unknown ***x*** by multiplying both sides of the equation by ***d***:

$$x = d\tan\theta$$

- However, the ***total*** height of the tree, ***h***, is of interest, & ***x*** is the height of the tree ***above*** the observer's eye level, so

$$h = e + x$$

$$h = e + d\tan\theta$$

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- It is important to remember when doing these calculations that tangents (and other trigonometric functions) represent simple ratios. Therefore, they have ***no units***. Remember, the tangent of an angle is calculated as follows:

$$\tan\theta = \frac{x}{d}$$

- Because the numerator ***x*** and the denominator ***d*** **MUST** be expressed in the same length units, when calculated as ***x***/***d***, the units cancel out!
- Before using the clinometer, try out the practice questions on the following slides to make sure you're ready to use it.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Q1.** Using a calculator, calculate tan (45º)

**CLICK FOR THE ANSWER!**

$\tan(45^\circ) = 1$

**Q2.** Using a calculator, calculate tan (10º)

**CLICK FOR THE ANSWER!**

$\tan(10^\circ) \approx 0.1763$

**Q3.** If you are 10 feet from a tree, & you find the angle to the top of the tree is 31º, what else do you need to know to calculate the height of the tree? How would you find this value?

**CLICK FOR THE ANSWER!**

You would still need to find ***e***, the distance between your eye and the ground. You could use a measuring tape to measure the height of your eye above the ground.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Q4.** How can you measure the distance from the tree to your eye most accurately? Explain.

**CLICK FOR THE ANSWER!**

You can measure along the ground from your feet to the base of the tree. This distance would be the same since you and the tree are both standing at right angles to the ground. Measuring through the air might allow the tape measure to flop around.

**Q5.** If your measured **θ** angle is 60º, your distance from the tree 10 ft, and ***e*** is 3.8 feet, what is the height ***h*** of the tree?

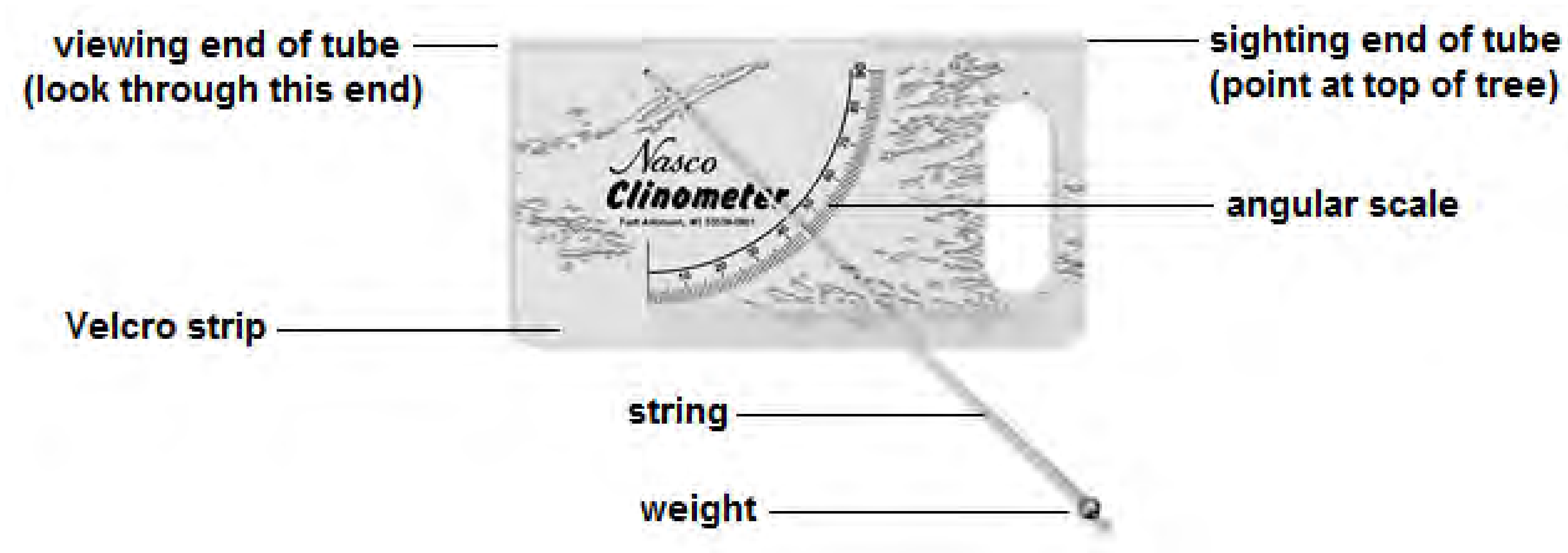
**CLICK FOR THE ANSWER!**

$$h = e + x$$
$$h = e + d\tan\theta$$
$$h = 3.8 + 10\tan(60º)$$
$$h = 3.8 + 17.32$$
$$h = 21.12\ ft$$

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

- In this unit, you have been provided with a simple clinometer.
- Foresters often use much more sophisticated clinometers with lenses and digital displays, but the one provided performs the exact same function: helping estimate tree height.
- There are several parts of the clinometer that you should note, which will help you understand the instructions on how to use it.
- First, look at both ends of the upper long edge of the clinometer.
- Note that this upper edge forms a tube through which you can sight the top of a tree whose height you wish to determine.
- Next, note the angular scale (which is in degrees) on both sides of the clinometer.
- You will also notice that there is a hole, through which a string, with weights on either end, passes.
- Finally, look at the lower rear corner of the clinometer, and you will notice a small Velcro strip.

# Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)



## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Using the clinometer to determine the height of a tree**

- ❑ Find a point in an area on level ground even with the base of the tree. Conducting these measurements on a slope will result in inaccurate calculation of the tree's height!
- ❑ Pull the string through the hole until the entire length of the string is on one side of the clinometer. Pull the string to the side away from your body (to the right side if viewing through your right eye, or to the left if viewing through your left eye).
- ❑ Hold the string out and away from the clinometer to make sure it is not caught in the Velcro.
- ❑ Close one eye, and using the other eye, look through the viewing end of the tube at the clinometer's top edge, and sight the top of the tree of interest through the viewing tube.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Using the clinometer to determine the height of a tree**

- ❑ While keeping the top of the tree in sight through the tube, release the string.
- ❑ While you still have the top of the tree in sight, and without pulling the string in any direction, press the string firmly into the Velcro strip to hold it in place.
- ❑ **Make sure to mark your current observation position so you can accurately measure the distance to the tree.**
- ❑ Now look at the angular scale on the clinometer, and the position of the string. The place on the angular scale that the string intersects is the measurement of the angle $\boldsymbol{\theta}$ (in degrees) between your eye and the top of the tree. Record this value.
- ❑ Using the provided 10m measuring tape, measure the distance ***d***, along the ground, between your viewing position and the tree. Record this value, as well.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Using the clinometer to determine the height of a tree**

- ❑ Now you can use the trigonometric relationship you learned earlier to determine the height ***h*** of the tree. Remember, your angle measurement allows you to calculate, based on the right triangle formed by your eye, the top of the tree, and the distance from your eye to the tree, the height of the portion of the tree *above your eye* level, ***x***:

$$\tan\theta = \frac{x}{d} \quad \underset{a}{\Rightarrow} \quad x = d\tan\theta$$

- ❑ Using a calculator, find the tangent of the angle, $\boldsymbol{\theta}$, obtained from your measurement of the angle used to sight the top of the tree.
- ❑ Multiply $\mathbf{tan}\,\boldsymbol{\theta}$ by the horizontal distance, ***d***, between your position and the tree.
- ❑ The result, ***x***, is the height of the portion of the tree above your eye level, in the same units you used to measure ***d***.

## Exercise 1b.5. Foresters for a Day (*Open-Ended Exploration*)

**Using the clinometer to determine the height of a tree**

- Now you can use the trigonometric relationship you learned earlier to determine the height ***h*** of the tree. Remember, your angle measurement allows you to calculate, based on the right triangle formed by your eye, the top of the tree, and the distance from your eye to the tree, the height of the tree *above your eye* level, ***x***:

$$\tan\theta = \frac{x}{d} \quad \Rightarrow \quad x = d\tan\theta$$

- Using a calculator, find the tangent of the angle, $\theta$, obtained from your measurement of the angle used to sight the top of the tree.
- Multiply $\tan\theta$ by the distance, ***d***, between you and the tree.
- The result, ***x***, is the height of *the portion of the tree above your eye level*, in the same units you used to measure ***d***.
- To get the total height, simply add the height of your eye level ***e*** to ***x***:

$$h = e + x \quad \Rightarrow \quad \mathrm{h} = e + d\tan\theta$$

# Exercise 1c. Leaves & Seed Cases

- Leaves are important to tree survival and growth because they contain chloroplasts (klor-oh-plasts) that make the food the tree needs to grow and reproduce.

- To convert light energy from the sun into sugars, leaves need water and nutrients, which are captured by the roots and transported through the xylem to the leaves.

- To make sugars, the leaf chloroplasts also need carbon dioxide, which they collect from the air.

- The sugars produced through the process of photosynthesis are transported from the leaves through the phloem to the other parts of the tree.

# Exercise 1c. Leaves & Seed Cases

- **A tree's seeds are important because they make new trees.**
- **Seeds can travel by water, wind, or in an animal's fur or stomach to a new location.**
- **If the environment there is ideal, a new tree will grow.**
- **Trees produce special structures that surround their seeds to help with dispersal, so what you see is not the seed exactly since it is hidden inside (and there may be many hidden in there!).**
- **We call these fruits, cones, or pods, and they come in many varieties unique to each kind of tree.**
- **For this exercise we'll use a very general term for all of these: we'll call them seed cases.**

# Exercise 1c. Leaves & Seed Cases

**Exercise 1c.1. Leaf and Seed Case Match**
(*Grades K-5*)

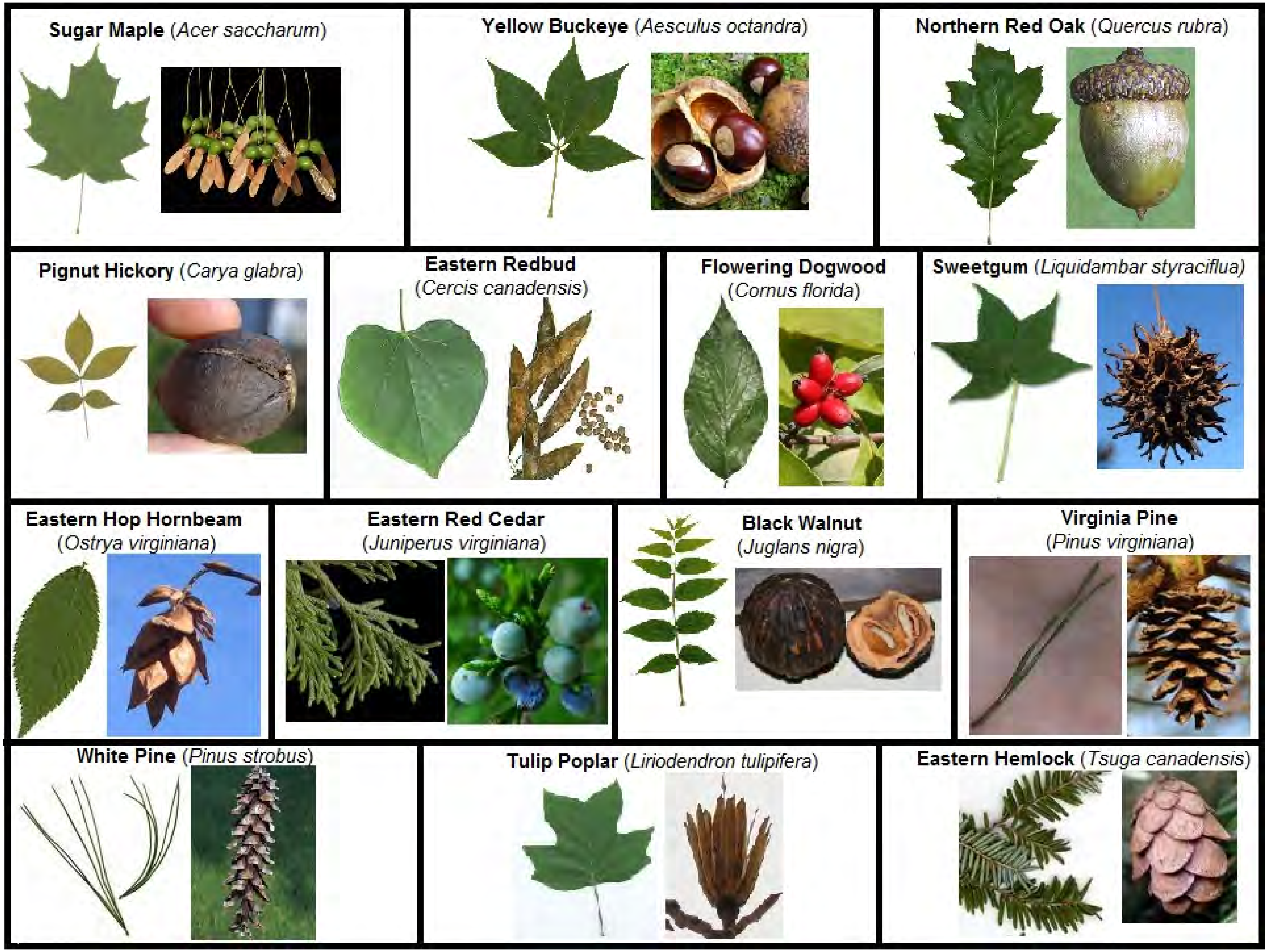
**Exercise 1c.2. Sorting Seed Cases**
(*Grades 3-12*)

**Exercise 1c.3. Using Dichotomous Keys**
(*Grades 6-12*)

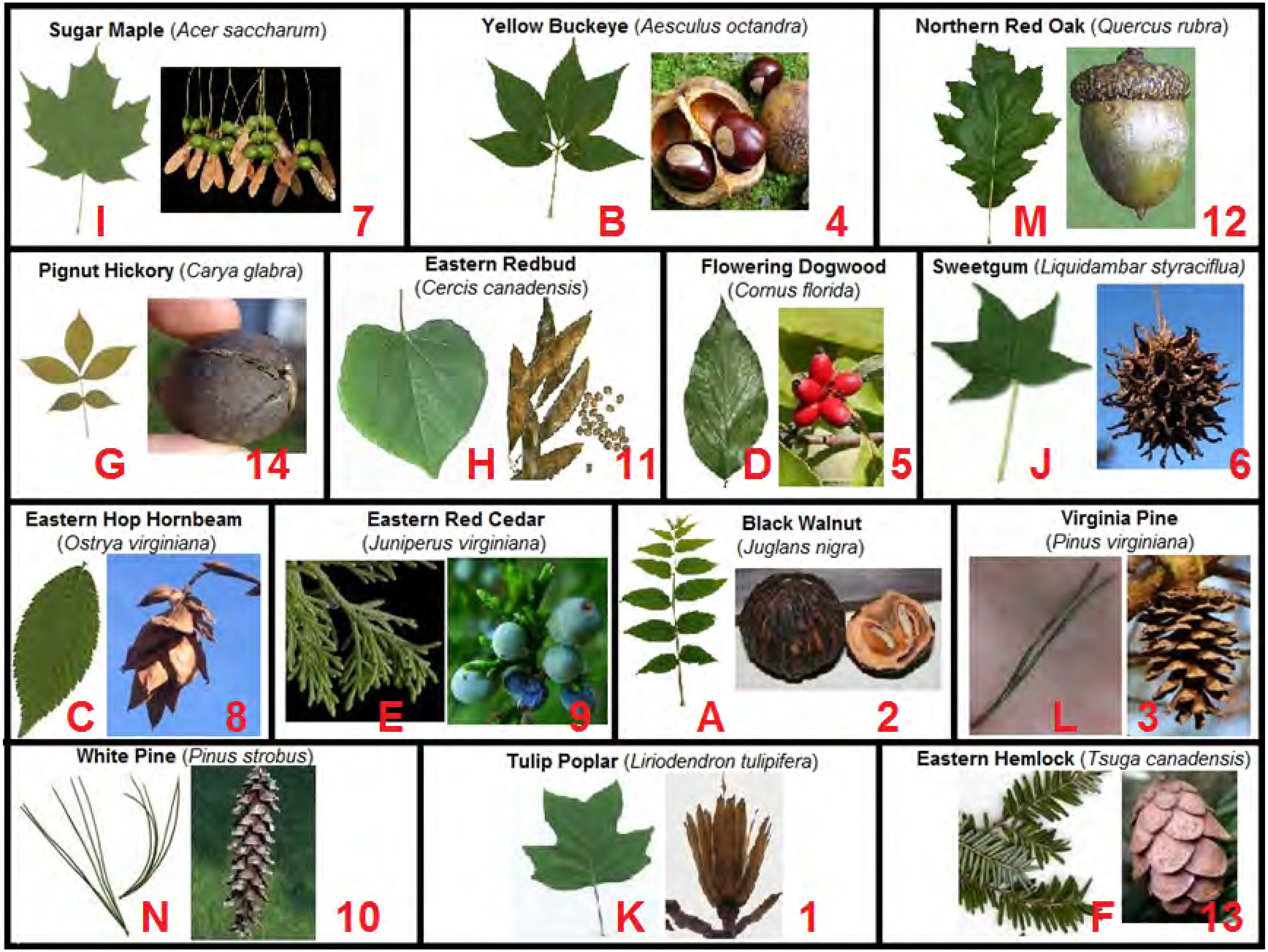
**Exercise 1c.4. Developing a Dichotomous Key**
(*Open-ended Exploration for Grades 6-12*)

# Exercise 1c.1. Leaf and Seed Case Match

- Examine each of the provided leaves.
- Study their shapes and forms, and see if you can match each leaf with the pictures of leaves from the tree species on the following slide.
- Once you have figured out the tree species of each leaf, try to find the seed or seed case that goes with each leaf. Look at the picture of the seed next to each leaf to help you with this task.
- Since size is difficult to assess from the pictures, be sure to pay attention to the shape and texture of the seeds.




**Go to the next slide to check your answers!**


Sugar Maple (*Acer saccharum*)
I
7
Yellow Buckeye (*Aesculus octandra*)
B
4
Northern Red Oak (*Quercus rubra*)
M
12
Pignut Hickory (*Carya glabra*)
G
14
Eastern Redbud (*Cercis canadensis*)
H
11
Flowering Dogwood (*Cornus florida*)
D
5
Sweetgum (*Liquidambar styraciflua*)
J
6
Eastern Hop Hornbeam (*Ostrya virginiana*)
C
8
Eastern Red Cedar (*Juniperus virginiana*)
E
9
Black Walnut (*Juglans nigra*)
A
2
Virginia Pine (*Pinus virginiana*)
L
3
White Pine (*Pinus strobus*)
N
10
Tulip Poplar (*Liriodendron tulipifera*)
K
1
Eastern Hemlock (*Tsuga canadensis*)
F
13

# Exercise 1c.2. Sorting Seed Cases

- **Trees produce a wide variety of structures to protect their seeds, since those seeds are their offspring!**
- **Below are a few types of structures, which we will call seed cases, that trees produce.**
- **With the exception of cones, all of the others are classified as fruits:**
  - **Cone** –woody structures that open and release seeds when dry; some need high heat of fires for the cones to open
  - **Samara** – fruit with “wings” that allows wind to carry seeds far from the parent tree
  - **Nut** – hard-shelled dry fruit containing the seed inside; do not open naturally; often round to allow dispersal by rolling; may float to allow dispersal by water; often nutritious to attract animal dispersers (via forgotten caches)
  - **Capsule** – dry fruits that split open at maturity to release seeds.
  - **Legume** –seeds are contained in a pod, which can split open along its seams to release the seeds (beans are an example)
  - **Drupe** – a fleshy fruit with a large seed in the center (a peach is a an example)

# Exercise 1c.2. Sorting Seed Cases

- **Try to sort each of the seed cases provided in this unit into one of the categories from the previous slide.**
  **NOTE: Some seed cases are hard to categorize. See hints below:**
- In the **hop hornbeam**, the seeds are hidden inside clusters that hang down like pendulums. However, if you were to open up the clusters further, you would see the seeds are in hard-shelled fruits that don't split open.
- In the **tulip poplar**, the seed case may be cone-shaped, but when it is dry, it splits apart and the seeds are carried away in the wind on light wings.
- In the **red cedar**, the seeds are hidden inside tiny woody structures that open when conditions are dry and close when conditions are moist. These woody structures are fleshy, and fuse together during development, giving them a berry-like appearance. They are not a berry, though!
- The sample you have from a **buckeye** is actually a seed released from a mature fruit.
- **Once you have sorted all of the seed cases into each of the types on the previous slide, go to the next slide to check your answers!**

# Exercise 1c.2. Sorting Seed Cases

**Capsules**
Yellow Buckeye (#4)
Sweetgum (#6)

**Cones**
Virginia Pine (#3)
Eastern Red Cedar (#9)
White Pine (#10)
Eastern Hemlock (#13)

**Drupes**
Flowering Dogwood (#5)

**Legumes**
Eastern Redbud (#11)

**Nuts**
Black Walnut (#2)
Eastern Hop Hornbeam (#8)
Northern Red Oak (#12)
Pignut Hickory (#14)

**Samaras**
Tulip Poplar (#1)
Sugar Maple (#7)

# Exercise 1c.2. Using Dichotomous Keys

- **Scientists often use dichotomous keys to identify organisms.**
- **A dichotomous key is like a "choose your own adventure" book where different choices in the story require you to  a different page.**
- **In a dichotomous key, each step in the key has two choices.**
- **To use a dichotomous key, you start at the first step and pick which choice best describes the organism you are trying to identify.**
- **The choice will either give you the organism's identity, or tell you to  another step.**
- **If you have to  another step, keep repeating this process, following the directions given by your choice, until you arrive at the organism's identity.**

# Exercise 1c.2. Using Dichotomous Keys

- Examine the provided leaves.  They are labeled A-N.
- Make a list of the letters A-N on a piece of paper.
- Pick a leaf, and note its letter.
- Use the key on the next slide to see if you can identify the tree species from which the leaf came.
- Repeat until you have done this for all leaves.
- You may wish to sketch/take notes on the image below to help you with terminology:

**1a**. Needle-shaped......**2**
**b.** Broad and flat......**5**
**2a.** Needles connect at central point......**3**
**b.** Needles connect along stem......**4**
**3a**. 2 needles......**Virginia Pine (*Pinus virginiana*)**
**b.** 5 needles......**White Pine (*Pinus strobus*)**
**4a.** Scale-like or three-sided needles......**Eastern Red Cedar (*Juniperus virginiana*)**
**b.** Flat needles......**Eastern Hemlock (*Tsuga canadensis*)**
**5a.** Leaf is simple...... **6**
**b.** Leaf is compound...... **12**
**6a.** Leaf is lobed...... **7**
**b.** Leaf is not lobed...... **10**
**7a.** Leaf edge is smooth...... **8**
**b.** Leaf edge is jagged or toothed like a saw...... **9**
**8a.** Leaf has 4 lobes**......Tulip Poplar (*Liriodendron tulipifera*)**
**b.** More than 4 lobes...**Northern Red Oak (*Quercus rubra*)**

**9a.** Leaf had 5 distinct lobes......**Sweet gum (*Liquidambar styraciflua*)**
**b.** Leaf w 3-5 shallow lobes...**Sugar Maple (*Acer saccharum*)**
**10a.** Leaf is heart-shaped......**Redbud (*Cercis canadensis*)**
**b**. Leaf is not heart-shaped...... **11**
**11a.** Edge jagged/toothed...**Eastern Hop Hornbeam (*Ostrya virginiana*)**
**b.** Edge smooth...**Flowering Dogwood (*Cornus florida*)**
**12a.** Compound, central pt...**Yellow Buckeye (*Aesculus octandra*)**
**b**. Leaflets not from a central point...... **13**
**13a.** More than 7 leaflets......**Black Walnut (*Juglans nigra*)**
**b.** 7 or less leaflets......**Pignut Hickory (*Carya glabra*)**

**Do not go on to the next slide until you are ready to check your answers!**

# Exercise 1c.3. Using Dichotomous Keys

A. Black Walnut (*Juglans nigra*)
B. Yellow Buckeye (*Aesculus octandra*)
C. Eastern Hop Hornbeam (*Ostrya virginiana*)
D. Flowering Dogwood (*Cornus florida*)
E. Eastern Red Cedar (*Juniperus virginiana*)
F. Eastern Hemlock (*Tsuga canadensis*)
G. Pignut Hickory (*Carya glabra*)
H. Eastern Redbud (*Cercis canadensis*)
I. Sugar Maple (*Acer saccharum*)
J. Sweet Gum (*Liquidambar styraciflua*)
K. Tulip Poplar (*Liriodendron tulipifera*)
L. Virginia Pine (*Pinus virginiana*)
M. Northern Red Oak (*Quercus rubra*)
N. White Pine (*Pinus strobus*)

- **You may wish to look at each leaf again and work backwards through the key to see where you may have made incorrect choices!**

## Exercise 1c.4. Developing a Dichotomous Key

- See if you can construct your own dichotomous key for the seed cases provided in this unit!

- It may be helpful to use what you have learned about various seed case types in the earlier exercise!

# Exercise 2. Wood Types

- ❑ **Take a few minutes to look around at all the different objects in your classroom that are made of wood.**
- ❑ **List them on the board.**
- ❑ **Do you notice any differences in the types of wood used to make these items?**
- ❑ **Why do you suppose different things are made from different types of wood?**
- ❑ **For example, why would your desk be made from a different type of wood than a picture frame or a ruler?**

# Exercise 2. Wood Types

- **Because there are many different species of trees, there are many different types of wood.**

- **Each unique wood type has its own combination of properties such as**
  - **color**
  - **scent**
  - **strength**
  - **density**
  - **flexibility**
  - **grain pattern**

- **These factors make different types of wood better for making certain items we use in our daily lives.**

# Exercise 2. Wood Types

- Wood can be broadly classified in two main groups:
  - softwoods
  - hardwoods
- The structure of the cells, or wood fibers, is what determines whether the wood from different tree types is considered hard or soft.
- What kinds of objects do you think a heavy, hard wood would be used to make?
- What types of things do you think would be made from a soft flexible wood type?
- Think about the importance of color, grain pattern, and scent of different woods.
- Why would these properties be important in making something like furniture or other items found in your classroom or home?

# Exercise 2. Wood Types

- Click one of the underlined exercise names below to go to that exercise.

- In <u>Exercise 2a. What's That Wood?</u>, students in grades 3-12 will try to match several unknown wood samples to wood from known species.

- In <u>Exercise 2b. Wood Density</u>, students in grades 5-12 will examine the property of wood density, and calculate densities for three different types of wood.

- In <u>Exercise 2c. Wood Porosity</u>, students in grades 3-12 will examine the porosity of different woods, and relate this to the classification and tissue properties of various species.

- <u>Exercise 2d. Tennessee's Trees</u>, is an open-ended exploration for students in grades 3-12.

# Exercise 2a.  What's That Wood?

- Sort the wood chips into two groups on the front table: named and unknowns (letter only).
- As the class is engaged in some other assignment, have one student at a time visit the front table with a sheet of paper and pencil or pen.
- The student should write down the name of each named wood chip as it is examined, and note some characteristics of each. Some examples include:
  - Color and grain pattern
  - Scent (if present)
  - Perceived weight or density
- Read about the traits and uses of this type of wood on the next slide for class viewing.
- Once all of the named chips have been examined, students should try to match each of the unknowns to one of the known species.
- Students should record the letter of the mystery chip next to the named chip you think it corresponds to.
- When all of the students have had a chance to complete the exercise, go to the slide after the table on the next slide so they can check their answers.

| Type | Characteristics | Uses |
|---|---|---|
| **ASH** | Tough & elastic | Bows & arrows, ribs of boats & chairs, baseball bats, tool handles, canoe paddles |
| **BASSWOOD** | Soft , consistent light color, lack of grain | Carving, wood boxes, window sashes & door frames, molding |
| **BIRCH** | Light and odorless | Wooden bowls, tongue depressors, toothpicks, kitchen cabinets |
| **CEDAR** | Durability, pleasant odor | Telephone poles, wood fences, patios & decks, pencils, roof shingles, boats & canoes chests, closet paneling; used in smoking food |
| **CHERRY** | Reddish in color, little grain,<br>easy to sand and take finishes well, pleasant odor – smoking wood | Indoor projects-fine furniture, paneling, specialty items (e.g., pipes, musical instruments); used in smoking food |
| **MAHOGANY** | Beautiful reddish brown color, straight grain, resistance to rot | Pianos, acoustic guitars, drums, boats & furniture |
| **MAPLE** | Hard; often called “sound wood,” as it resonates well | Necks of guitars & drums, bowling pins, bowling alleys & gym floors, butcher blocks, decorative furniture surfaces |
| **OAK** | Hard dense wood with distinct grain. Has tannic acid which turns black on exposure to water. | Railroad ties & pallets but mainly indoor use (furniture & flooring) |
| **PECAN** | Hard, strong, stiff, tough | Furniture, flooring, cabinets, used in smoking food |
| **PINE** | Strongest of soft woods (fast growing timber) | Construction lumber, plywood, pine plank flooring, outdoor furniture, pet litter |
| **TULIP POPLAR** | Large size and soft, easily worked wood | Cabinets and furniture, dugout canoes, barn siding |
| **WALNUT** | Beautiful dark color & stability to fracture, pungent odor | Fine furniture, musical instruments, interior trim and decorative work, gun stocks |

# Exercise 2a. What's That Wood?

## Click to see the answers!

A. Maple
B. Pine
C. Basswood
D. Ash
E. Birch
F. Oak
G. Walnut
H. Cedar
I. Tulip Poplar
J. Cherry
K. Mahogany
L. Pecan

# Exercise 2b. Density

- As you have already observed, the woods of different tree species have different properties.
- One of these properties is density, which is defined as the mass per unit volume.
- For example, imagine a cotton ball the same size as an apple. The apple is heavier, because it has a greater density..

In this exercise you will

- calculate and compare the density of three different types of wood.
- think about how wood density affects the uses of the wood
- think about how a tree's growth and life history affect density

# Directions

- Find the container labeled "Wood Density Samples". In it you will find cubes of three different types of wood: balsa, white birch, and lignum vitae.
- Fill in the chart on the next page which establishes the relative weight of the different samples relative to one another.
  - To obtain the data for filling in the chart, have students come up to the front of the room one at a time, or in groups, and hand them a pair of wood samples.
  - Have them handle and compare the woods and decide on which seems heavier (have them reach a consensus if using groups).
  - For the pair, place a mark under the column for the wood the student thinks is heaviest.
  - Repeat for each pair of wood samples and all students/groups.
- Rank the samples from most dense(heaviest) to lightest based on the results of the pair-wise comparisons.

# Exercise 2b. Wood Density

| Balsa versus Lignum Vitae | |
|---|---|
| Which seemed heavier?  Place a mark under the wood that felt heaviest. | |
| **Balsa** | **Lignum vitae** |
| | |

| Lignum Vitae versus White Birch | |
|---|---|
| Which seemed heavier?  Place a mark under the wood that felt heaviest. | |
| **Lignum Vitae** | **White Birch** |
| | |

| White Birch versus Balsa | |
|---|---|
| Which seemed heavier?  Place a mark under the wood that felt heaviest. | |
| **White Birch** | **Balsa** |
| | |

# Exercise 2b. Wood Density

- You just used observational skills to rank the woods' densities. This is what is considered a qualitative measure.
- These observations can serve as a hypothesis for the actual relative densities of each of the woods.
- Quantification, on the other hand, involves actual measurement and provides for numerical comparison.
- Now you will quantify the densities of each of these woods as a test of the hypothesis generated by your observations.
- Each group should measure the length, width, and height of each wooden cube in millimeters, & record their results.
- Remember, density is defined as mass per unit volume. Knowing the dimensions of the cube, you can now find its volume in $mm^3$ by multiplying its length x width x height.
- Densities are usually reported in $g/cm^3$, so convert this volume to $cm^3$ by dividing by 1000.
- Using the provided scale, calculate the mass of the cube.
- Using this information, calculate the wood's density.

# Exercise 2b. Wood Density

- Different groups' calculations may vary. Why? How would you account for this?

- Groups may vary in the way they measured/read their results. To correct for this, you may wish to calculate the mean, or average, volume, mass, & density for each wood.

- Remember, the mean is equal to the total of all measurements divided by the number of measurements.

- Make a bar graph of the average densities of each wood type, making sure to clearly label your axes.

- Using these results, think about the questions on the following slides.

- Discuss these questions as a class, then check your answers on the following slides.

# Exercise 2b. Wood Density

**Did your results of calculating the woods' densities agree with the hypothesis of your qualitative observations?**

**Your answers may vary, but based on the magnitude of differences in the densities of the woods, it is likely that your results agreed with your hypothesis.**

**If so, does this PROVE your hypothesis? Why or why not?**

**No. In science, a hypothesis is never completely *proven*. However, hypotheses can be *supported* with substantial evidence.**

**If your results did not agree with your hypothesis, does this prove that your hypothesis was wrong? Why or why not?**

**No. When results do not agree with a hypothesis, the hypothesis is simply not supported. If greater amounts of data were collected, it is possible that the hypothesis would be supported.**

# Exercise 2b. Wood Density

**What are some ways you could improve your testing methods?**

Your answers may vary, but some ideas include using more accurate instruments, multiple samples, etc.

**What is the disadvantage of only using one sample of each wood type?**

Perhaps the wood of a particular sample is non-typical of the wood of that species. For example, it could have been taken from a region of growth resulting in density that is higher or lower than the typical range.

**What are some properties that may make a particular wood heavy?**

More tightly packed cells, the presence of compounds that give the wood color and/or scent, etc.

# Exercise 2b. Wood Density

**What types of uses do you think each wood might have, based on their densities?**

- Balsa is used in carving and crafts (like model airplanes) and surgical splints, but not well-suited for heavy-duty construction.
- Birch's strength makes it a good choice for veneers, furniture, cabinets, and indoor plywood, and its resonance makes it useful in musical applications like speaker cabinets, drums, guitars, and keyboard mallets.
- Lignum vitae's high density makes it good for heavy-duty uses like pulleys, croquet mallets, and mortars and pestles. Its high oily resin content make it self-lubricating, and good for underwater and at-sea uses, like propeller shafts and ship rigging.

**How would you expect each wood to behave if placed in water?**

The balsa should float completely on the surface, and the lignum vitae should sink to the bottom. The birch should also float, but only partially above the water's surface.

# Exercise 2b. Wood Density

**How could you get a cube of lignum vitae to float?**

**You could increase the density of the water by adding salt, since saltwater is denser than fresh water. You could also make a hollow cube of the wood with thin walls. Even though the wood would still have the same density, the air inside the hollow cube would make the *average* density of the cube low enough so it could float.**

**What aspects of the growth and life histories of each might explain differences in their densities?**

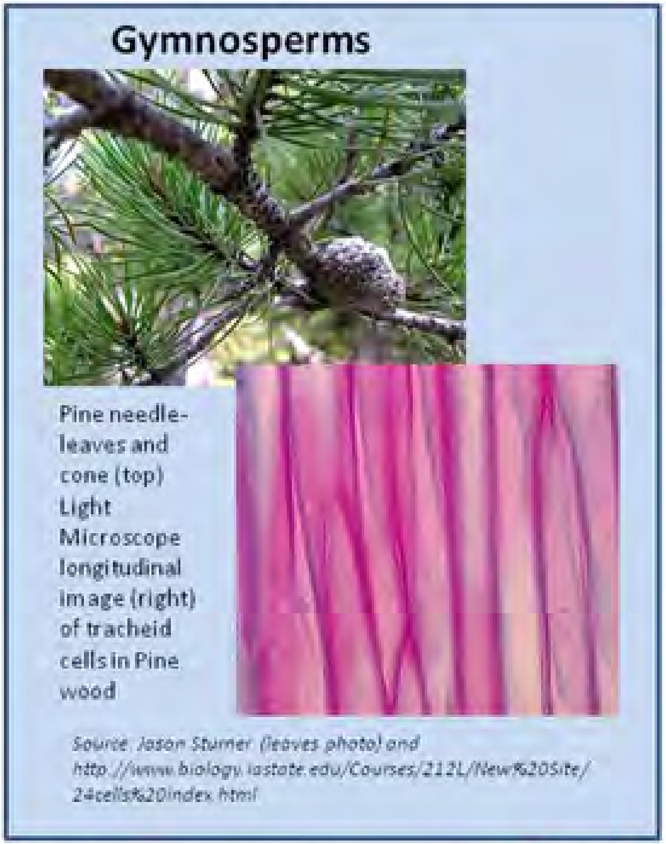
**Balsa and birch are fast growing pioneer or weedy species. In producing rapid growth for height, greater density is sacrificed. Lignum vitae is a late succession tree species that grows in the shade of the canopy. Since they grow less tall and more slowly, greater energy is put towards increased cell density. It is more energetically costly to produce higher density wood, but greater longevity.**

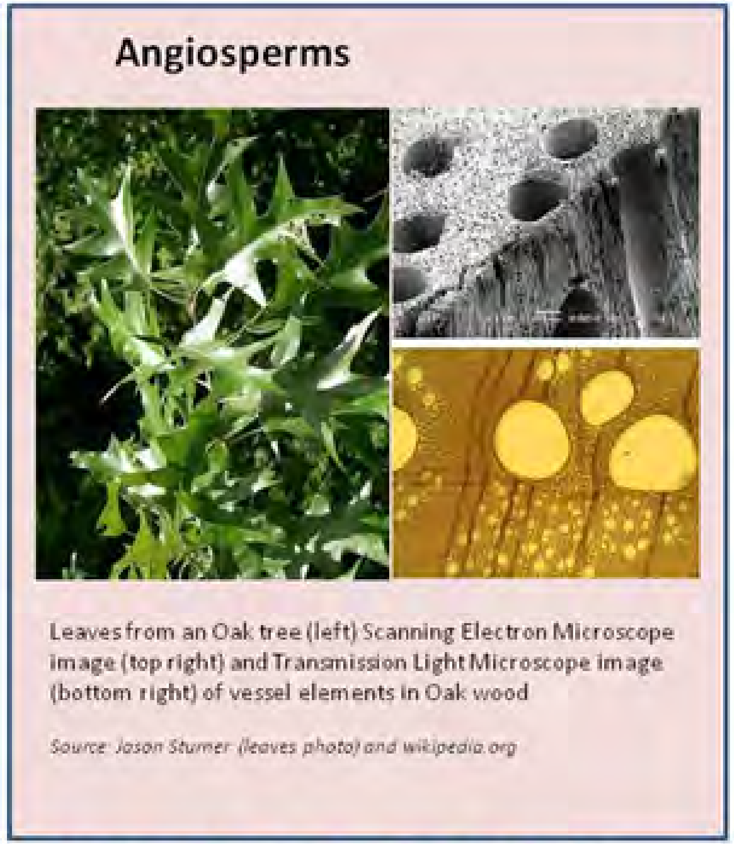
# Exercise 2c. Wood Porosity

- **A further classification of wood is based on the porosity of the wood.**
- **The wood of angiosperms, or flower-bearing trees, has pores called vessels.**
- **The vessels are vertical "pipes" that transport liquids in the xylem.**
- **The wood of conifers, or cone-bearing trees, does not have pores. Conifers use a system of tracheids, which are long tapered cells with pitted walls, in the transport of water and other materials.**
- **These different circulation systems give the two types of woods different levels of porosity (a measure of how quickly a liquid will pass through a material).**

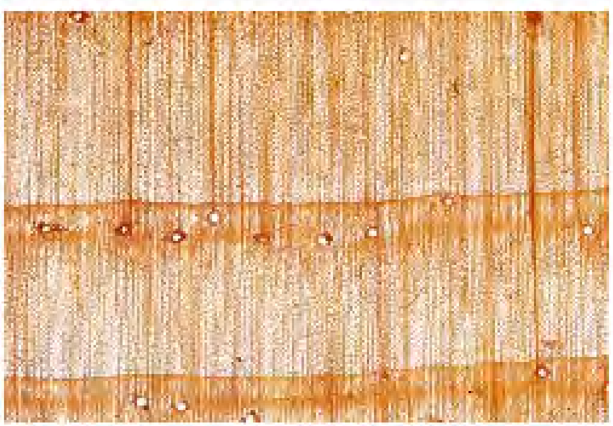
# Exercise 2c. Wood Porosity

- ❑ Find the container marked "Wood Porosity Samples".
- ❑ You should find either tree cores of both a pine and an oak mounted on wood chips, or two small pieces of pine and oak.
- ❑ Tree cores are wood samples extracted from the tree trunk using a boring tool.
- ❑ You can also use cores to age a tree by its rings in the same way as you did with the tree cookies.
- ❑ Pass the two samples around the class with a magnifying glass.
- ❑ Each student should use the magnifying lens provided in the trunk to examine each sample for pores. Use the images on the next slide to help you.

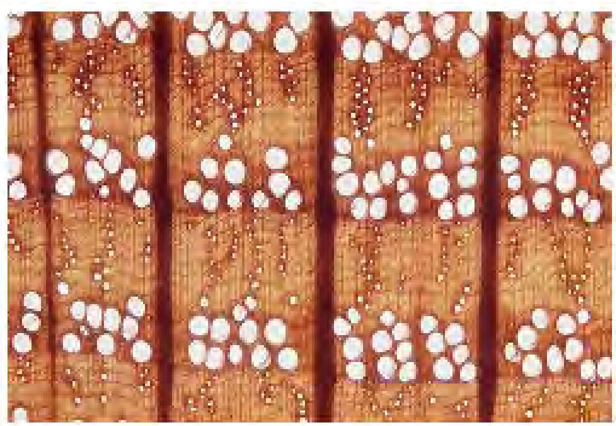



**One of the woods will have small open structures that are actually resin ducts. Don't confuse these with vessels!**



Nonporous wood



Porous wood

**See if you can tell which sample is from an oak, and which sample is from a pine.**

# Exercise 2c. Wood Porosity

- Answer the following questions. Click after each question to see the answer.

**Which sample was pine, and which was oak?**

Sample A is from pine, and sample B is from oak.

**If you dipped chips of pine and oak in soapy water and blew on one end, which one would produce bubbles? Why?**

The oak would produce bubbles due to the presence of pores/vessels.

**What function do pores have in a tree?**

To carry water from the roots through the tree.

**Which wood sample is an angiosperm, and which is a gymnosperm?**

Oak is an angiosperm, and pine is a gymnosperm.

**Which one would absorb the most water if soaked overnight? Why might this be important?**

The oak would absorb more water. Wood used to build outdoor structures should not be very absorbent! Why?

# Exercise 2d. Tennessee's Trees and Their Properties

- Below are some ideas for open-ended explorations on trees and wood properties:

- Do some research on habitats, growth rates, environmental conditions, etc. of the woods in the previous exercises.  Do you think any of these aspects are related to the properties of the wood they produce?

- See if you can find some information on density and porosity of other Tennessee trees.  What factors (see above) could have possible relationships to those properties?

- Do some research on the relative abundance of various tree species in Tennessee.  Are there particular regions of the state where particular species are more common?  Why might this be the case?

# Exercise 3. Forest Products: Trees are Good!

- Trees play extremely important roles in many ecosystems. They help provide:
  - homes for other organisms
  - clean air
  - clean water
  - soil quality
  - erosion control
- However, trees also provide us with many products that are useful to us, such as paper.
  - In one year, the average person uses an amount of paper equal to a tree 100 feet tall and 18 inches in circumference!
- Trees are thus an extremely important renewable resource.
- A renewable resource is one that, if we are careful, is available to us indefinitely.
- This is one of the reasons that it is important that we manage and preserve the planet's forests.

# Exercise 3. Forest Products

- Click one of the underlined exercise names below to go to that exercise.

- In Exercise 3a. That Came from a Tree?!, students in grades K-12 will learn about many products obtained from trees, as well as the parts of trees from which they are made.

- Exercise 3b. Ask the Experts! is an open-ended exploration that encourages students in grades K-12 to learn about forest products firsthand from individuals that produce or sell them.

# Exercise 3a. That Came from a Tree?!

- As a class, try to make a list on the board of materials we use that are tree products.
- Once you have had time to work on this list, try to think of the part of the tree that is the source of each of these materials, such as:
  - Wood
  - Bark
  - Cellulose (material that the plant cell wall is made of)
  - Sap or resin
  - Leaves
- Make a table with columns corresponding to each of the parts above.
- Examine the items in the "Forest Products" container.
- List each item under the column that corresponds to the part of the tree you think the item comes from. On the next few slides are answers. See how many you got right, and correct your table based on the answers.

# There are over 5000 products made from the wood of trees!

## ❑ FROM WOOD

**Toothpicks:** Toothpicks are made from steamed birch logs. The logs are then peeled into a thin sheet. Flat toothpicks are stamped out of the sheets and round toothpicks are fed into a milling machine called a "rounder," which shapes them.

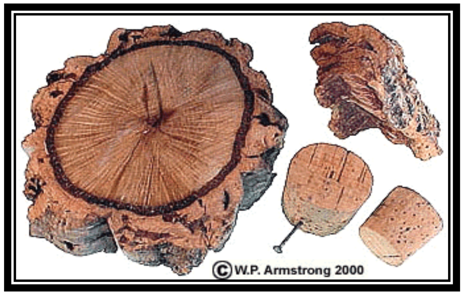
**Clothespins:** Clothespins are manufactured from the wood of a tree.

**Other things made from tree wood: furniture, bridges, wooden spoons, lumber, doors, matchsticks, flooring, chopsticks, bats, guitars, canoe paddles, bird houses, charcoal, tools, toys, fences, boats, ladders, pencils, seesaws, crates, sleds, jewelry boxes, doll houses, dice, and many more.**

# BARK PRODUCTS

**Latex:** Latex is made from a milky, thick liquid, found in the **rubber tree (***Hevea brasiliensis*). Experts can “tap” a tree to harvest it so that the tree is not harmed, just as maple syrup is harvested from maple trees. After the latex hardens, it becomes rubbery. It was named rubber by the British chemist Joseph Priestly, who noticed that it could be used to ‘rub’ away pencil marks.

**Cork:** Most trees have an outer layer of cork bark, but this layer in the tree called **cork oak (***Quercus suber*) is extra thick. Cork oak grows in the Mediterranean region. The thick corky layer helps to protect the tree from harsh conditions, like droughts and fire. The cork layer can be harvested about every 10 years. The tree can regenerate this layer and live for about 150 years.

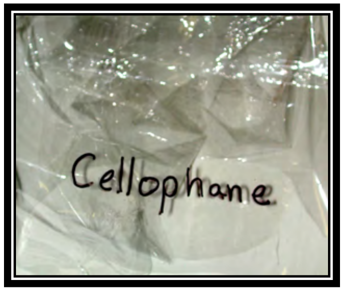



**Aspirin:** Extracts from the bark of the willow tree was the original source of aspirin.

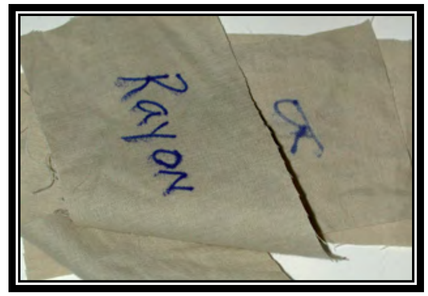
**Some other bark products:** Wax products, tannin, cork products, plastics, adhesives, flooring materials, soil conditioner

## CELLULOSE PRODUCTS

Cellulose is the material that cell walls are composed of in trees and other plants. To obtain cellulose from a tree, the tree bark is removed, and the underlying wood is chipped up, cooked, and chemically treated. The end product is called pulp.

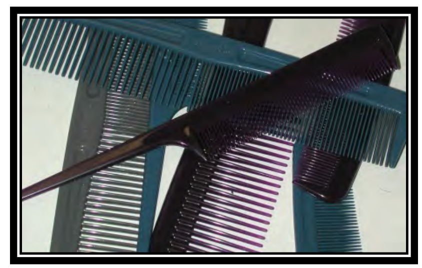



**Cellophane:** Cellulose is further treated so that it forms this type of used to wrap foods to keep them fresh, and to prevent tampering with objects.




**Rayon:** Rayon is made by treating cellulose fibers, just like cellophane.

**Film:** Film is made with a chemical called cellulose acetate, obtained from wood pulp cellulose.



**Plastics:** Plastics made from cellulose fibers are also used to make combs and other items.

# CELLULOSE PRODUCTS (continued)

**Paper products: Paper (**toilet paper, notebook paper, magazines, newspapers, cardboard) is made from cellulose fibers that are strained, washed, and then bleached. Different kinds of pulp are then blended, drained, matted, dried, and compressed to make different types of paper.


**Toothpaste:** Cellulose is also added to toothpaste to give it thickness and texture. (Also terpene, a wood derivative, is often added for the spearmint or peppermint flavors).

**Other cellulose products:** sponges, toilet seats, tool handles, helmets, electrical outlets, nail polish, solid rocket fuel, industrial explosives, eyeglass frames, steering wheels, hairbrush handles, and food thickener in such yummy treats as milk shakes, ice cream, cake frosting, and pancake syrup!

# SAP/RESIN PRODUCTS

Resin is the sticky stuff that a tree secretes to coat a wound. It helps to protect the tree from harmful microorganisms and insects. After making a shallow wound in a tree, the sap that is secreted from the wound is then collected in a tin that is strapped to the tree. This is called “tapping a tree”.


**Gum:** Gum base is what makes some chewing gum chewy. A hard resin, called **rosin** in this case, is added to the gum base to improve the texture.


**Glue:** Some gums are used to make the stickiness of glue and adhesives.


**Soap:** Some gums of certain trees have antiseptic qualities and are therefore used in making soap.

## SAP/RESIN PRODUCTS (continued)


**Maple syrup:** We collect sap by tapping maple trees. This sap is boiled until only the sweet stuff you put on your pancakes remains.

**Oils:** Some essential oils used in aromatherapy are derived from treating certain saps with alcohol.


**Other resin products:** paint, varnish, soap, shoe polish, and turpentine. Musicians use rosin on the bows of their stringed instruments to make the draw of the bow smoother, and baseball players and gymnasts use rosin to improve their grip.

# LEAF PRODUCTS


**Crayons:** The wax from the leaves of the **carnauba palm tree** (*Copernica cerifera***)** is the ingredient that makes your crayons waxy.

**Other uses for leaves:** Compost, essential oils, crafts, and more!

# Exercise 3a. That Came from a Tree?!

**<u>Other important uses of trees:</u>**

- ❑ Oxygen/clean air
- ❑ Clean water
- ❑ Shade
- ❑ Foods
- ❑ Drinks
- ❑ Recreation

**As you can see, forests are very important to us!**

## Exercise 3b. Ask the Experts! (*Open-Ended Exploration*)

- ❑ Can you think of any business in your area that produces or sells wood products?  Some ideas might include:
  - ❑ A sawmill
  - ❑ A lumber supply company
  - ❑ A paper mill
  - ❑ A furniture manufacturer
  - ❑ A logging company
  - ❑ A log home manufacturer
  - ❑ A home improvement store
- ❑ See if you can visit one of these or a similar business to learn more about wood products from someone that is actually involved in their production, and prepare a report to deliver to your class.

# Exercise 4. Who Lives Here?

- **Forests are not just a place for trees! The forest is a home for many animals of all kinds.**
- **While trees do create homes for animals within them, they also help create habitat in other ways.**
  - **Providing shade**
  - **Protection from wind/humidity**
  - **Promotes growth of other plants that could not normally live there**
  - **Nooks and crevices in root systems**
- **In part, trees also provide many animal homes because they extend the available habitat well above the forest floor.**

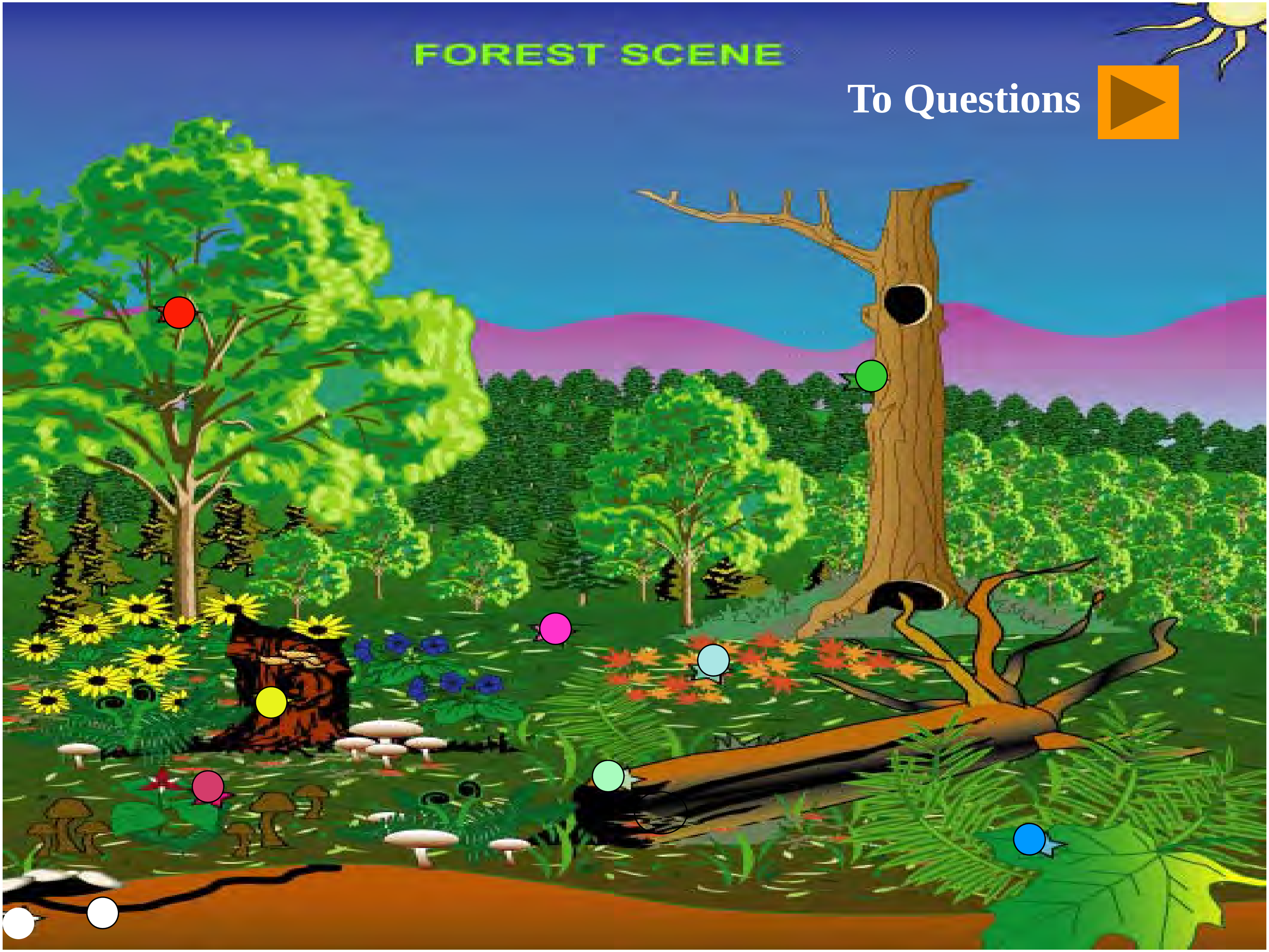
# Exercise 4. Who Lives Here?

- **Trees also provide many animal homes because they extend the available habitat well above ground level:**
  - **In the canopy**
  - **Along the trunk**
  - **Leaf litter on the forest floor**

- **Animals also vary in the space that they need.**
  - **Some wander throughout an entire forest.**
  - **Others may only use the space of a single leaf.**

# Exercise 4. Who Lives Here?

- Divide the class into small groups.
- Spread the deck of habitat cards face down on the front table.
- Spread the animal deck face up on the table so that all animals can be seen.
- The first group should pick up a habitat card and describe the habitat to the class.
- Locate this habitat on the scene (next slide). **HINT: Look at the colored circles!**
- Have the group try to find an animal card with an animal that would live in that habitat.
- Click on the colored circle on the scene to see if the match was correct. Remove cards for which correct guesses are made.
- Repeat until all groups have had an opportunity to match an animal with a habitat, or until all of the matches have been made.


FOREST SCENE
To Questions

# Exercise 4. Who Lives Here?

- ❑ **Have a class discussion to answer the following questions:**

**In what ways does each animal depend on the forest?**

**Click for the answer!**

**Many of these animals use forest habitats for shelter. Other animals may visit the forest to forage for food (such as nuts, berries, insects, etc.) that can only be found in a forest ecosystem. Others may use the clean waters of forest streams for activities such as drinking water or laying eggs.**

# Exercise 4. Who Lives Here?

**How might the forest help an animal that may not even use trees to live in?**

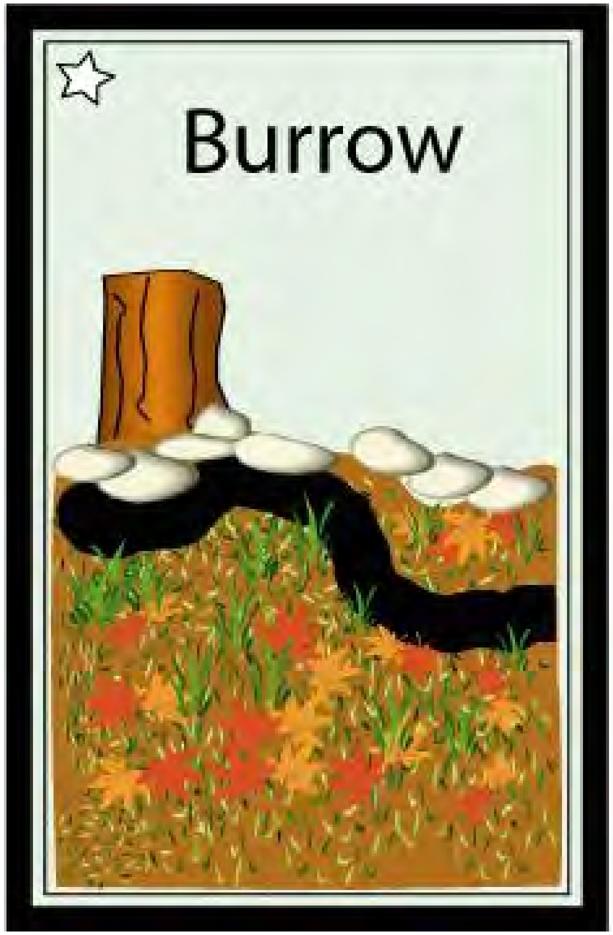
**Click for the answer!**

**The forest is a host to many plants and animals that are food for other animals. For instance, an animal that visits the forest may eat insects that primarily live in the forest.**

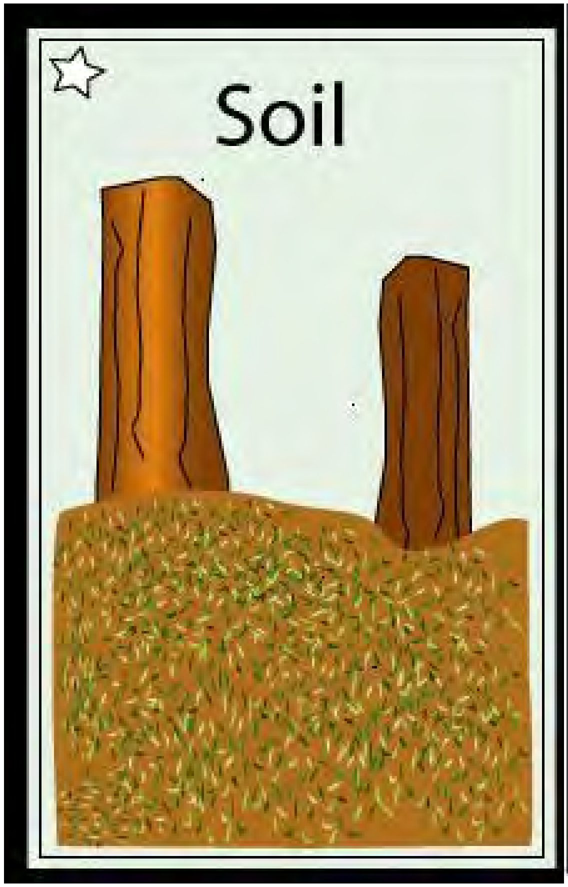
# Exercise 4. Who Lives Here?

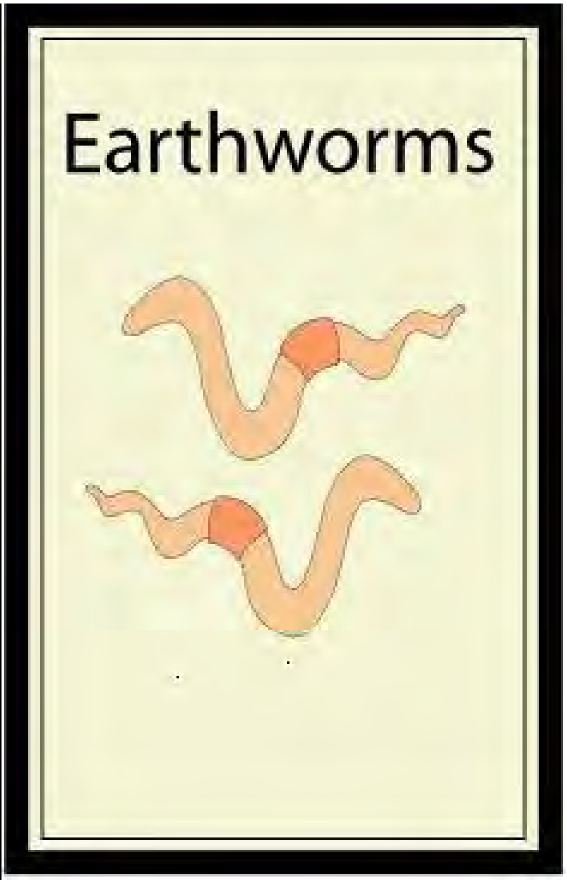
**Which animals do you think might change the forest and what do they do to influence it? Click for the answer!**

**Some animals (moles, mice, foxes, chipmunks, earthworms, termites) dig burrows that help aerate the soil. Some organisms (lizards, frogs, snakes, spiders, birds, and sometimes mammals like mice, chipmunks and even foxes and coyotes) prey on insects (such as the maple leaf miner, termites, and cicada) and other invertebrates (such as the snail) that feed on trees and other plants. Some mammals (such as the deer, mice, chipmunks, and sometimes even foxes and opossums), also eat plant material, including leaves, shoots, fruits, and seeds of trees and other plants. However, these animals also often help disperse seeds to new locations, either in their fur, by dropping them, or passing them in their feces. Some organisms, such as bees, hornets, and ants, and even birds like the hummingbird, act as pollinators. Major predators, such as owls and coyotes, prey on a wide variety of other organisms. Scavengers like the opossum also help clean up dead organisms, reducing the spread of diseases. Organisms like millipedes eat and help break down fallen leaves, helping process them to eventually become soil.**

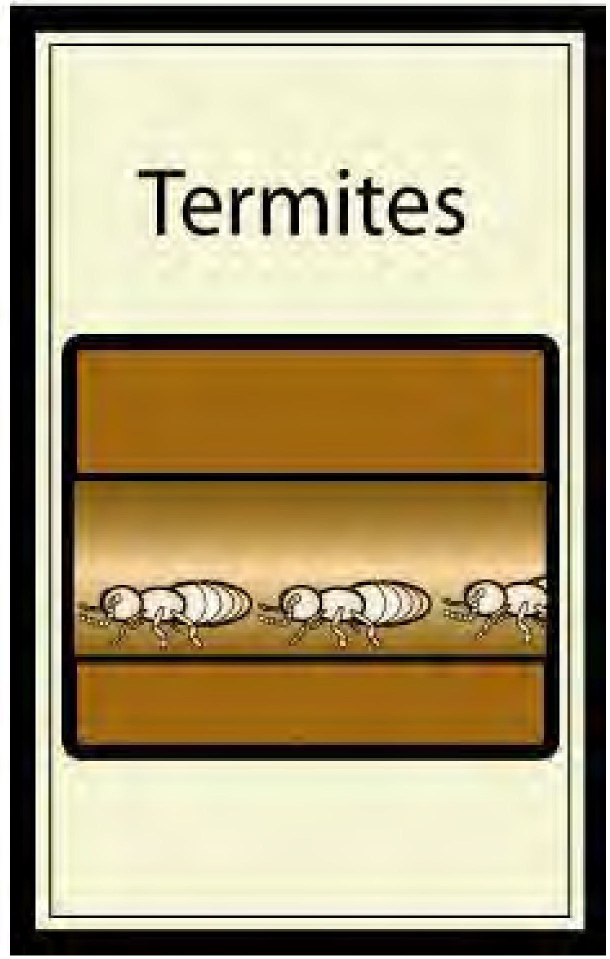

Burrow


Mole


Soil


Earthworms

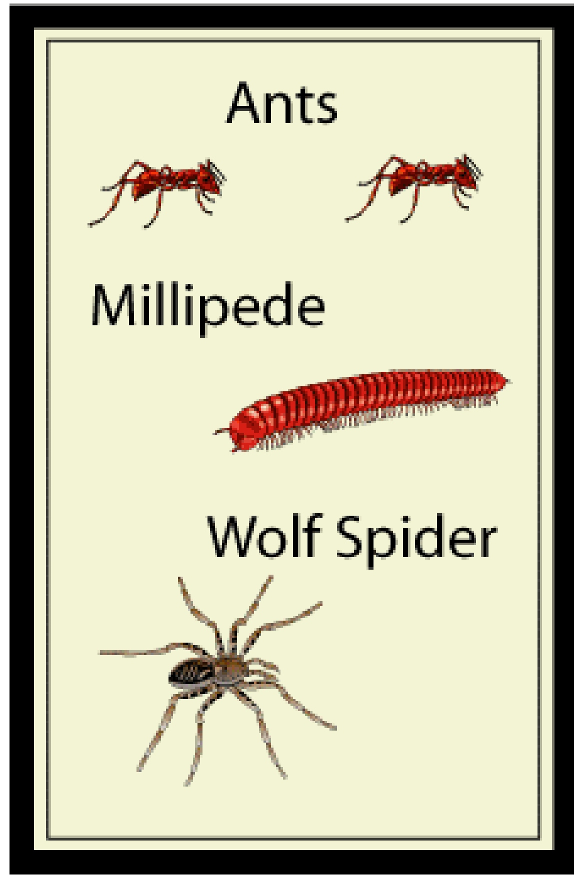

Fallen Log


Termites

Tree nest

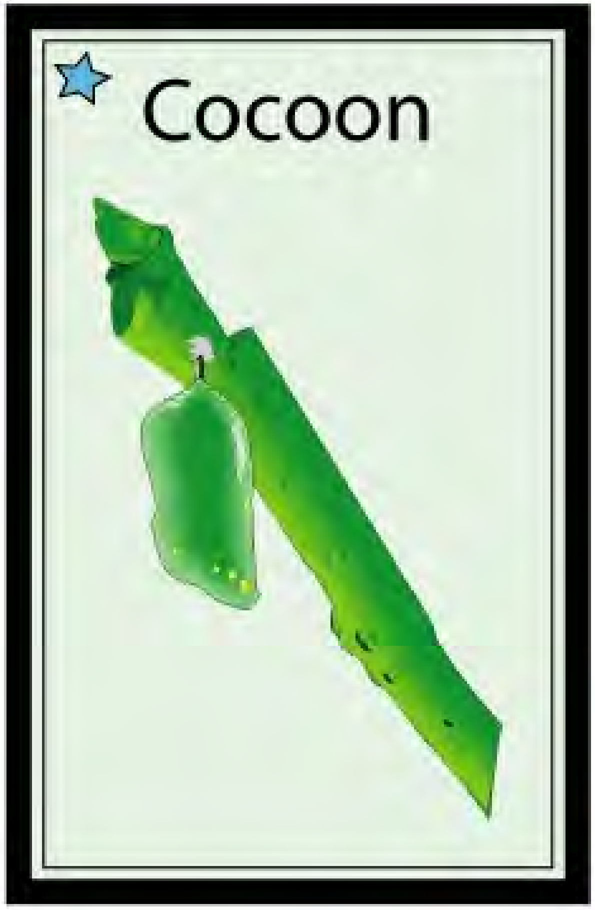
Chipping Sparrow


Leaf Litter


Ants
Millipede
Wolf Spider


Maple
Leaf

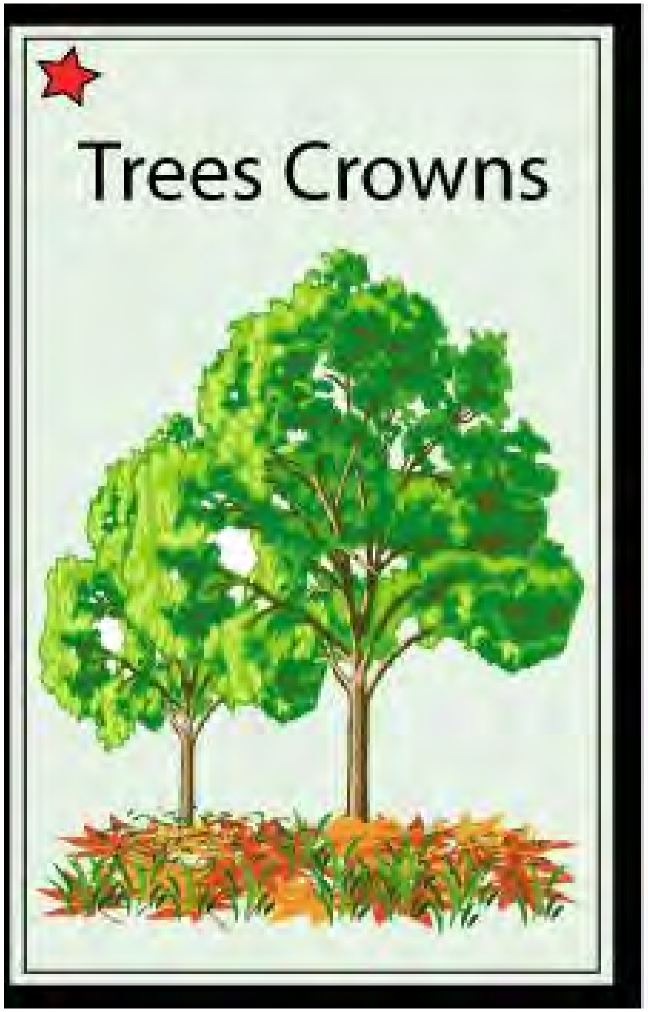

Maple Leaf
miner


Cocoon


Butterfly

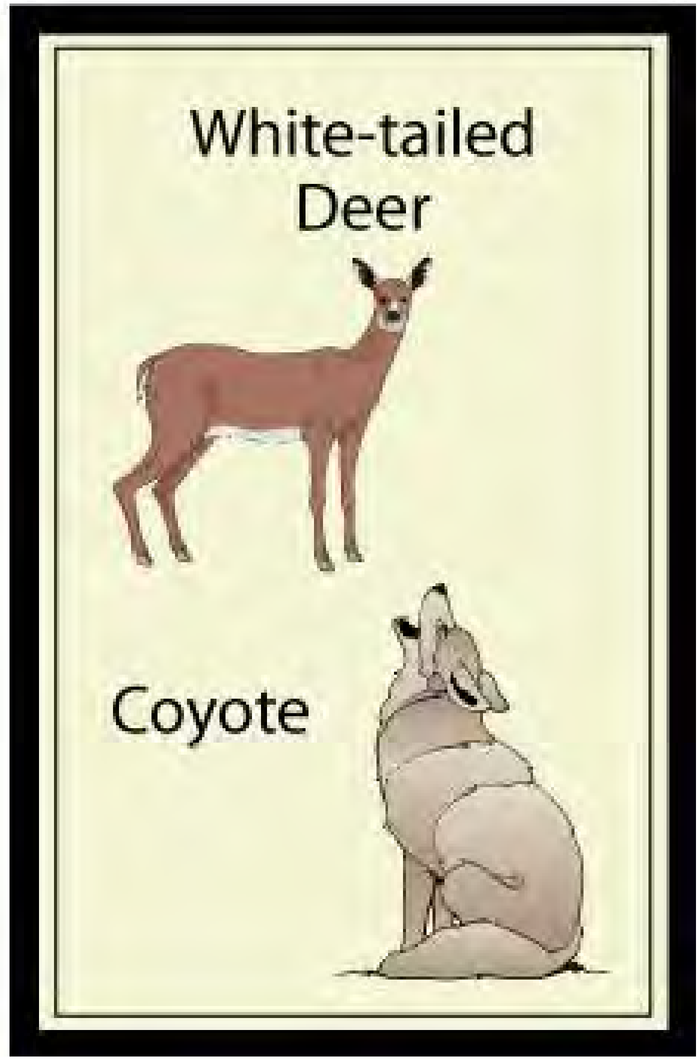

Tree Trunk

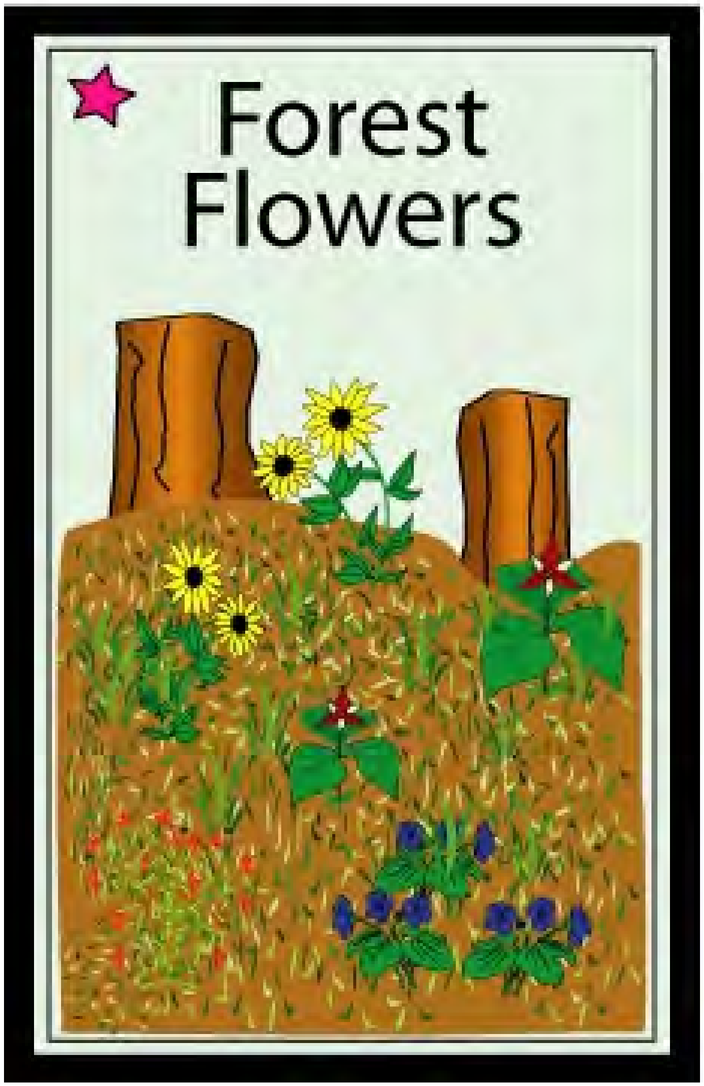

Fence Lizard
Cicada


Trees Crowns

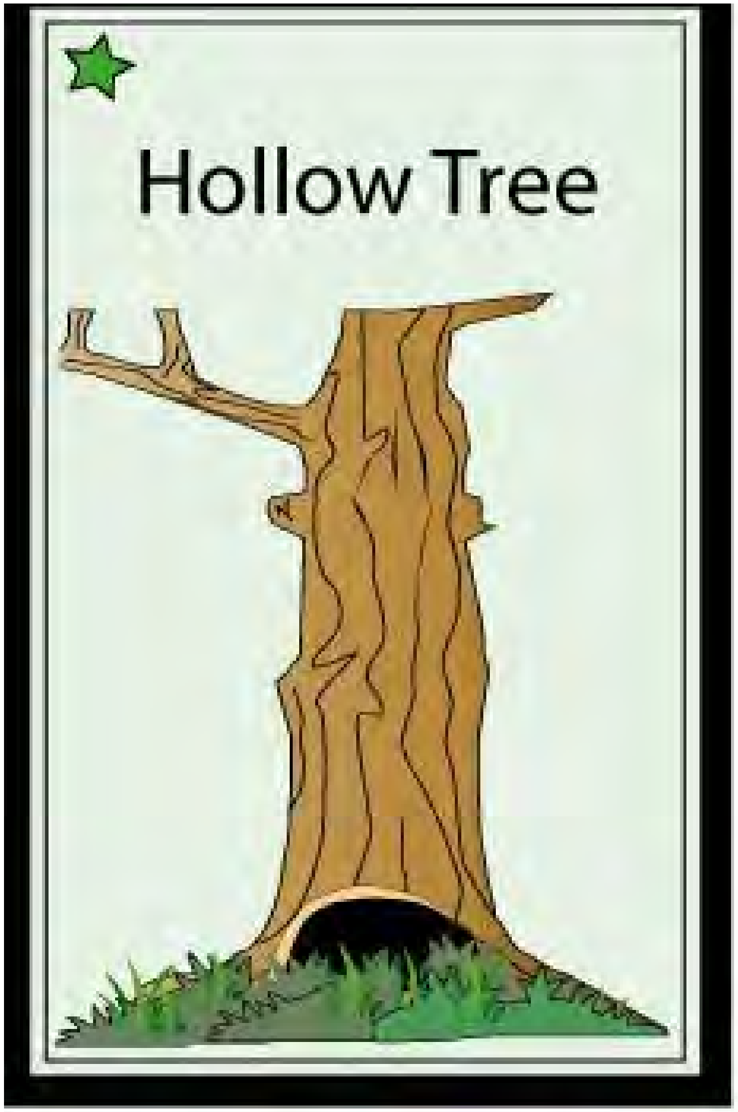

Opossum
Hornet
Nest
Blue Jay

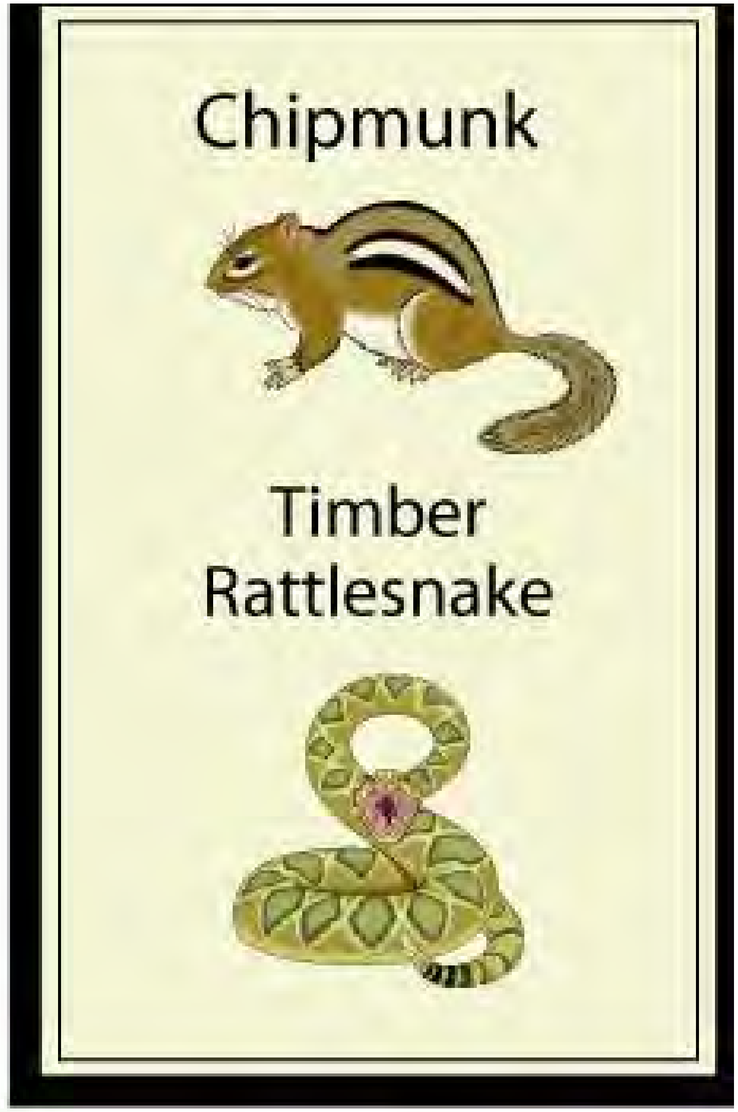

Forest
Floor


White-tailed
Deer
Coyote


Forest
Flowers


Honey Bee
Hummingbird


Hollow Tree


Chipmunk
Timber
Rattlesnake

# Exercise 5. Forest Succession

- **The forest is an ecosystem that is influenced by numerous factors.**

- **An external or internal influence, whether natural or human, can completely change the structure of a forest and the habitats within it.**

- **For instance, lightning may strike a large old tree in a mature forest, leading to a fire that spreads throughout it.**

- **In its wake, this fire may leave patches within the forest with no vegetation at all, and may also kill those tree species that lack fire resistance.**

# Exercise 5. Forest Succession

- **This allows the growth of plants that were unable to grow in the shade of the large tree canopy, as well as a shift to pines and other tree types that are adapted to fires.**

- **These trees might have already been present in low numbers, kept in check by the more shade tolerant large canopy trees.**

- **The resulting vegetation shifts attract different animal species to the forest as well.**

- **This kind of effect is called a cascade. Something happens to a dominant species, and this affects other species which affects other species and so on.**

# Exercise 5. Forest Succession

- **The observed change in forest composition, however, is not permanent.**

- **Over time, the forest as it was composed before the burn, returns.**

- **This process of recovery from a disturbed forest to a mature forest is called succession.**

- **The maturation process is not one that will be completed in 10-20 years, but even within this time period you would see a shift in the plant species present from those taking over immediately after the fire.**

# Exercise 5. Forest Succession

- **In order to maintain the health of a forest system you must first understand it.**

- **Foresters work to understand the presence of influences and their subsequent effects on forest interactions.**

- **One thing is certain. The forest is always changing.**

- **Your job will be to try to make it a stable mature system, but the deck may be stacked against you!**

# Exercise 5. Forest Succession

- Click one of the underlined exercise names below to go to that exercise.

- In Exercise 5a. The Succession Game, students in grades 6-12 will play a game that simulates forest succession, and the external forces that affect the process.

- In Exercise 5b. Probability in the Forest Succession Game, students in grades 6-12 will learn more about probability by examining its role in Exercise 5a.

# Exercise 5a. The Succession Game

## The Situation

- You have acquired a large tract of land planted with a hardwood tree species (say black walnut) whose wood is valuable to the furniture trade.

- Across this property, there are different levels of tree growth and some areas with no tree growth at all.

- Think of your property as a mosaic of forest patches that are in different stages of succession from disturbed (bare soil) to mature (mature tree) and finally to senescent (old/dying trees) in a managed forest plot (planted and maintained by foresters).

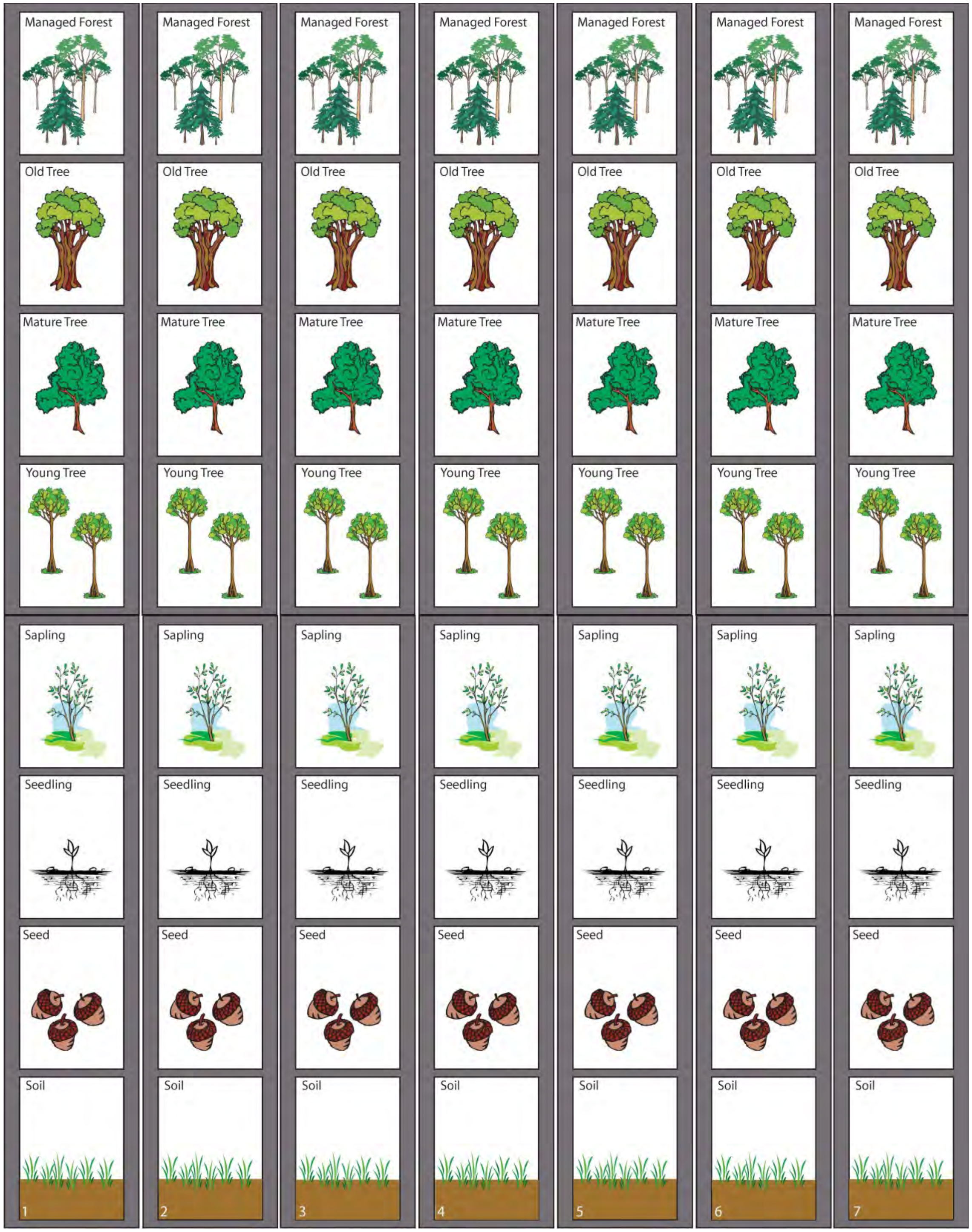
# Exercise 5a. The Succession Game

- Study the board to see the patches of different successional stages available:
  - bare soil
  - seed
  - seedling
  - sapling
  - young tree
  - mature tree
  - old tree
  - managed forest

- Each column represents a stage of growth of a patch of trees, each 10 acres in area (not just one tree).

- The position of the paper clips in the column will determine the growth stage of each forest patch.

# Succession Game Board *handout*



# Exercise 5a. The Succession Game

- Your teacher will provide each student or group of students a copy of the game board & 14 paper clips (7 each of 2 colors).
- Remember, each column on the game board represents a patch in the forest 10 acres in area (NOT just a single tree).
- To start, place one paper clip each of a single color on the following squares in any order, with one clip per column.
  - Soil patches: 2
  - Seed patches: 2
  - Seedling patches: 1
  - Sapling patches: 1
  - Young tree patches: 1
  - Mature tree patches: 0
  - Old tree patches: 0
  - Managed Forest patches: 0

# Exercise 5a. The Succession Game

- Each round of play represents the passage of time.

- Each round will consist of:

  - Going through a set of rules described on the Rules Sheet (on a later slide) to determine where your clip moves within each column (or each patch of your land).

  - Choosing a card from the “External Forces” deck to see how the structure of your forest changes because of outside forces.

# Exercise 5a. The Succession Game

## In each round:

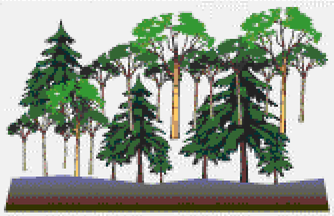
1. Go through the rules on the next slide. Place a paper clip of the second color on the new space to indicate growth/succession, as specified by the rules.
2. Remove all the paper clips of the first color.
3. Choose a card from the "External Forces" deck, and follow the directions on it.
    - If no clips can be moved, start another round.
    - If the card asks you to move more clips than you have available, just move as many as you can and start a new round.
4. Record the stages for each patch.
5. Repeat steps 1-4 for 10 rounds.

# Exercise 5. Forest Succession Game Rules

**In each column, move a clip up to the next stage if it meets any of the following criteria:**

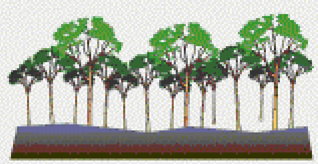
- **Soil patch is next to a mature, old, or managed forest patch. (The bare soil needs a seed source from surrounding adult trees.)**
- **Seed patch is next to a soil, seed, seedling, or sapling patch. (These seeds will germinate faster if there is no dense canopy above them to block the sunlight.)**
- **Seedling patch is next to a soil, seedling, or sapling patch. (These seedlings grow faster if there is no dense canopy above them to block the sunlight.)**
- **Sapling patch is next to a soil, seed, seedling, sapling, or young tree patch. (These saplings grow faster if there is no dense canopy above them to block the sunlight.)**
- **Young tree patch is next to a soil, seed, seedling, sapling, or young tree patch. (These young trees will grow faster if there are no older trees to out-compete them.)**
- **Mature tree patch is next to a soil, seed, seedling, sapling, or young tree patch. (These mature trees will grow faster if there are no older trees to out-compete them.)**

# Exercise 5. External Forces Cards



You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

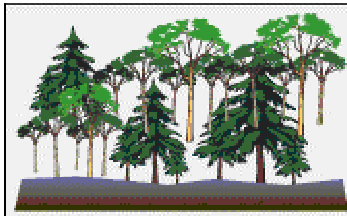


Severe flooding can damage a tree's roots and drown saplings.

Move a sapling patch to a soil patch.

When a large tree falls to the ground it leaves a gap in the canopy. More sunlight can get to the saplings growing in the understory.

Move two old tree patches to sapling patches.



You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

Lightening strikes can kill trees and cause forest fires.

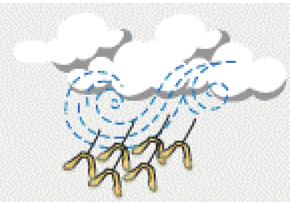
Move two mature tree patches to soil patches.

Diseases that escape to forests can impair the functions of a tree and keep it from making its own food.

Move one young tree patch to a soil patch.

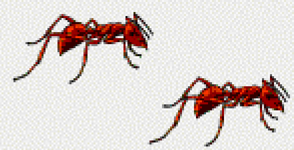
You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again



Wind is an important factor in bringing new seeds to a forest. The wind brings in some types of seeds that can be carried by wind.

Move one soil patch to a seed patch.



Some insects damage trees by eating the wood. If enough damage is done the tree will die.

Move one mature tree to a seed patch and one old tree patch to a seed patch.

You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

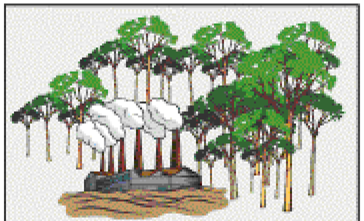
**To instructions**

**Next External Forces cards**

# Exercise 5. External Forces Cards

You decide to harvest some of your older trees to sell to a timber company.

Choose an old, mature, and managed forest patch and move them to soil patches.

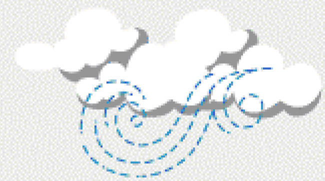


Air pollution from nearby industries can damage trees. Trees need clean air to function properly.

Move one mature tree and two old tree patches to seed patches.

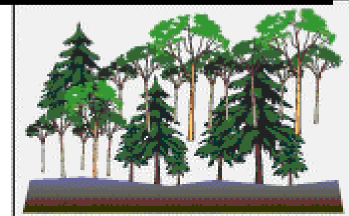
You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again



Storms that bring in strong winds can damage trees that are weak and vulnerable.

Move two mature tree patches to soil patches.

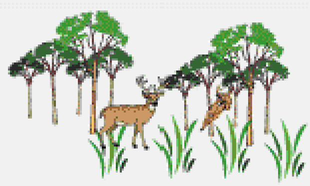


You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

Heavy machinery used improperly can compact the ground and cause root damage, crush saplings, and make it hard for seeds to push up through the ground.

Move one sapling patch to a soil patch.



Deer and other grazers like to browse on tree saplings.

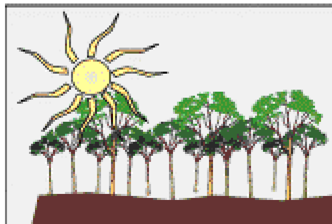
Move one sapling patch to a soil patch.

You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

Dirty water in a nearby stream can be absorbed by the tree roots and hurt the health of the tree.

Move two mature tree patches to a seed patches.



Severe drought can keep a tree from making its own food if the leaves and roots cannot absorb water.

Move a mature and an old patch to a soil patch.

**To instructions**

**Next External Forces cards**

# Exercise 5. External Forces Cards

Fire has an important role in forests. While a hot fire can kill some adult trees, a mild fire can help stimulate seeds in the soil. Some seeds need the heat of a fire to begin growing.

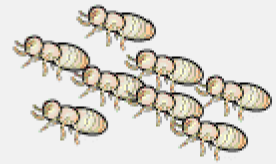
Move a young tree patch to a seedling patch.

Stumps left from dead or harvested trees can sprout new saplings.

Move two mature patches to sapling patches.

Tornados can cause a lot of damage to forests. Weak trees may break or fall in high winds and tornados.

Move two old tree patches to seed patches.

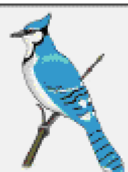


Insects can cause damage to trees by eating the wood. Sometimes, if the insect population is large, then the number of dying trees can be quite large.

Move one mature and one young tree patch to soil patches.

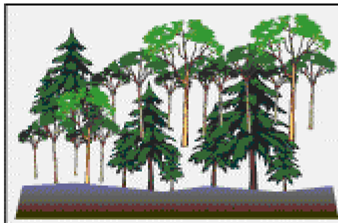
You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again



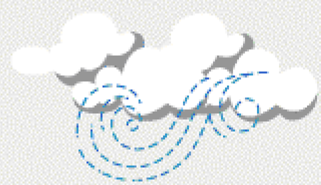
Birds can bring in seeds from other forests by carrying fruit and nuts that they want to eat. After eating the fruit the seed is left behind.

Move one soil patch to a seed patch.



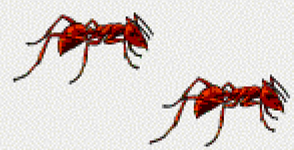
You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again



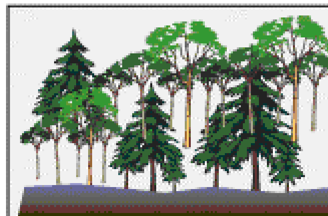
Storms that bring in strong winds can damage trees that are weak and vulnerable.

Move two mature tree patches to soil patches.



Some insects damage trees by eating the wood. If enough damage is done the tree will die.

Move one mature tree to a seed patch and one old tree patch to a seed patch.



You have successfully managed a patch on your land so that it is more resistent to damaging forces. Choose a mature or old patch and move it to a managed forest patch.

Draw again

**To instructions**

# Exercise 5a. The Succession Game

**Answer the following questions as class discussion after students have completed the exercise. Click after each question to see the answer.**

**What did you notice about the stability of the forest?**

> **Different students will have different answers depending on the outcome of their trials. The only constant answer would be that the forest is always changing due to natural succession and external forces, but that trees do grow back in time.**

**What factors helped patches advance in succession?**

> **When tree patches were next to patches either the same age or younger than them, which minimizes competition. Also, soil patches near mature or old trees provide places for seeds to sprout and grow.**

# Exercise 5a. The Succession Game

**Click after each question to see the answer.**

**How can managers use these trends to manage stable forests?**

**By observing stages that benefit most from being near other stages, and planning harvests to promote growth of nearby patches. Also monitoring for patches in need of seed, and planting them.**

**What factors caused you to lose trees?**

**Fire, pests, herbivory, weather, pollution, other human activity. These represent real factors that can result in loss of trees from forests.**

# Exercise 5a. The Succession Game

**Click after each question to see the answer!**

**What strategies can you use to help you reach the goal of a forest of mature trees?**

**Planting seeds in bare patches, thinning canopies to encourage understory growth, managing against pests, managing to maintain wildlife that promote forest growth, and many others.**

**What could you do to help induce bare patches to produce trees faster?**

**Manual planting of seeds and/or seedlings.**

# Exercise 5a. The Succession Game

**Click after each question to see the answer.**

**What patch type(s) were least likely to change? Which was/were most likely to change?**

> **Managed forest and bare soil are least likely to change. Managed forests generally are managed to promote stability. Bare soil (which could represent a clearcut) takes a long time to become a mature forest. Seed, seedling, sapling, and young tree patches are most likely to change. This reflects the fact that young trees are more vulnerable to all sorts of damage.**

**If all patches started in the mature stage, what do you think would happen? Try it!**

> **You would be unable to proceed in succession until external forces cause some patches to change. This might seem ideal to managers, but due to external forces, change can still happen at any time!**

## Exercise 5b. Probability in the Succession Game

- Games often use probability, or the likelihood that something will occur, to make the game interesting.
- In a coin toss game, you must guess if a coin will land on heads or tails.
- There is a chance you will be right, and a chance you will be wrong.
- Probability is simply a ratio:

  Probability = # of desired outcomes/# of possible outcomes
- In the coin example, there is one desired outcome: your guess, and two possible outcomes (heads or tails).
- Thus, the probability you will guess correctly is equal to

  Probability = ½ = 50%
- This is the theoretical probability of success.
- However, if you guessed on 10 coin tosses, you may get 6 correct (or a different number).
- Though this differs from the theoretical probability, if you repeated the coin toss many, many times, you would expect to get close to 50% of the tosses right.
- However, the element of chance/uncertainty is what makes games fun!

## Exercise 5b. Probability in the Succession Game

- **You can use probability to think about the difficulty of aspects of games.**
- **For example, you could figure out how difficult it is for a mature or old tree patch to move to a managed forest patch in the previous game.**
- **The only way to do this is to draw a favorable card.**
- **First, you would count the total number of *possible* outcomes (cards that can be drawn). There are 27.**
- **Then, you would count the number of cards that would result in advancing a mature or old patch to a managed patch. There are 9 such cards.**
- **So, the probability that you would advance one of these patches would be**

**Probability = 9/27 = 33.3%**

- **Look at all the External Forces cards, and use them to answer the questions on the following slides.**

## Exercise 5b. Probability in the Succession Game

**What is the probability that you will draw a card that causes insect damage?**

**Click for the answer!**

**There are two cards that cause insect damage. The theoretical probability is thus 2/27 = 7.4%.**

**What is the probability that you will draw a card that will result in moving a patch back to bare soil?**

**Click for the answer!**

**There are nine cards that move patches to bare soil. The theoretical probability is thus 9/27 = 33.3%.**

**What is the probability that you will draw a card that causes damage from humans?**

**Click for the answer!**

**There are four cards that involve damage from humans. The theoretical probability is thus 4/27 = 14.8%.**

## Exercise 5b. Probability in the Succession Game

**What if you wanted to make the game easier to move from an old or mature patch to a managed one. How many cards would you need to remove from the deck to make the probability of advancing to a managed forest patch equal to 50%?**

**Click for the answer!**

- **There are 9 cards with the desired outcome. One way we could think about this is to set up an equation to solve for the total number of cards needed in the deck.**
- **Since 50% is equal to ½, ½ = 9/x, where x is the total number of cards needed in the deck.**
- **Solving the equation, we see that there are 18 cards needed.**
- **Since there are 27 cards in the deck, you would need to remove 9 cards that didn't achieve the desired result.**

**Draw five random cards from the deck. Based on your results, what is the probability of moving a mature or old patch to a managed one?**

**Click for the answer!**

**Your answers will vary, and that is the point to notice!**

## Exercise 5b. Probability in the Succession Game

- You can use probability to think about the difficulty of aspects of games.
- For example, you could figure out how difficult it is for a mature or old tree patch to move to a managed forest patch in the previous game.
- The only way to do this is to draw a favorable card.
- First, you would count the total number of *possible* outcomes (cards that can be drawn). There are 27.
- Then, you would count the number of cards that would result in advancing a mature or old patch to a managed patch. There are 9 such cards.
- So, the probability that you would advance one of these patches would be

**Probability = 9/27 = 33.3%**

- Look at all the External Forces cards, and use them to answer the questions on the following slides.

# Exercise 6. Forest Pests

- Every forest has pests that can cause damage or spread disease to the trees within it. Such organisms include viruses, bacteria, fungi, nematodes, parasites, and insects, as well as others.
- Some pest damage is unavoidable and can even be healthy for a natural forest ecosystems by helping remove stressed trees.
- Since the relationships of forest trees with native pests have co-evolved over thousands of years, native pest species rarely lead to the catastrophic loss of a forest.
- However, poor management techniques and the introduced species can devastate a forest ecosystem and even cause the local extinction of some tree species.
  - Humans can interrupt the natural defenses that evolved within the system we are changing.
  - In the case of exotic pests, the forest has not evolved with these organisms and may be defenseless against attack.

# Exercise 6. Forest Pests

- **Pests may damage leaves, roots, or stem tissues, which severely reduces the tree's ability to function in a healthy manner.**
- **One good example of how pests have affected forests is the case of the American chestnut.**
  - The chestnut once dominated southeastern forests.
  - However, in the early 1900s, a fungus, called chestnut blight, was accidentally introduced in imported lumber.
  - By the 1940s, the American chestnut was almost completely wiped out by this disease, and now exists only as sprouts from stumps of long dead trees.
  - Pests that are on their way or are already a problem in southern forests number in the hundreds.
- **Other major southeastern forest pests that you may have heard of include dogwood anthracnose and the hemlock wooly adelgid.**

# Exercise 6. Forest Pests

- Modern forest management techniques include protecting our forests against these pests as foresters continuously work to try to stay ahead of any impending attacks.

- These techniques can also be modified to meet the specific goals of the landowners for their forests, such as:
    - timber to sell
    - recreation
    - hunting
    - aesthetics
    - habitat quality
    - sentimental reasons

# Exercise 6. Forest Pests

- **This activity presents a simplified exercise for one struggle that a tree plantation manager might face, using an example of a real pest, the Southern Pine Beetle (*Dendroctonus frontalis*).**

- **It will help you to understand some of the factors that influence the level of damage within a forest.**

- **You will learn some simple methods of management that can help improve forest resistance to disease.**

# Exercise 6. Forest Pests

- The Southern Pine Beetle is a native forest pest of pines, and is considered the most destructive pine pest in the southeast.
- Females bore into trees and send out pheromones to attract mates. The damaged tree also releases chemicals that attract other beetles.
- Once inside the bark, the beetles reproduce, and both the larvae and adults feed on phloem tissue.
- When feeding, the beetles chew serpentine (winding) tunnels and galleries into the living inner bark.
- This eventually cuts off the food supply of sugars to the tree and kills it, and the beetles spread to nearby pines.
- Pass around the bark sample so that everyone can see the evidence of pine beetle damage in it.
- One sign of beetle damage is the presence of popcorn-like blobs of pitch (resin) called pitch tubes on the outside of the bark. These are formed when resin leaks out of beetle entry points.

# Exercise 6. Forest Pests

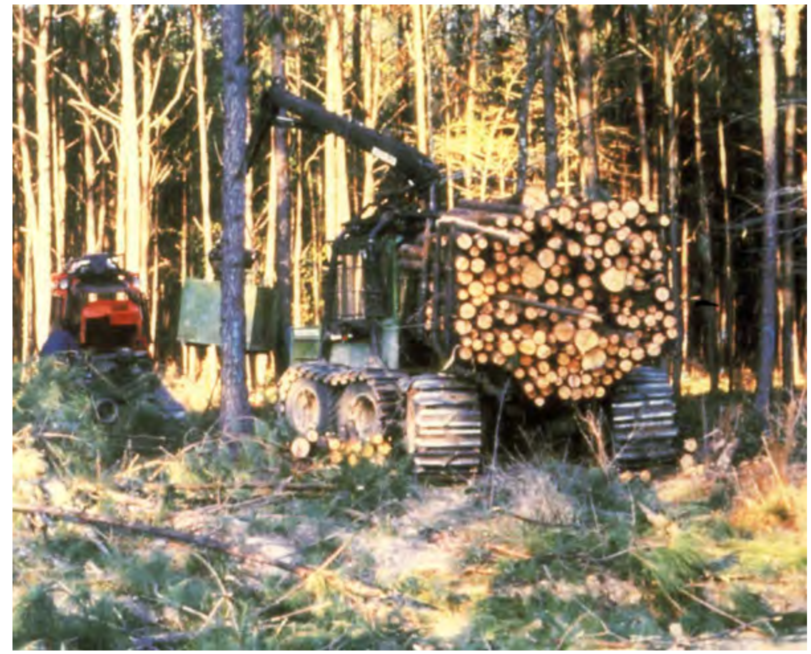


**Above:** The Southern Pine Beetle (*Dendroctonus frontalis*).
**Above Right:** Damage to a pine's inner bark (phloem tissue) caused by the beetle, showing the characteristic serpentine galleries.
**Right:** Pitch tubes show external evidence of Southern Pine Beetle infestation.

# Exercise 6. Forest Pests

- **These aggressive beetles can attack and kill large tracts of pine in one growing season.**
- **Beetle outbreaks (huge population numbers) occur on a cycle of every 7-10 years in local areas.**
- **Most infestations are limited to small areas but occasionally these infestations can sometimes kill thousands of acres of pines.**
- **After infestation, forest managers remove infected trees and some surrounding healthy trees to act as a buffer to stop the infestation.**
- **However, this can be challenging, as adult beetles can fly up to around 2 miles.**
- **Another strategy used with pests is planting zones of different tree species in a plantation.**
- **This is because many pests are specific to one species, so this can help disease stop from spreading widely.**

# Exercise 6. Forest Pests



**Above Left:** An aerial photo showing a large scale infestation of the Southern Pine Beetle.  All of the reddish-brown trees are pines killed by beetle damage.

**Above Right:** Foresters removing infected pines and a buffer zone of surrounding healthy pines in an attempt to curb further infestation.

# Exercise 6. Forest Pests

- In this exercise, you will imagine you own a tract of land planted with pines with a goal to sell them for pulp & timber.
- Your challenge is to maximize your profits while faced with possible infestation by Southern Pine Beetles.
- For simplicity, in this exercise, we will imagine that the beetles reproduce at regular one year generation intervals, spreading to new patches of trees each year.
- However, in reality, they may spread even faster!
- Below is a table showing hypothetical profits for pine patches (both infected and uninfected) at various ages. You will need to have these values handy for this exercise, so copy this table!

| **Age (years)** | **Price for uninfected patch** | **Price for infected patch** |
|---|---|---|
| 1 | $100 | $40 |
| 2 | $150 | $50 |
| 3 | $200 | $60 |
| 4-6 | $250 | $70 |

# Exercise 6. Forest Pests

- In this exercise, you will conduct several different simulations depicting various scenarios in terms of planting and management strategies:

- First, you will simulate the situation of Southern Pine Beetle infestation in a monotypic stand (a stand that contains only one species, in this case, the cash crop – pine).

- Next, you will simulate the effects of a plantation that consists of pines and buffer zones of another species.

- Finally, you design a planting scheme for your own mixed stand, to see if you can maximize your profits while minimizing the extent of beetle infestation.

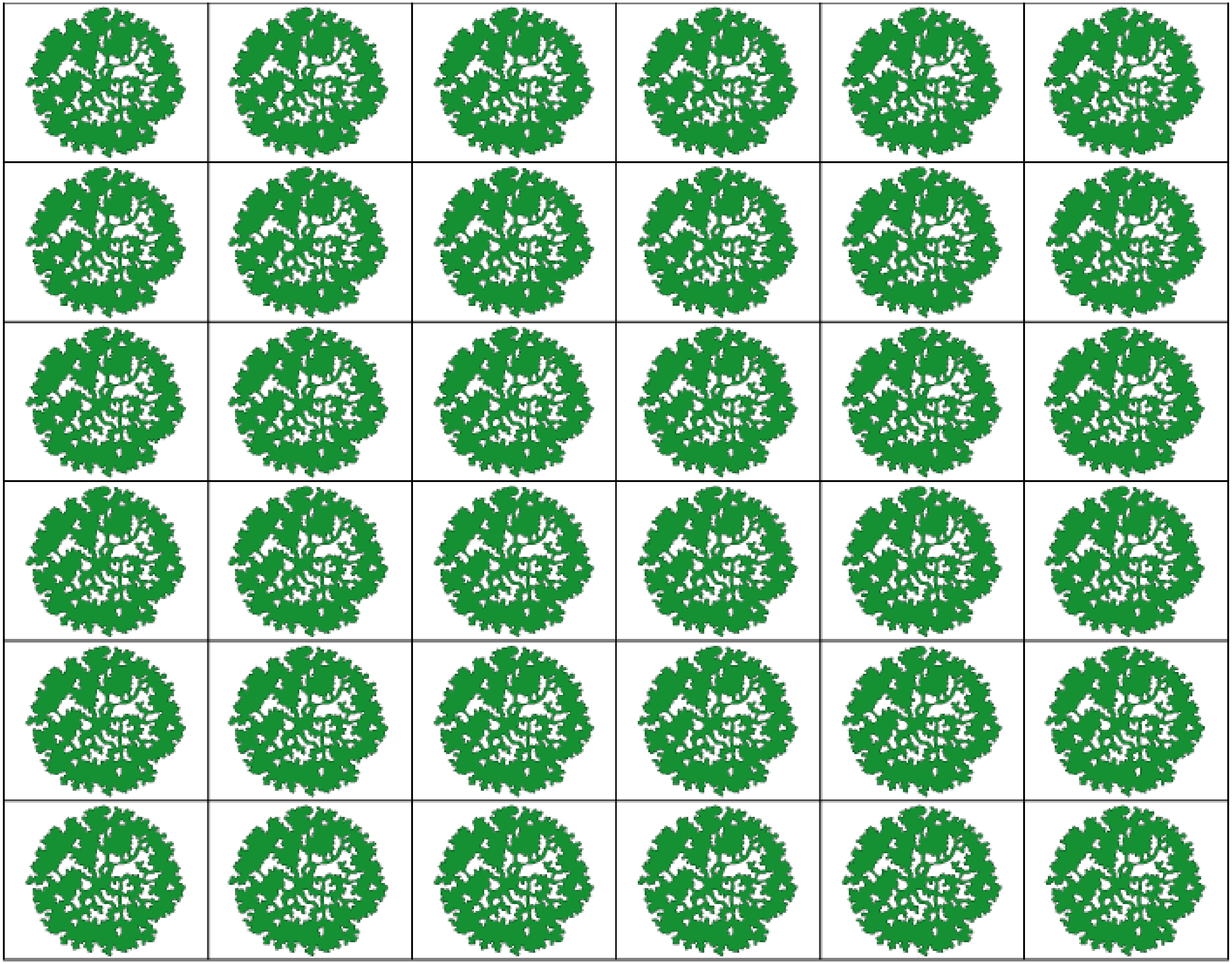
# Exercise 6. Forest Pests

- **Click one of the underlined exercise names below to go to that exercise.**
- **In Exercise 6a. Infestation in a Monotypic Stand, students will learn about the possible consequences of planting in monocultures.**
- **In Exercise 6b. Infestation in a Mixed Stand, students will learn about how strategies of mixed species planting can affect spread of pest infestations.**
- **In Exercise 6c. Managing Your Own Mixed Stand, students will design their own mixed stands in attempts to maximize profits while minimizing losses to pests.**
- **Exercise 6d. Bugs? In Our Trees?! is an open-ended exploration for students to research forest pests historically or currently associated with TN forests.**

# Exercise 6a. Infestation in a Monotypic Stand

- Find the game board covered with images of tree crowns of only one color.
- This represents your land, with 36 plots of pine.  Each crown on the grid **represents a plot of pines**, not just one tree.
- Choose any plot on the board, and place a paper clip on it. **This represents the initial infestation point of the Southern Pine Beetle.**
- This means that you now have only 35 healthy plots.
- Make a table like the one on the following slide, and fill it in for Year 1.
- For each following year, any plot adjacent to an infested plot (including diagonals) also gets infected.  Add a clip to each newly infected plot.
- Continue to fill out your data table, keeping track of the number of healthy and infected plots, and your potential profits if harvested, for each year.
- To calculate the potential profit, you will need the price data from the table on an earlier slide.

# Monotypic Stand Game Board



# Exercise 6. Forest Pests

- Below is an example table for calculating the best time and scenarios to maximize profits from harvesting when a plantation is infested with Southern Pine Beetles.
- You will use a table like this for each scenario in this exercise.

| Year | Healthy Plots | Infected Plots | Profit if Harvested |
|---|---|---|---|
| 1 | 35 | 1 | (35 x \$100) + (1 x \$40) = \$3540 |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

# Exercise 6. Forest Pests

- ❑ Using the data in your table, make a plot of the number of infected plots over time.

- ❑Plot time (in years) on the x-axis, and number of infected plots on the y-axis.

- ❑You may also wish to make a separate plot showing your profits over time, with time on the x-axis, and profit from a harvest of all pines on the y-axis.

- ❑Now answer the questions on the following slides.

# Exercise 6. Forest Pests

**Click after each question to see the answer!**

**What happened to the pine plantation?**

**Most or all of it was infested by year 5.**

**What is the health of the plantation in year 5?**

**Not healthy at all!**

**What year should you harvest to maximize profits?**

**This will vary based on your initial infestation point.**

**What is a disadvantage to having a monoculture?**

**It will be devastated if a pest attacks.**

**What are some solutions to keep an infection contained?**

**Buffers of other species or gaps larger than beetle dispersal ability.**

**Where would you want an infestation to start to have the most healthy trees after 5 years?**

**One of the corners would be best. Try this yourself to see!**

# Exercise 6. Forest Pests

**Use the example data below to make a new table and graph, and use these to answer the following questions:**

| Year | Healthy Plots | Infected Plots | Profit if Harvested |
|---|---|---|---|
| 1 | 35 | 1 | |
| 2 | 27 | 9 | |
| 3 | 16 | 20 | |
| 4 | 0 | 36 | |
| 5 | 0 | 36 | |

**In what year does the infection begin to level off?**
**You should have found that the infection levels off in year 4.**

**In what year should the manager have harvested to maximize profits?**
**Profits for each year would have been $3540, $4500, $4400, $2520, and $2520. The manager should have harvested in year 2.**

**Can you figure out where the infestation may have started?**
**Possibilities include R2C3, R2C4, R3C2, R3C5, R4C2, R4C5, R5C3, R5C4, where the # after "R" is the row, and the # after "C" is the column.**

# Exercise 6. Forest Pests

**Finding the Percent Infected**

- Foresters often want to communicate the **proportion** of trees infected.
- A **proportion** is a **fraction** that **expresses part of a quantity to the whole**.
- For example, if you took a test with 10 questions, and answered 8 right, the proportion you got right was 8/10 (which can be simplified to 4/5).
- However, your teacher usually gives you grades in terms of a **percent**.
- A percent is a proportion that has a denominator of 100.
- You can remember this by thinking about the word. There are **100 *cents*** in a **dollar**, and **100 years** in a ***cent*ury**.
- What would your test grade be converted to a percent?
- An easy way to do this is to multiply the original proportion by 100%:

$$\frac{\boldsymbol{Part}}{\boldsymbol{Whole}} \times \mathbf{100\%} = \frac{\mathbf{8}}{\mathbf{10}} \times \mathbf{100\%} = \mathbf{80\%}$$

- Foresters often use percents, because they make it easier to compare health between forests with different numbers of trees.
- Use your new knowledge of percents to answer questions on the following slide.

# Exercise 6. Forest Pests

- **Click after each question below to see the answer!**

If Forest A has 80 trees, and 60 are infected, and Forest B has 140 trees, of which 70 are infected, which has a greater percent infected?

**Forest A has a greater percent of infected trees (75%). Only 50% of the trees in Forest B are infected.**

In a forest of 200 trees, 15 are infected. What percent are infected?

**7.5% are infected**

In a forest of 900 trees, 800 are infected. What percent are infected?

**88.9% are infected**

# Exercise 6. Forest Pests

**Click after each question below to see the answer!**

Forest X has 210 trees (100 infected). Forest Y has 70 trees (40 infected). Which one has a greater percent infected?

**Forest Y has a greater percent of infected trees (57.1%) than Forest X (47.6%).**

In a forest of 36 trees, one is infected. What percent are infected?

**2.8% are infected.**

In the previous forest, what percent are healthy?

**97.2% are healthy.**

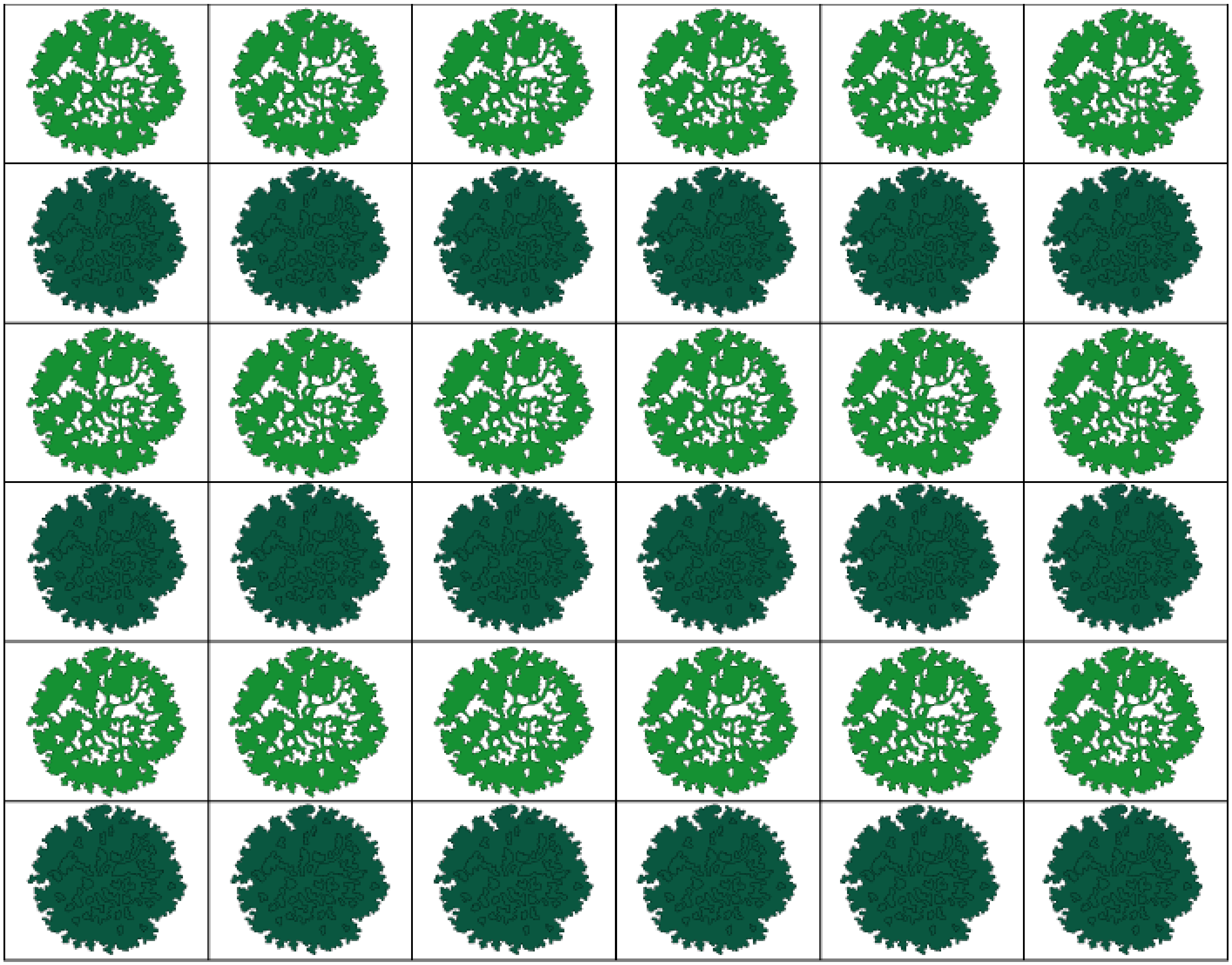
If you add up the percent of healthy and infected trees in any year, what do they add up to? Why does this make sense?

**They add up to 100%. This should make sense, as all the parts (healthy or infected) have to add up to the whole.**

# Exercise 6b. Infestation in a Mixed Stand

- Now you will simulate the effects of planting other tree species not attacked by a pest as a buffer between susceptible trees (pines).
- Find the board with rows of light green & dark green trees.
- The light green crowns still represent plots of pines.
- The dark green crowns represent hickories.
- Hickories are not attacked by the Southern Pine Beetle, but offer no cash reward in this case. (Hickories can be valuable for timber, but they grow much more slowly than pine).
- Repeat the invasion process you used in the monotypic stand example, and fill out a table just like you did earlier, except this time, also add a column in which you will calculate the PERCENT of pines infected, as well.
- Also remember when calculating potential profits, ONLY count pines!
- Graph your results as before, and after completing this exercise, answer the questions on later slides.

# Mixed Stand Game Board



# Exercise 6b. Infestation in a Mixed Stand

**Click after each question to see the answer!**

**What differences are there after 5 years of beetle damage as compared to the monoculture?**

**A greater number of trees are still undamaged.**

**What did planting alternate rows of hickories do for your pines?**

**It provided a buffer of trees to keep all pines from getting infected.**

**What other management techniques might give a similar outcome?**

**Creating gaps that are larger than the beetles' dispersal capabilities.**

**What happened to your pine profits?**

**In the short term, they are lower, because less trees can be harvested for profit. In the long term, though, this allows all the other trees to grow to reach a higher value.**

**What are you compromising by trying to manage against Southern Pine Beetle damage?**

**It is a tradeoff between planting fewer trees and earning less if there is NO infection, but losing more trees if there IS an infection.**

# Exercise 6c. Managing Your Own Mixed Stand

- Now you will continue to play the role of a forest manager, but this time, you are planting your own plot of pines and hickories from scratch, again with the goal of selling your pines.
- Find the blank 6x6 game board.
- First, see if you can come up with a planting scheme consisting of 18 pine plots and 18 hickory plots, in which no more than 4 pine plots can become infected.
- Next, see if you can think of a way to plant any number of pines and hickory plots (to a total of 36 plots) that will reduce beetle damage, but maximize profits from pine yields.
- Make a table and a plot that depict the percentage of healthy pines for each generation based on the total initial number of pines.
- Do this a few times and compare your results to those of others.  What patterns did you come up with?
- Answers can be found on the following slides.
- Also answer the questions on the following slides.

# Exercise 6c. Managing Your Own Mixed Stand

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**The first configuration is an example of how one can arrange plots using the requirement of 18 hickory plots and 18 pine plots and lose no more than 4 pine plots to an infestation.**

**In this configuration, a manager could make between $3780 and $4140 profit after 5 years, depending on the initial point of infestation.**

# Exercise 6c. Managing Your Own Mixed Stand

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**The 2nd and 3rd configurations are ways to plant a more pines (increasing potential profits), while protecting as many as possible.**

**In the 2nd, 40-60% of the trees could become infested, but you would still make a return on them.  In this scenario, you could make between $4260 and $5340 even if an infestation occurred.**

# Exercise 6c. Managing Your Own Mixed Stand

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**In the 3rd, 48.2-51.7% of the trees could get infected, and you could make between $4550 and $4730.**

**This is a smaller maximum profit, but provides a greater minimum profit, and a smaller maximum % of trees infected (though a greater minimum % of trees infested).**

**Either of these could be considered the best possible solutions if an outbreak did occur, depending on your criteria.**

**This should also illustrate the difficulty of evaluating risks and profits in making management decisions, when considering tradeoffs if an infestation does/does not occur. Did you find any configurations that came close to this example?**

# Exercise 6c. Managing Your Own Mixed Stand

**Click after each question to see the answer!**

**What challenges did you have in making your decisions?**

**Maximizing profits while minimizing damages can be difficult.**

**What challenges do you think land managers and foresters face in real situations?**

**Finding maximum yield, predicting outbreaks, managing correctly, etc.**

**What other factors, not in this activity, could affect the outcome?**

**Fire, pollution, market saturation, drought, strains that may be resistant to damage, etc.**

# Exercise 6c. Managing Your Own Mixed Stand

- Now imagine a pest species that cannot be managed by buffer zones such as you experienced in this activity.
- For instance, there are spore-producing fungi that affect butternut trees in Tennessee.
- These spores can be carried on air currents, birds, cars, people, and other far-reaching carriers.  Now answer the following questions:

**Q26.  What special challenges does this pest present to managers?**

**CLICK FOR THE ANSWER!**

**Since there are so many possible means of transmission of the pest/disease, it is practically impossible to manage each and every one of them.  However, managers must consider the modes of transmission that are most likely to affect each plot in question, and manage those accordingly.**

# Exercise 6c. Managing Your Own Mixed Stand

**Q27. What are some ways that a manager may use to keep the pest from spreading across forests?**

**CLICK FOR THE ANSWER!**

**Various management practices might include application of chemicals that kill the pest (and/or insect vectors that may transport the pest), removal and destruction of infected individuals, taking care to thoroughly clean tools and clothing to avoid transporting the pest to other areas, culture and planting of individuals that are resistant to the pest, etc.**

**Q28. Why would it be important to preserve genetic diversity in the population of butternut trees?**

**CLICK FOR THE ANSWER!**

**If there is greater genetic diversity, then the possibility of resistance to the canker is greater.**

# Exercise 6d. Bugs? In Our Trees?

- Do some research on a forest pest that is (or was historically) problematic in Tennessee. Choose one of the examples below, or find another one of your choice.
  - Hemlock wooly adelgid (*Adelges tsugae*)
  - Balsam wooly adelgid (*Adelges piceae*)
  - Ips beetles (*Ips sp.*)
  - Gypsy moth (*Lymantria dispar*)
  - Pales weevil (*Hylobius pales*)
  - Pitch-eating weevil(*Pachylobius picivorus*)
  - Nantucket pine tip moth (*Rhyacionia frustrana*)
  - Emerald ash borer (*Agrilus planipennis*)
  - Red oak borer (*Enaphalodes rufulus*)
  - Asian longhorned beetle (*Anoplophora glabripennis*)
  - Beech scale (*Cryptococcus fagisuga*)
  - Beech bark disease (*Neonectria galligena*)
  - Dutch elm disease(*Ophiostoma ulmi*)
  - Dogwood anthracnose (*Discula destructiva*)
  - Thousand cankers disease (*Geosmithia morbida*)
- You may wish to also consider problematic trees and other plants that can affect forests!
- Prepare a report to share with your class on your chosen species.

# Suggested Reading

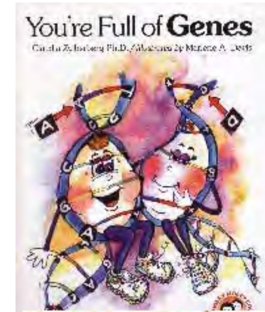
- There are lots of great books related to forestry and forest environments for this unit, so separate slides are included for suggested reading materials for various grade levels.

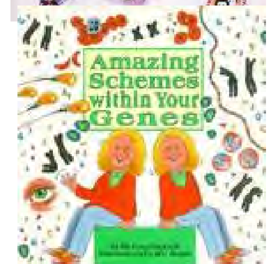
- Click an underlined grade range below to see suggested reading appropriate to that students in that range.

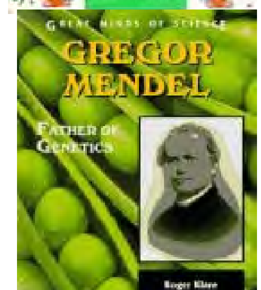
  **<u>All Ages & Grades K-3</u>**

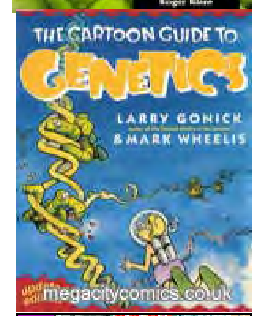
  **<u>Grades 4-6</u>**

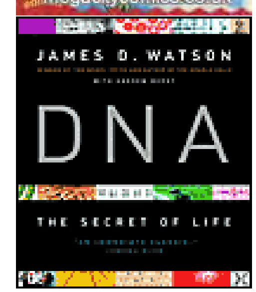
  **<u>Grades 7+</u>**



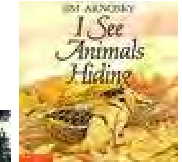



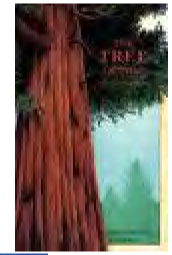
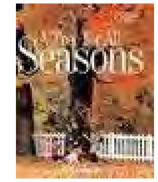



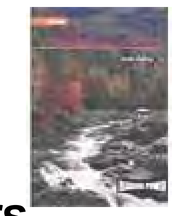



# Suggested Reading for Grades K-3

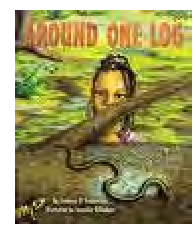
***I See Animals Hiding*** - Jim Arnosky
***The Tree of Time: A Story of a Special Sequoia*** - Kathy Baron
***A Tree for All Seasons*** - Robin Bernard
***Looking at Trees and Leaves (My First Field Guides)*** - Lara Rice Bergen & Tim Haggerty (Illustrator)
***While a Tree Was Growing*** - Jane Bosveld & Daniel O'Leary (Illustrator)
***One Small Place in a Tree*** - Barbara Brenner & Tom Leonard (Illustrator)
***Deciduous Forests*** - Holly Cefrey
***Grand Old Tree*** - Mary Newell Depalma
***Forest*** - DK Publishing
***Leaf Man*** - Lois Ehlert
***Around One Log: Chipmunks, Spiders, and Creepy Insiders*** - Anthony D. Fredericks & Jennifer Dirubbio (Illustrator)
***Trees*** - Linda Gamlin
***In the Woods: Who's Been Here?*** - Lindsay Barrett George
***Tell Me, Tree: All About Trees for Kids*** - Gail Gibbons
***The Big Tree*** - Bruce Hiscock

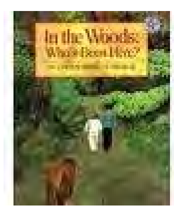


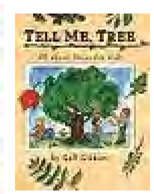







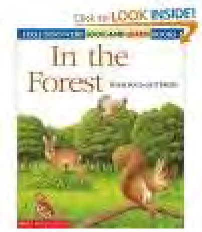





- [ ] **Click for more suggested reading for Grades K-3!**

# Suggested Reading for Grades K-3

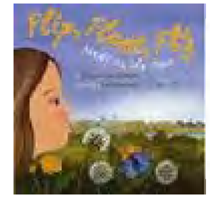

***Who Lives Here? Forest Animals*** - Deborah Hodge & Pat Stephens (Illustrator)




***My Favorite Tree - Terrific Trees of North America*** - Diane Iverson

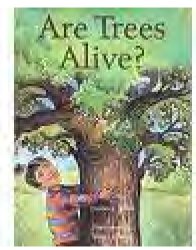
***In the Forest*** - Gallimard Jeunesse & Pierre de Hugo

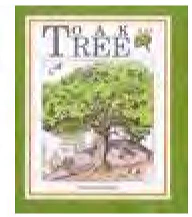
***Flip, Float, Fly!: Seeds on the Move*** - JoAnn Early Macken & Pam Paparone (Illustrator)




***The Mystery of the Tree Rings*** - Mark Meierhenry, David Volk, & Jason Folkert (Illustrator)

***Are Trees Alive?*** - Debbie S. Miller & Stacey Schuett (Illustrator)




***Oak Tree*** - Gordon Morrison

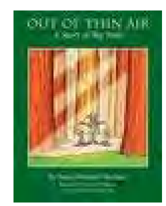
***This is the Tree*** - Miriam Moss

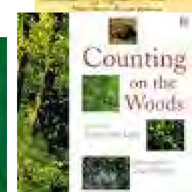

***Out of Thin Air: A Story of Big** Trees* - Nancy Muleady-Mecham Robert E. Muleady & Sandra Kim Muleady (Illustrators)

***Counting on the Woods*** - George Ella Lyon & Ann W. Olson

***The Forest*** - Claire A. Nivola

***Old Elm Speaks: Tree Poems*** - Kristine O'Connell George & Kate Kiesler (Illustrator)

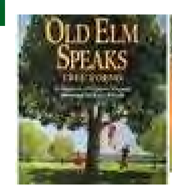


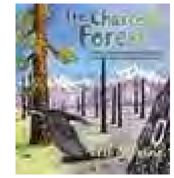


***Who Will Plant a Tree?*** - Jerry Pallotta & Tom Leonard (Illustrator)

- **Click for more suggested reading for grades K-3, & a great classic for all ages!**




# Suggested Reading for Grades K-3

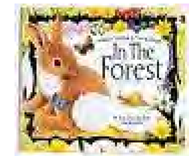


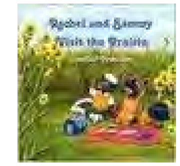
***The Charcoal Forest: How Fire Helps Animals & Plants*** - Beth A. Peluso & Lynn Purl (Editor)

***A Log's Life*** - Wendy Pfeffer & Robin Brickman (Illustrator)

***In the Forest: A Nature Trail Book*** - Maurice Pledger

***Rachel and Sammy Visit the Forest*** - Jannifer Powelson

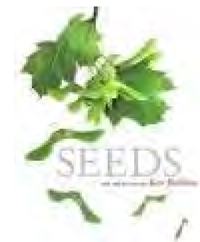




***Investigating Why Leaves Change Their Color*** - Ellen Rene

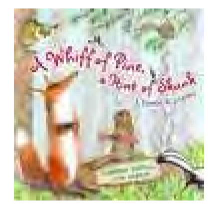
***Seeds*** - Ken Robbins

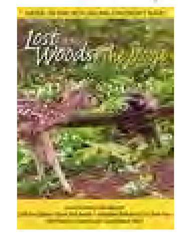
***A Whiff of Pine, a Hint of Skunk: A Forest of Poems*** - Deborah Ruddell & Joan Rankin (Illustrator)




***Lost In the Woods*** - Carl R. Sams & Jean Stoick

***Shelterwood*** - Susan Hand Shetterly & Rebecca Haley McCall (Illustrator)





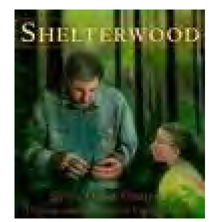
***One Small Square: Woods*** - Donald Silver & Patricia Wynne

***Look What I Did with a Leaf!*** - Morteza E. Sohi

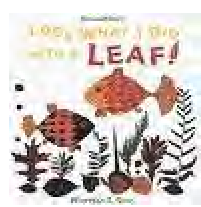
***The Gift of the Tree*** - Alvin Tresselt & Henri Sorensen

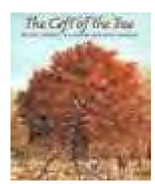
***Busy Tree*** - Jennifer Ward & Lisa Falkenstern (Illustrator)

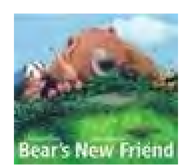
***Bear's New Friend*** - Karma Wilson & Jane Chapman (Illustrator)




***Nature Hide & Seek: Woods & Forests*** - John Norris Wood & Maggie Silver (Illustrator)



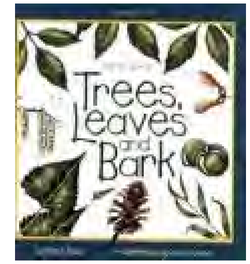



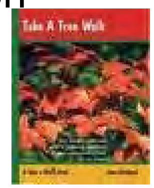

<u>**For All Ages:**</u>

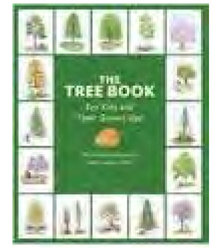
***The Giving Tree*** – Shel Silverstein

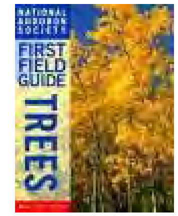
# Suggested Reading for Grades 4-6



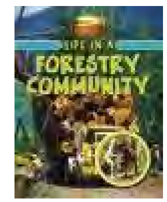

***Trees of North America: A Field Guide to the Major Native and Introduced Species North of Mexico*** - C. Frank Brockman
***Trees, Leaves, and Bark*** - Diane Burns & Linda Garrow
***Trees* (National Audubon Society First Field Guide)** - Brian Cassie
***The Temperate Forest: A Web of Life*** - Philip Johansson
***Julia Butterfly Hill*** - Dawn Fitzgerald
***Life in a Forestry Community*** - Lizann Flatt
***Forest Food Webs*** - Paul Fleisher
***Why Do Leaves Change Color?*** - Terry Allan Hicks
***Faces in the Forest*** - Ron Hirschi & Thomas D. Mangelsen
***The Tree Book for Kids and Their Grown Ups*** - Gina Ingoglia
***Take a Tree Walk*** - Jane Kirkland
***Amazing Biome Projects You Can Build Yourself*** - Donna Latham & Farah Rizvi (Illustrator)
***The Maple Syrup Book*** - Marilyn Linton & Lesley Fairfield (Illustrator)
***Trees (Fantastic Facts)*** - Peter Mellett
***Pharmacy in the Forest: How Medicines Are Found in the Natural World*** - Fred Powledge
***Fire in the Forest: A Cycle of Growth and Renewal*** - Lawrence Pringle & Bob Marstall (Illustrator)
***Longleaf*** - Roger Reid
***Who on Earth is Aldo Leopold?: Father of Wildlife Ecology*** - Glenn Scherer & Marty Fletcher
***Temperate Forests*** - John Woodward

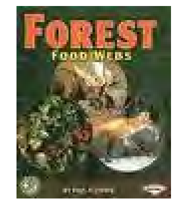


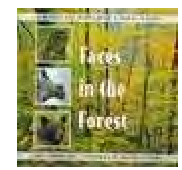



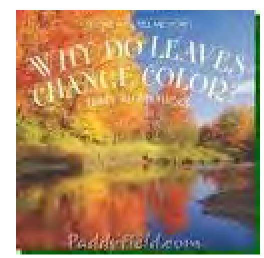







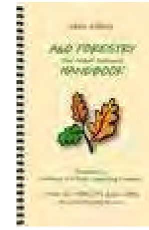



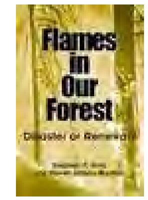



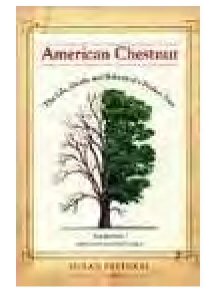



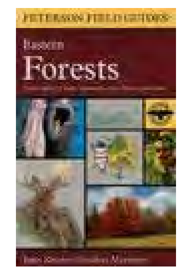

# Suggested Reading for Grades 7+

***A&O Forestry (And Outdoor Enthusiast) Handbook*** - Thomas Anundson
***Flames in Our Forest: Disaster or Renewal?*** - Stephen F. Arno & Steven Allison Bunnell
***The Global Forest*** - Diana Beresford-Kroeger
***Living in the Appalachian Forest: True Tales of Sustainable Forestry*** - Chris Bolgiano
***Finding the Forest*** - Peter P. Bundy
***Handmade Forests: The Treeplanter's Experience*** - Helene Cyr
***Ecoforestry: The Art and Science of Sustainable Forest Use*** - Alan Drengson, Duncan Taylor, & Jerry Mander
***American Chestnut: The Life, Death, and Rebirth of a Perfect Tree*** - Susan Freinkel
***Elers Koch: Forty Years a Forester*** - Elers Koch
***A Field Guide to Eastern Forests: North America (Peterson Field Guide)*** - John C. Kricher, Roger Tory Peterson (Editor), Gordon Morrison (Illustrator)
***Forever Green: The History and Hope of the American Forest*** - Chuck Leavell
***The Life of the Forest*** - Jack McCormick
***Once Upon a Tree: Life from Treetop to Root Tips*** - James B. Nardi
***Remarkable Trees of the World*** - Thomas Pakenham
***The Hidden Forest*** - Sigurd F. Olson; Les Blacklock & Nadine Blacklock (Photographers)
***The Urban Tree Book: An Uncommon Field Guide for City and Town*** - Arthur Plotnik & Mary H. Phelan (Illustrator)
***The Tree Doctor: A Guide to Tree Care and Maintenance*** - Daniel Prendergast & Erin Prendergast
***Forests (Diminishing Resources)*** - Allen Stenstrup
***The Way of the Woods: Journeys Through American Forests*** - Linda Underhill
***Forests: A Naturalist's Guide to Woodland Trees*** - Laurence C. Walker
***Opportunities in Forestry Careers*** - Christopher Wille










- ❑ **There is a scientific journal article, as well as MANY UT Extension publications on forestry available on the Teacher CD for this unit!**

# LINKS

- Since there are tons of great links for this unit, separate slides are included for links that work well with each individual exercise.
- Click the name of an underlined exercise below to  the links slide for that exercise.

# Links for Exercise 1: Dendrology
## (Underlined text is clickable!)

**Crossdating: Introduction** – A cool site from The University of Arizona, Tucson's Laboratory of Tree Ring Research, which has an interactive exercise allowing students to cross date tree cores based on their rings. Probably most appropriate at the high school level, or perhaps for fairly advanced middle school students.

**Dendrochronology** - A fairly advanced, yet succinct introduction to dendrochronology, including its history, principles, and utility.

**Forests: What Are the Parts of A Tree?** - This site from EcoKids gives a good very basic introduction to parts of a tree. Also contains links to other good introductory info on forests.

**Label Tree Anatomy Printout** - A great simple printout for younger students to color and label parts of a tree.

**Measuring the Tree Trunk** - A site from the Fenner School of Environment and Society (associated with the Australian National University) on taking measurements of tree trunks.

**NASA - First-of-its-Kind Map Depicts Global Forest Heights** - A super cool site from NASA that shows data on forest heights obtained from space!

**NOVA Online | The Vikings | Build a Tree-Ring Timeline** - A really neat page that includes an interactive exercise on dendrochronology.

**Real Trees 4 Kids –** A great site sponsored by the National Christmas Tree Association with TONS of information on trees for kids, broken down into several pages based on grade level, as well as resources for teachers.

**UT Knoxville | Forest Resources Research and Education Center** - A great UT site with lots of tree facts, featured plants, videos, and other great links about the forests of Tennessee, and forests and forestry in general.

# Links for Exercise 2: Wood Types
## (Underlined text is clickable!)

**Amateur Woodworker: Wood Types** - A site giving descriptions and uses of many different types of wood.

**Friends of the Earth: Different types of wood timber: Good Wood Guide** - A great website with TONS of information on various wood types, with information on region of origin, as well as conservation status, to assist in making environmentally conscious decisions when buying/using wood.

**NASA - What on Earth are "Moon Trees?"** - A really cool site from NASA. Instead of spoiling the coolness for you, we suggest you just go check it out!

**The Space Place :: Sorting Out Trees in the Forest** - Another awesome site from NASA describing how different tree species can even be identified from space with current technology!

# Links for Exercise 3: Forest Products
## (Underlined text is clickable!)

**Forest Products Extension at the University of Tennessee** - "Forest and wood products are an important part of the environment, culture and economy of Tennessee. The Forest Products Extension Program at the University of Tennessee exists to assist the wood products industry and the citizens of Tennessee through information transfer and applied research." Contains maps of TN wood industry, as well as extension forest products publications.

**UT Knoxville: Forest Products Center** - Great UT website with lots of cool information about forest products, including forest product research going on right here in our home state of Tennessee! Lots of great links full of info to explore!

# Links for Exercise 4: Who Lives Here? (Underlined text is clickable!)

**Deciduous Forest Biome** - A nifty overview of decidous forests, including information on locations of these forests on earth, climate, and details of several forest plants and animals.

**eNature: FieldGuides** - Excellent online field guide that allows you to enter your ZIP code to access field guides to plants and animals in your area!

**Ijams Nature Center** - Located in Knoxville, Ijams is a "275-acre wildlife sanctuary and environmental learning center, providing community-wide connections and experiences through education, conservation, recreation and responsible environmental stewardship for all people."  A great place to visit and walk in the woods to see plenty of trees, other forest plants, and forest critters!

**Special Habitats of Tennessee** - Supported by the National Geographic Society Education Foundation, the Tennessee Geographic Alliance, and many other sponsors, this website focuses on, you guessed it, special habitats found in Tennessee.  Teachers and students can register their schools to participate in collaborative projects to form a network of information about their own local special habitats and wildlife in Tennessee.  Geared primarily towards grades 4-6.

**Tennessee Wildlife Resources Agency** - State website with lots of great information about Tennessee's wildlife.

**Temperate Deciduous Forest Animal Printouts -** Information on temperate deciduous forests, along with pictures and information on forest animals from around the world (approximately at the 4th-5th grade level).

**TLC Family Animal Crafts** - Lots of cool animal-related activities and crafts for all ages.

**What's It Like Where You Live?** - Great website covering the many diverse biomes and ecosystems on earth.  The link below goes to the main page for temperate deciduous forests, with lots of additional subtopics on temperate deciduous forests, and other cool links!

**Wildlife Extension** - UT's Wildlife Extension site contains links to several publications on wildlife research in Tennessee.

# Links for Exercise 5: Forest Succession
## (Underlined text is clickable!)

**American Field Guide: Primary and Secondary Succession in America's Forests** - A site from PBS with three grade 9-12 classroom activities for learning about forest succession.

**Ecological Succession** - Middle school level information on succession from Barry Hoffman, an 6th grade math & science teacher at Weber Middle School in Port Washington, New York.

**Exploring Nature: Forest Succession** - Good introductory information (including a video) from Exploring Nature.

**MI Watchable Wildlife: Ecology - Succession** - Short interactive introductory lesson on succession from Michigan's Department of Natural Resources.

# Links for Exercise 6: Forest Pests
## (Underlined text is clickable!)

**BugGuide.Net** – Do you have bugs on your trees or other plants, or maybe you just found a cool bug that you want to identify. This site is THE one-stop shop for insect (and other invertebrate) identification. Browse through the extensive photographic field guide, or even submit your own insect photos to be identified by experts!

**Forest Pests** – Great site with tons of info on forest pests, including insects, diseases, and weeds, as well as other agents of forest damage.

**Invasive.Org** – From the Center for Invasive Species and Ecosystem Health, this site is a comprehensive source for information on invasive species.

**NASA Finds Trees and Insect Outbreaks Affect Carbon Dioxide Levels** - Though a few years old (2004), this study by NASA is quite pertinent to the topics outlined in this exercise.

**Study Finds Hemlock Trees Dying Rapidly, Affecting Forest Carbon Cycle** - Data from NASA that is extremely relevant to forests and forest pests in Tennessee.

# General Forestry Links for Unit 9
## (Underlined text is clickable!)

**Arbor Day Foundation** - A well-known 501(c) organization devoted to "inspiring people to plant, nurture, and celebrate trees.“

**Forestry Extension** - The University of Tennessee Knoxville's Forestry Extension site.  Contains interesting links to departmental and extension research, other forestry organizations in Tennessee, and publications about Tennessee's forest treasures.

**TDA - Forestry Division** - The Tennessee Department of Agriculture's Forestry site, which contains lots of great info on management, urban forests, forest health, forest pests and diseases, state timber sales, and much more.  Great overall link that has information tied to all exercises in this unit.

**TDA - Tennessee's State Forests** - Links to information on Tennessee's 15 beautiful state forests.  This could provide good field trip ideas!