How to Measure Trees
What is DBH?

Purpose

- Students develop an understanding of tree size and how scientists measure trees. Students observe and measure tree cookies and explore the relationship between tree circumference and diameter.
- Students compare the estimates of diameter made from circumference measurements (and vice versa).

Overview

In this activity students will observe and explore the relationship between circumference and diameter using tree cookies (cross sections from real trees), in preparation for the measurement of tree CBH (circumference at breast height - 1.35m) in the field. They will also discuss the importance of accuracy and precision in measurement.

Student Outcomes

Students will be able to:

- Observe physical characteristics of and suggest ways to measure tree cookies (i.e. cross sections of real trees).
- Measure circumference and diameter of one tree cookie.
- Calculate circumference or diameter based on equations.
- Compare and contrast calculated values to actual measurements.

Questions

Content

- How do scientists measure trees?
  - What is the relationship between circumference and diameter?
  - What is diameter-at-breast-height?

Science Concepts

Grades 5-8

Scientific Inquiry

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Use mathematics in all aspects of scientific inquiry.

History and Nature of Science

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models

NGSS (Black-covered directly, gray-addressed, but not directly covered)

- *Science and Engineering Practices*
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
- *Crosscutting Concepts:*
  - Scale, Proportion, and Quantity
  - Energy and matter

Time/Frequency

60 minutes

Level

Secondary (Middle & High School)

Materials and Tools

- Several different sized tree cookies (1 per student group)
- Flexible measuring tape (metric) (1 per student group)
- Calculator (1 per student group)
- Student Worksheet (1 per student)
- Notebook and pencil (1 per student)
- Items for circumference height tool [Optional]
  - Sticks and permanent marker OR Strings and scissors (see part 2)

Prerequisites

- None

Preparation

- Write the main question on the board.
- Gather all the materials for the activity.

Background

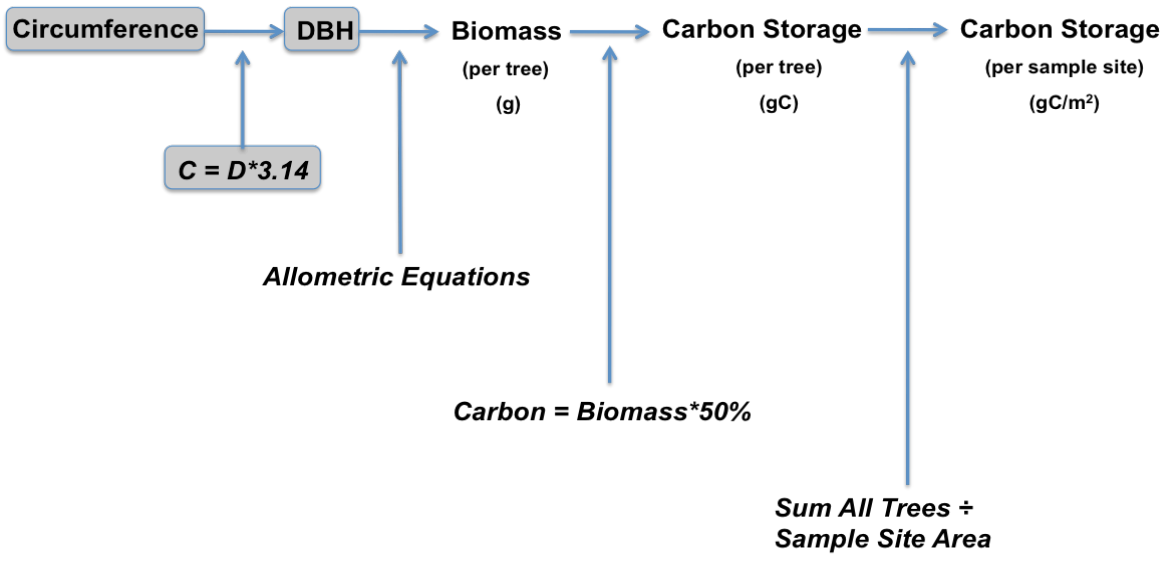
Scientists use a standard method to measure the size of trees, diameter-at-breast height (DBH), to ensure consistency over time, across plots and between data collectors. DBH means the diameter of each tree is measured at "breast height", as defined from the highest point of ground at the tree's base (See Tree Circumference Guide for pictorial examples). This height was chosen as a standard because the easiest way for a forester to measure is by reaching their arms in front of them and around the tree rather than bending over or using a ladder. While it would be best if all scientists around the world agreed on the exact height of DBH, it does vary slightly based on the country in which a study is being conducted. For example, the US Forest Service uses 1.37m, while scientists in Thailand use 1.3m, and Puerto Rico studies use 1.4m. Since GLOBE investigations are international, students measure DBH at 1.35m.

DBH measurements can be used to estimate the board feet, volume, biomass, and carbon storage of trees - to learn more about the relationship between DBH and biomass refer to the activity, Allometry: Not a Llama Tree.

From geometry class, we know that diameter is a line that passes through the center of a circle, with the endpoints of the line located on the edge of the circle. How then can foresters and scientists measure tree diameter without cutting down the tree and measuring its cross section? Scientists measure the circumference of a tree (CBH) and calculate the diameter using a standard geometric an equation. Sometimes they use tape measures that are calibrated or adjusted for diameter, these tapes are referred to as DBH tapes. During Carbon Cycle field data collection, students will measure CBH instead of DBH due to tool restrictions; therefore it is important for them to know how circumference and diameter are related.

Circumference = π*diameter (where π = 3.14) or Diameter = Circumference/ π

The diagram below shows the concepts students need in order to understand the carbon stock of forest ecosystems. The concepts addressed in this activity are highlighted in gray.



What To Do and How To Do It

ENGAGE **Grouping:** Small Groups (Part 1) **Time:** 10 Minutes

- Students select a tree cookie and complete Part 1 of the Student Worksheet.
- Class discussion of student's observations and suggestions for tree cookie measurement.

EXPLORE **Grouping:** Small Groups (Part 2) **Time:** 20 Minutes

- Introduce the content question, equation 1, and set the expectations for Part 2
  - If students ask to which decimal place they should measure, tell them to make a best guess.
- Students conduct measurements and calculations as directed on the student sheet. This is a proof of concept excercise to show students how diameter and circumference are related.

EXPLAIN **Grouping:** Class **Time:** 15 Minutes

- Interpret the measurements and discuss answers student questions #4a-c.
- Use question 4c as a lead in to the next part of the activity: How might scientists (and you) use the circumference/diameter relationship to study live trees?
- Discuss the standard height at which circumference (diameter) is measured, (1.35m, called diameter-at-breast-height (DBH)
- This is a good point to have a discussion about accuracy and precision. You may want to brainstorm some ideas about what those terms mean before students read about them in Student Worksheet: Part 3.

ELABORATE **Grouping:** Small Groups **Time:** 30 Minutes

- Students determine the height of 1.35m against their own body.
- Students follow teacher directions to create a height measurement tool. [Optional]
  - Use a measuring tape or meter stick, measure out 1.35m:
    - on a stick and mark with a permanent marker OR
    - on a string and cut the string so it is exactly 1.35m tall
- Students perform activities to investigate accuracy and precision.

EVALUATE **Grouping:** Class **Time:** 10 Minutes

- Show where students are in the Field Concepts Diagram
- Discuss the assessments
- Be sure all the students are confident in how they will measure trees in the field.

**See activity example in *HowToMeasureTrees_example.xls*

Assessment

- Students should answer the content question individually and explain the connection between this activity and the upcoming fieldwork

Resources

- Carbon Cycle eTraining: https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867717/3099387

TEACHER VERSION
(Suggested student responses included)

How To Measure Trees - What is DBH?

Content Question: How do scientists measure trees?

Part 1: Tree cookie observations

1. Record the physical traits of your selected tree cookie. Draw and/or describe.

Cylindrical like, top and bottom have rings of differing colors and widths, bark is the outer most layer, the bark has some bumps/ridges

1. Suggest some ways that your tree cookie could be measured to learn about its size.

Count the number of rings, Measure circumference, Measure diameter, Measure height, Weigh the cookie, Displace water to find density

Part 2: Circumference versus diameter

1. Measure 1 tree cookie per group.
   a). Pull the measuring tape tightly around the tree cookie and record its **circumference** in the data table below for a total of **3 times**, sharing measurement responsibilities between group members.
   b). Measure the tree cookie's **diameter 3 times** and record each measurement in the data table. Note: Measure the diameter in several directions across the surface of the tree cookie, as they will not be perfectly round and you want to make sure your measurements represent the overall shape of the tree cookie.

2. Calculate an average circumference and average diameter for the tree cookie.

Average (mean) = Sum all of the values ÷ by the # of values.

	Circumference	Diameter
Trial A	25.2	7.6
Trial B	25.4	8.0
Trial C	25.4	7.8
Average (A+B+C)/3	25.3	7.8

3. Use your averages above in the equations below to fine the calculated circumference and diameter. (Hint: Use the Average *Diameter* to find the Calculated Circumference and the Average *Circumference* to find the Calculated Diameter).

	Circumference = π*average diameter	Diameter = average circumference/ π
Calculated	C = 3.14*7.8 = 24.5	D = 25.3/3.14 = 8.1

4. Compare calculations to averages by answering the following questions:

a) How similar are your measured circumference values?

Circumference values should be pretty close, as long as all students are practicing good measurement technique, which they may not be. Measurement accuracy and precision are discussed at greater depth in Part 3, so here just get students to examine the measurements they have made.

b) How similar are your measured diameter values?

Diameter measurements will vary more widely especially if you have odd shaped tree cookies. Students will probably decide to measure diameter of the tree cookie on several different axes so the more odd shaped the cookie the more different the measurements could be.

c) Why might calculated values be different from measured average values?

Students will probably make note of the challenges they encountered when choosing how to measure diameter. Some may observe that in order to get a better average value of diameter you would want to measure the cookie on more than 3 axes, perhaps 10 or 20 measurements would get an average that would be closer to the calculated value. This would be the case because the calculated value basically assumes that the tree cookie surface is a perfect circle and does not account for bumps, ridges, growths, etc. that may exist on the tree cookie. Students may also suggest measurement error as a source of difference.

d) How might scientists (and you) use the circumference/diameter relationship to study live trees?

You should explain to students that when scientists/foresters want to know about the mass of trees, how much carbon they store, how many board feet they contain or how much wood product exists in a whole forest they must know at least one aspect, tree diameter at 1.35meters.

Why tree diameter? The primary reason is pretty simple; it is easier for people to conceptualize a tree with a diameter of 8cm than one that has a circumference of 24.5cm. Over the years there have been many methods developed to measure tree diameter, such as the Biltmore stick and tree calipers. The most commonly used method today, especially for highly accurate measurements that will be used in scientific studies, is the diameter tape. This is a calibrated tape where every 1inch marked on the tape is actually a distance of 3.14inches. This means that although you are measuring circumference you are reading the diameter.

5. Discuss Part 2 as a class.

<u>Part 3: Prepare to measure tree circumference in the field.</u>

1. How high is 1.35m?
   a) This is also referred to as CBH or DBH, circumference or diameter at breast height. This measurement height was chosen as a standard because the easiest way for a forester to measure is by reaching their arms in front of them and around the tree to measure it rather than bending over or using a ladder. The arm height of an “average” sized forester is 1.35m.
   b) Measure 1.35m from the ground and determine where this falls on your body.

* You may have students create a height measurement tool for 1.35m (string, stick, etc).

These quick references will allow students to walk up to each tree and quickly measure CBH.

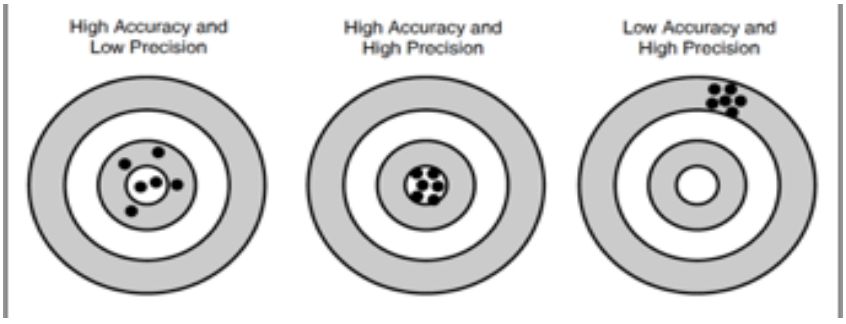
2. Measuring trees greater than 15 centimeters circumference.
   a) When measuring trees you will only record information for trees ≥15cm circumference. While this value may seem arbitrary it is equal to 2 inches diameter, a cutoff used by scientists in many other forest research studies. A cutoff value is used because:
      i) It is not practical to measure every small sapling on a sample site,
      ii) In a forest, saplings do not contribute a significant amount of biomass,
      iii) Many saplings smaller than 15cm die off due to lack of available light.

In some forest inventories saplings are counted separately on a sub-plot. In this study saplings are part of the Shrub/Sapling Measurement Protocol, which should only be completed if together shrubs and saplings comprise >25% of the sample site area.

3. Two concepts scientists consider as they measure trees are accuracy and precision.
   a) Accuracy: Accuracy is the degree to which a measured or calculated value matches the true value. In the case of circumference measurements this can be influenced by:
      i) Placement of the measuring tape: Is the measurement 1.35m from the ground? Was the tape perpendicular to the main axis of the tree? Was the tape twisted?
      ii) Reading and recording data: Was the correct number read from the tape? Was this number correctly entered on the datasheet?

Follow the *Tree Circumference Guide*, and carefully record data, to make accurate circumference measurements. Accuracy becomes particularly important if trees are measured in future years and compared to previous measurements.

   b) Precision: Precision is the degree to which repeated measurements of the same tree are in agreement. You can determine how precise circumference can be measured by making repeated measurements of the same tree – either by one person, or by several.
      i) With your group, re-examine your tree cookie circumference results from Part 2. How precise were your measurements? Why might they be different? How tight did you pull the tape to read the measurement? What decimal place did they record to? Was the measuring tape flat or twisted as it was pulled around cookie? How many measurements do you think should be made in order to know if you have a precise measurement? Why?



Example: *Our measurements were relatively precise. All measurements were taken to the 10ths place and they were separated by only one tenth.*

Example:
I think that our measurements were so similar because we pull the tape around the tree cookie using the same tightness all 3 times. We also all agreed ahead of time that we wanted to record the circumference to the nearest tenth of a centimeter.

I think there should be at least three trials completed for each measurement type. It is best to use more than two trials because if the results were different we would not know which one is more accurate.

c) Make a list of at least 4 things you can do in the field to make sure all of your measurements are made accurately and precisely?

- *Follow the Tree Circumference Guide for marking 1.35m, circumference at breast height, on each tree.*
- *Re-mark any trees where the 1.35m line is fading to ensure the measurement is made at the exact same height each year.*
- *Make all circumference measurements to the nearest tenth of a centimeter.*
- *Work as a team to make sure the measuring tape is horizontal around the tree (not lower in the back where it is hard to see)*
- *Make sure there are no twists in the tape.*
- *Practice making a few measurements before beginning to record the data to make sure everyone agrees how tightly to pull the tape and knows how to read the measurement off of the measuring tape.*
- *Have the recorder repeat the measurement back to the measurer to ensure it is recorded correctly.*
- *If you have any doubt that a measurement you just made was not executed well, make the measurement again before reporting it to the recorder.*
- *Label/number the tree in some way to make sure you are comparing measurements from the same tree each year.*

Name: Date:

How To Measure Trees - What is DBH?

Content Question: How do scientists measure trees?

Part 1: Tree cookie observations

1. Record the physical traits of your selected tree cookie. Draw and/or describe.

2. Suggest some ways that your tree cookie could be measured to learn about its size.

Part 2: Circumference versus diameter

1. Measure 1 tree cookie per group.
   a) Pull the measuring tape tightly around the tree cookie and record its **circumfer ence** in the data table below for a total of **3 times**, sharing measurement responsibilities between group members.
   b) Measure the tree cookie's **diameter 3 times** and record each measurement in the data table. Note: Measure the diameter in several directions across the surface of the tree cookie, as they will not be perfectly round and you want to make sure your measurements represent the overall shape of the tree cookie.

2. Calculate an average (mean) circumference and average (mean) diameter for the tree cookie.

Average (mean) = Sum all of the values ÷ by the # of values.

	Circumference	Diameter
Trial A		
Trial B		
Trial C		
Average (A+B+C)/3		

3. Use your averages above in the equations below to find the calculated circumference and diameter. (Hint: Use the Average *Diameter* to find the Calculated Circumference, and the Average *Circumference* to find the Calculated Diameter).

	Circumference = π*average diameter	Diameter = average circumference/ π
Calculated		

4. Compare calculations to averages by answering the following questions:
   a) How similar are your measured circumference values?

   b) How similar are your measured diameter values?

   c) Why might calculated values be different from measured average values?

d) How might scientists (and you) use the circumference/diameter relationship to study live trees?

5. Discuss Part 2 as a class.

Part 3: Prepare to measure tree circumference in the field.

1. How high is 1.35m?
   a) Also referred to as CBH or DBH circumference or diameter at breast height, this measurement height was chosen as a standard because the easiest way for a forester to measure is by reaching their arms in front of them and around the tree to measure it rather than bending over or using a ladder. The arm height of an "average" sized forester is 1.35m.
   b) Measure 1.35m from the ground and determine where this falls on your body.

2. Measuring trees greater than 15 centimeters circumference.
   a) When measuring trees you will only record information for trees ≥15cm circumference. While this value may seem arbitrary it is equal to 2 inches diameter, a cutoff used by scientists in many other forest research studies. A cutoff value is used for several reasons:
      i) It is not practical to measure every small sapling on a sample site,
      ii) In a forest, saplings do not contribute a significant amount of biomass,
      iii) Many saplings smaller than 15cm die off due to lack of available light.

In some forest inventories saplings are counted separately on a sub-plot. In this study saplings are part of the Shrub/Sapling Measurement Protocol, which should only be completed if together shrubs and saplings comprise >25% of the sample site area.

3. Two concepts scientists consider as they measure trees in the field are accuracy and precision.
   a) Accuracy: Accuracy is the degree to which a measured or calculated value matches the true value. In the case of circumference measurements this can be influenced by:
      i) Placement of the measuring tape: Is the measurement 1.35m from the ground? Was the tape perpendicular to the main axis of the tree? Was the tape twisted?
      ii) Reading and recording data: Was the correct number read from the tape? Was this number correctly entered on the datasheet?

Follow the *Tree Circumference Guide*, and carefully record data, to make accurate circumference measurements. Accuracy becomes particularly important if trees are measured in future years and compared to previous measurements.

   b) Precision: Precision is the degree to which repeated measurements of the same tree are in agreement. You can determine how precise circumference can be measured by making repeated measurements of the same tree – either by one person, or by several people.
      i) Examine your circumference results from Part 2. How precise were the measurements? Why might they be different? How tight did you pull the tape to read the measurement? What decimal place did they record to? Was the measuring tape flat or twisted as it was pulled around cookie? How

many measurements do you think should be made in order to know if you have a precise measurement? Why?

c) Make a list of at least 4 things you can do in the field to make sure all of your measurements are made accurately and precisely?