CHICAGO BOTANIC GARDEN

Activity 2.2: What Can Tree Rings Tell Us About Climate?

Grades 10 – 12

Description: In this activity, students will investigate tree rings and attempt to figure out what environmental conditions cause differences in the width of rings in a given tree. They will use data to build an argument to support their hypotheses.

Time: Three to five class periods

National Science Education Standards:

H.U.2. Evidence, models, and explanation:

"Evidence consists of observations and data on which to base scientific explanations. The goal is to help students use evidence to understand interactions and predict changes."

H.U.3. Change, constancy, and measurement: "Change denotes making something different. Changes in systems vary in rate, scale, and pattern, including trends and cycles. The goal is for students to identify and measure changes in properties of materials, positions of objects, motion, and form and function of systems. Measurement makes quantitative observations about objects, events, or systems. The goal is to help students use tools of measurement and measurement systems and to achieve understandings of scales and rates."

Materials:

- Samples of tree branches or trunk cross-sections with clear rings ("cookies") with information on date and place of harvest and/or photographs of tree ring sections. You can make your own by cutting slices of different types of trees, or you can purchase a set of tree cookies at: http://www.enasco.com/product/SB26464M
- Samples (or images) of various types of wood; in particular, wood samples that grew in a temperate climate, and wood that grew in a tropical or arid climate if possible.
- Master set of simulated tree cores
- Student Handouts:
  - #1: What Are Tree Rings?
  - #2A and #2B: You are a Dendrochronologist
  - #2C: Making Sense of Tree Rings
- MS Excel files of climate data
- Computers with MS Excel and Internet access
- Student journals
- Metric rulers
- Magnifying hand lenses
- Colored pencils for sketching
- Tape

AAAS Benchmarks:

The Nature of Science, Scientific Inquiry: "Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanation to make sense of the collected evidence."

Guiding Questions:

- What factors affect the appearance of tree rings?
- How can we use tree rings to learn about climate?

Background Information:
The study of tree rings and their relationship to past environmental conditions is known as **dendrochronology**.

Tree rings are regular patterns formed in the trunks of trees as the tree grows in diameter from the center out. The rings are caused by variations in the rate of growth throughout the year in temperate climates. In spring and early summer, the length of day increases and there is more available water, so the tree grows more rapidly, forming a lighter ring called **early wood**. As the day-length shortens, and winter brings dryer conditions, trees continue to grow, but not as much. A darker, denser ring forms inside the trunk, and this is known as **late wood**. The combination of a dark and light rings together represent one year of growth, from October through September of the following year, a period of time dendrochronologists refer to as a **hydrologic year**. By counting the rings, we can accurately determine the age of the tree.

Because tree-ring width varies with environmental conditions, we can also analyze tree rings to learn about weather conditions in the past. During wet, cool years, most trees grow more than they do during hot, dry years. As a result the tree tends to make wider rings in these years. Drought or a severe winter can reduce tree growth, causing narrower rings. Tree rings of similar width suggest similar weather patterns in those years. By matching the age of the tree to the width of the ring, we can make a pretty accurate guess about the weather that year.

Tree-ring width also varies with different species. The eastern cottonwood is a relatively fast grower, and lays down wider growth rings than other species (12–20 mm/year). By contrast, the bristlecone pine grows very slowly (often <1 mm/year) and it is difficult to count the rings with the naked eye. Though different trees grow at different rates, trees of different species growing in a location will show the same pattern of thick and thin annual growth rings because they have experienced the same conditions.

Researchers use computer analysis to match tree-ring data to climate patterns, ultimately to better understand large-scale climatic changes that have occurred in the recent or distant past. This information can also be used to develop highly specific and localized climate data. Archaeologists have used tree-ring data collected from log homes to determine when the structures were built. By comparing the pattern of line widths in the timbers to those of local trees of known age, they can determine the year the structure was built and get an idea of the weather patterns the builders experienced.

Dendrochronologists do not usually cut down entire trees to access tree-ring data. They use a tool called a **tree corer** to extract a sample without harming the tree. The tree corer bores a small hole from the bark to the center of the trunk and does not harm a healthy tree. The resulting core looks like a 1-centimeter dowel rod marked with lines from the tree rings.

In this activity, students will use simulated core samples printed on paper (masters in PDF form) to analyze and correlate tree-ring data spanning approximately the last 100 years in five old trees from different locations.

Introduction: What Are Tree Rings?

Time: One class period

1. Show students a cross-section of a tree or wood sample. Ask them what they know about tree rings. They will probably be able to state that we can count the rings to tell the age of a tree. They may or may not be able to tell you how a tree grows. If they do not already know this information, explain how trees grow from the center out.

2. Distribute tree cookies, hand lenses, and copies of the handout "What Are Tree Rings?" to the students. Have students work through the handouts as individuals or in pairs. Begin by asking students to look closely at the tree cookies and write what they see, not what they know. Take them through the questions, which will prompt them to notice similarities and differences in the tree rings.

3. At the end of question 8, gather some generalizations from the class about the similarities and differences they notice in different tree samples, and start a list of ideas about what causes these differences.

4. Use the final summary questions to check for understanding of key concepts.

You Are a Dendrochronologist

Part 1: Investigating causes of tree ring variation

In this activity, students will get a taste of how climatologists gather and analyze data from tree cross-sections to learn about climate change, and the challenges of presenting their findings to a skeptical public.

Time: One to two class periods

Pre-Class Preparation

- Prepare a set of simulated tree cores from the PDF Master **Student Tree Cores**. (These can be copied on heavier stock paper, or printed and glued to cover stock paper or light cardboard for better durability, if desired.) Depending on the size of your class, you may need to make more than one set, since you will assign three to four students to a group. Make sure you print them to the actual size of the PDF. This is important for student measurements.
    a. South Hero, Vermont – sugar maple
    b. Crosby, North Dakota – cottonwood
    c. Klamath Falls, Oregon – red alder
    d. Tullahoma, Tennessee – white pine
    e. El Paso, Texas – Mexican white oak
    f. Bluff, Utah – Douglas fir
- Gather photos or online images of a tree corer tool and a tree core.
- Set up computers with web access, at least one per group.
- Have available MS Excel or other spreadsheet software with graphing capability.
- Set of rulers with millimeter markings.

***Note**: If you are short on time, you may choose to provide students with the temperature and precipitation data (included in the teacher Excel spreadsheets) rather than having the students download the data themselves as part of the activity.*

Procedure

1. Review the concepts from the previous lesson. Introduce students to the field of dendrochronology. Explain that scientists do not need to cut down trees to see the rings; they use a tool called a tree corer that does not harm a healthy tree. Show picture of the tool and the core that is extracted.

2. Point out the pattern of dark and light lines on the picture of the core sample. Explain that dendrochronologists count a dark and light line together as one **hydrologic year**. A hydrologic year begins on October 1 and runs through September 30 of the following year. This means that each tree ring is labeled with two years 1990-1991, 1991-1992, 1992-1993, and so forth.

3. Review the student list of ideas about what causes variation in tree ring width. Explain to the students that they are going to investigate whether weather affects tree growth. They will be using data that has been gathered by the United States Historical Climatology Network and samples of tree cores from very old trees. This data will allow the class to test whether annual precipitation and temperature affect tree growth. Other ideas will have to be set aside for now.

4. Present the available data to the students. This includes:
   - simulated tree cores from six trees that are more than 100 years old; and
   - online records of historical weather data from the same locations, including information about total precipitation, average mean temperature, average minimum temperature, and average maximum temperature for each year.

5. Divide the class into groups of three to four students. Each group will design their own investigation to figure out how precipitation and annual temperature affect tree-ring growth. They will measure and graph tree-ring widths and compare that to a graph of climate data. Each group must:
   - reach consensus on a working hypothesis;
   - recognize that there is more data than they can work through in the time they have, so they must decide on a procedure that will yield good, convincing results. It will be up to them to decide what information to sample, how much data to use, and how to graph it.
   - measure, graph, and analyze the data;
   - reach a conclusion that the group agrees upon; and
   - present their findings in front of the class, providing sound arguments for their conclusion.
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   Whatever the students choose to do, it will be imperative that their information is accurate, the conclusions are based on sound reasoning, and the argument is compelling.

6. Demonstrate how to access climate data on the United States Historical Climatology Network website. Distribute tree-ring core samples, Student handouts #2A and #2B, and rulers. Allow students to begin their projects. Students can write the years and measurements directly on the tree cores. It may be helpful to make a mark on every tenth tree ring as a check to stay on track with the years. Assist as necessary.

***Note**: the simulated tree cores indicate the hydrologic year beginning with a light stripe (spring growth) instead of dark stripe. This is a reproduction error, and will not affect student results.*

Part 2: Present Your Findings
Time: One to two class periods

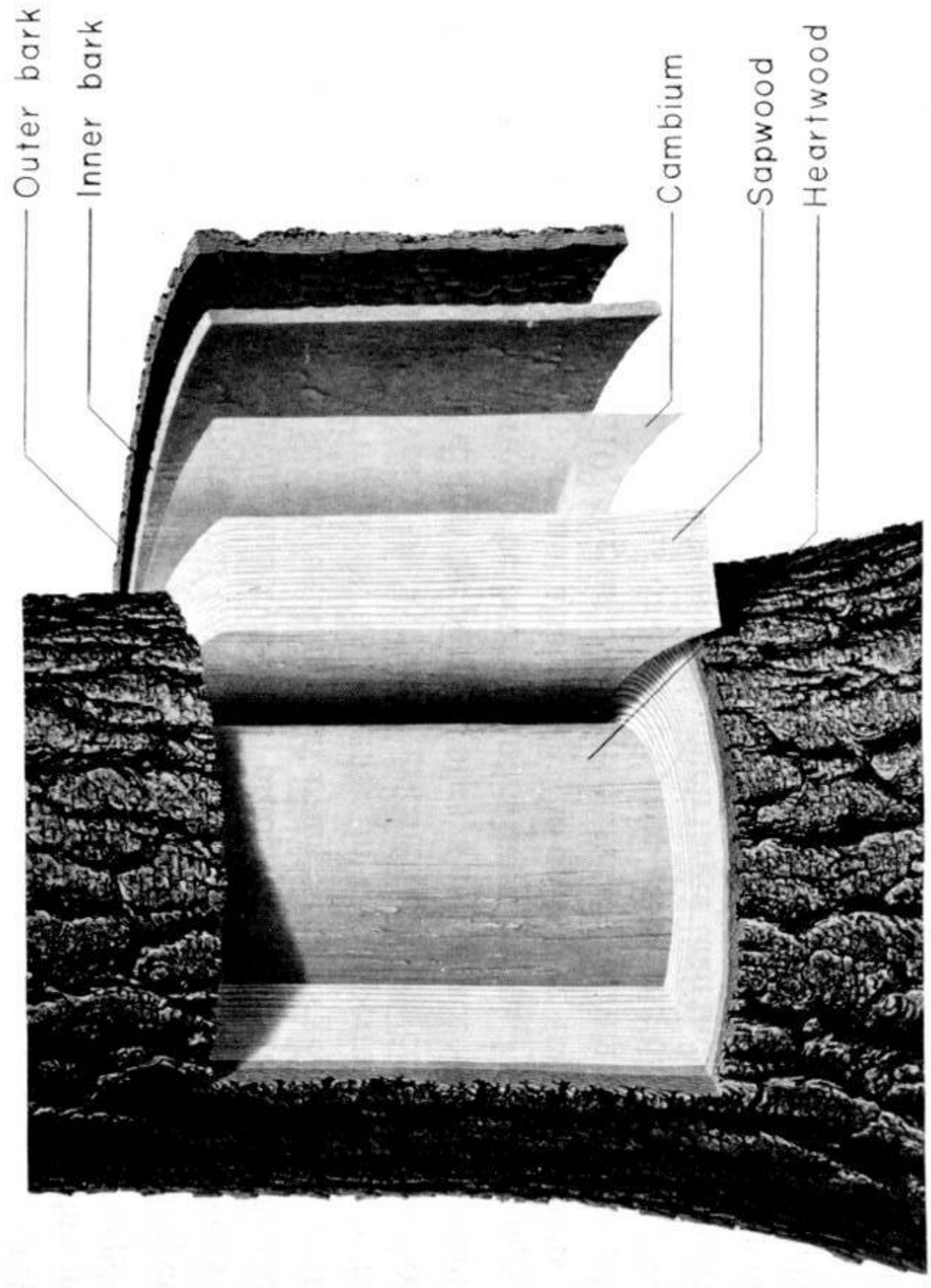
After students have analyzed their data and reached a conclusion, each group will prepare a brief presentation of their findings. Presentations should provide a compelling argument for their conclusion, whether or not the hypothesis was supported. This may be done in class or as a homework assignment. Each group then presents their project to the class. The class should be invited to ask questions, to find strengths or flaws in the reasoning, and to ask classmates to clarify or support their conclusion if necessary.

Part 3: Making Sense of Tree Rings
Time: One class period, or homework assignment

Use Student Worksheet #2C to assess student learning. Answers should reflect an understanding that tree growth is affected by climate, directly by precipitation and indirectly by temperature. Students should be able to predict that if climate changes, the growth pattern of local plants will also change.

Extensions and additional resources:
The USHCN has a tremendous amount of data available for download. Once students become familiar with the site, they could take the investigation further by doing a more sophisticated analysis such as scatter plots. If there is interest, they could develop formulas correlating various biotic and abiotic factors with tree growth and develop models to predict future trends. The following websites offer additional resources.

- http://web.utk.edu/~grissino/
  The ultimate tree-ring webpage
- http://www.uark.edu/misc/dendro/
  An outstanding source for tree-ring data and scatter plot information.
- http://www.ltrr.arizona.edu/
  A great resource on dendrochronology from the University of Arizona
- http://blogs.ei.columbia.edu/2011/05/26/tree-rings-open-door-on-1100-years-of-el-nino/
  Correlating tree-ring data to past El Niño events
- http://www.ldeo.columbia.edu/res/fac/trl/
  Link to the Lemont-Doherty Tree Ring Lab


Outer bark
Inner bark
Cambium
Sapwood
Heartwood

Tree-Ring Data Collection

Tree Coring Tool

Tree Core Sample

Using the tool to collect a tree ring core sample

Name______________________________________ Date______________ Class_________

Student Sheet #1: What Are Tree Rings?

1. Observe a sample of wood with and without a hand lens. Describe the pattern in the sample. Sketch a section of the pattern below and describe the pattern in words.

Describe the pattern below:

Sketch the pattern in this box:

2. Identify a year of growth on your sample. Label it on your sketch above.

3. How old was your sample when it was cut? _________ years

4. How can you tell in which years a tree grew a lot and in which years the tree grew only a little? Write your answer and draw a picture of the difference below.

The tree only grew a little this year:

The tree grew a lot this year:

5. Using a millimeter ruler, measure several of the rings.

Thinnest ring = ______ mm Widest ring = ______ mm.

What is the variation in ring width? (subtract the thinnest from the widest) _____ mm.

Name_________________________________ Date____________ Class________

6. Look at another sample of wood. List three ways the first and second samples are similar and three things that are noticeably different.

   Three ways the samples are similar:

   1. ____

   2.____

   3.____

   Three ways the samples are different:

   1. ____

   2.____

   3.____

7. Now look at a third sample. Is this sample similar in the same three ways? Yes or No
   Is it different in the same three ways? Yes or No

8. What do you think might cause variation in ring width? (We will test your ideas in our next lesson.)

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9. Write a summary of what you have learned about tree rings, including a description of how a tree grows and what the rings tell us.

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Student & Teacher Directions

How to Access Climate Data Online

Go to the United States Historical Climatology Network website:
http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html

Scroll down and
Click **DATA ACCESS** on the bottom of the screen
Click **WEB INTERFACE** (it will be the second bullet point in the text)

This takes you to a Google style map of the United States.

Select the desired state on the pull-down menu, (North Dakota, Oregon, Tennessee, Texas, Utah, or Vermont)

Click **MAP SITES**

A group of push pins and corresponding list of cities will appear. Click on the desired city and a bubble will appear over the push pin.

Click **GET MONTHLY DATA** inside this bubble. (You're almost there!)

This takes you to a new page.

Click **Create a download file of data summarized by hydrological year (October 1 – September 30)**

This takes you to a menu page. There are a lot of choices on this page. Whatever you select will give you a spreadsheet with one hundred years of records. You can choose more than one item. Depending on your hypothesis and procedure, select from the following choices:

- Total Precipitation – the annual total precipitation each year
- Mean Temperature (TMEAN) – the average temperature
- Minimum Temperature (TMIN) – the average lowest temperature during the year
- Maximum Temperature (TMAX) –average highest temperature during the year

You can choose more than one set of information.

Name the file in the window at the bottom.

Click **SUBMIT**

This generates a link to an MS Excel file. Download, copy, or cut and paste the information into a file and save it on computer or flash drive. This file will contain data sorted by year. (Precipitation is in inches, temperature is in degrees Fahrenheit.)

The spreadsheet will look something like this:

Source: MJ Menne RS CN Williams Jr. Vose NOAA National Climatic Data Center Asheville NC

State_id	Season_precip	HYD_MEAN_TMEAN (F)	HYD_SUM_PRECIP (in)
'420788'	'1894-95'	.	.
'420788'	'1895-96'	.	4.86
'420788'	'1896-97'	.	8.33
'420788'	'1897-98'	.	5.81
'420788'	'1898-99'	52.86	4.19
'420788'	'1899-00'	54.99	3.81
'420788'	'1900-01'	54.88	4.15
'420788'	'1901-02'	55.82	3.38
'420788'	'1902-03'	53.43	5.92
'420788'	'1903-04'	55.37	3.03
'420788'	'1904-05'	53.93	7.4
'420788'	'1905-06'	53.42	8.55
'420788'	'1906-07'	55.3	8.19
'420788'	'1907-08'	54.24	6.74
'420788'	'1908-09'	53.56	9.17
'420788'	'1909-10'	55	5.79
'420788'	'1910-11'	55.87	9.66
'420788'	'1911-12'	52.9	6.9
'420788'	'1912-13'	51.84	3.53
'420788'	'1913-14'	52.28	7.89
'420788'	'1914-15'	49.93	8.29

This partial spreadsheet shows annual mean temperature (HYD_MEAN_TMEAN) and total precipitation (HYD_SUM_PRCIP) for Bluff, Utah. The Season column is the hydrologic year.

Students should use a blank column to the right of the climate information to add their tree-ring measurements, taking care to record them for the correct hydrologic year.

Use the MS Excel program or other graphing software to graph the information. Study the graph (or graphs if you create more than one) and see if you can reach a conclusion.

Student Sheet #2A: You Are a Dendrochronologist

Dendrochronology comes from the Greek roots *dendros* meaning "tree," and *chromos* meaning "time." Combined with the suffix *ology* which means "the study of," the term describes the study of tree rings to learn about the past.

Your job is to figure out what environmental conditions affect tree growth, and then to convince the rest of the class that your conclusion is based on good research.

Materials and tools for your investigation:

- Six tree-core samples from different species and different locations
    - South Hero, Vermont – sugar maple
    - Crosby, North Dakota – cottonwood
    - Klamath Falls, Oregon – red alder
    - Tullahoma, Tennessee – white pine
    - El Paso, Texas – Mexican white oak
    - Bluff, Utah – Douglas-fir
- United States Historical Climatology Network records; more than 100 years of records for the same cities
- Rulers
- Spreadsheet and graphing software

Procedure

1. As a group, develop a hypothesis about the relationship between tree-ring growth and climate conditions. (Limit yourself to precipitation and temperature). Write your hypothesis on the Student Worksheet #2B.

2. Decide how you will conduct this study using the materials you have. How many data points do you need to answer your question and to convince others that your conclusion is valid? Will your data points be in consecutive years or will you look at every other year, every fifth year, etc?

3. Measure tree-core rings in millimeters and write the measurements on the tree-core sheets; combine this data with the climate data on a graph and try to figure out the relationships between tree rings, precipitation, and/or temperatures.

4. Think about the results. Why do you think you got these results? Write a conclusion.

5. Prepare a presentation where you support your conclusion in front of the class. *Good luck!*

CHICAGO BOTANIC GARDEN

Name________________________________ Date___________ Class_______

Student Sheet #2B: You Are a Dendrochronologist

Purpose: To determine the relationship between climate and tree growth.

Hypothesis: Write your hypothesis below.

____

____

Procedure: Describe how you will do this study. Which trees will you measure? How many measurements will you take? Write your procedure below.

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Results: Does the graph show a correlation between tree-ring width and any climate condition? Write your observations below.

____

____

____

Conclusion: What do your results tell us about tree growth and climate?

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____

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Name______________________________________ Date_________ Class __________

Student Sheet #2C: Making Sense of Tree Rings

1. Based on what you now know about precipitation, temperature, and tree growth, how could you use your tree-ring data to determine what the average temperature was 80 or 100 years ago at your sample site? Explain your answer in as much detail as possible.

2. Based on multiple sources of data over long periods of time, climatologists predict that global mean temperatures will rise by from 3 to 6 degrees over the next 100 years and precipitation patterns will change drastically if current trends continue. Predict how this trend might affect tree growth on a global level, and what impact this might have on your local community.

Teacher Answer Key
Student Sheet #1: What Are Tree Rings?

1. Observe a sample of wood with and without a hand lens. Describe the pattern in the sample. Sketch a section of the pattern below.

Describe the pattern below:	Sketch the pattern in this box:
Students should describe a pattern of concentric circles, with dark and light lines; they might mention variation in thickness; they might describe the bark layer being different from the wood.	***Drawing should show a pattern of lines in a circle; there should be variation in width. For question 6 below, there should be an indication that 1 year of growth is a dark and light line together.***

2. Identify a year of growth on your sample. Label it on your sketch above.

3. How old was your sample when it was cut? ______________ years (*answers will vary*)

4. How can you tell during which years a tree grew a lot, or during which years the tree grew less? Write your answer and draw a picture of the difference below. ***The thickness of the line indicates annual growth, the thicker the line, the more the tree grew that year.***

The tree only grew a little this year:	The tree grew a lot this year:

5. Using a millimeter ruler, measure several of the rings. ***Answers will vary.***

Thinnest ring = ______ mm Widest ring = ______ mm.

What is the variation in ring width? _____ mm

(Teacher Answer Key)

6. Look at another sample of wood. List three ways the samples are similar, and three things that are noticeably different.

   Three ways the samples are similar:

   Possible answers include: they both are round, there are circles, there is a light and dark pattern in the circles, there is bark on the outside, both trees have more than ten circles, etc.

   Three ways the samples are different:

   Possible answers include: the bark is different, there are a different number of lines, the lines are different widths, there are different marks (on the circles) on each piece, the wood is a different color.

7. Now look at a third sample. Is this sample similar in the same three ways? Yes or No
   Is it different in the same three ways? Yes or No

   They should be able to say yes, but if "no" they can still use their observations to make some generalizations about tree trunks.

8. What do you think might cause variation in ring width? (We will test your ideas in our next lesson.)

   All ideas accepted.

9. Write a summary of what you have learned about tree rings, including a description of how a tree grows and what the rings tell us.

   Answers should include that trees grow out from the center, that tree rings show annual growth, that the dark and light line together form in one year of growth, that the ring widths are different sizes, that different trees have different marks but they all have rings, etc.

Teacher Answer Key

#2C — Making Sense of Tree Rings

1. Based on what you now know about precipitation, temperature, and tree growth, how could you use your tree-ring data to determine what the average temperature was 80 or 100 years ago at your sample site? Explain your answer in as much detail as possible.

   Since growth and precipitation seem to be closely correlated, and temperature is inversely correlated, you could look at whether or not the growth trends followed precipitation trends in the same way they have over the past ten years. If growth is more than it is today, you might be able to say that the temperature was lower than today, if growth with the same precipitation was less than it is today, you could say that the temperature was higher.

2. Based on multiple sources of data over long periods of time, climatologists predict that global mean temperatures will rise by from 3 to 6 degrees over the next 100 years if current trends continue. Predict how this trend might affect tree growth on a global level, and what impact this might have on your local community.

   Answers will vary, but should reflect an understanding that if temperatures increase, tree growth may decrease, depending on whether the heat increase is accompanied by adequate precipitation. Tree growth is lowest when there are conditions of high temperatures and low precipitation, while it is greater when temperature is lower and moisture is higher.