LESSON 14: BRANCHING OUT
Exploring Dendrochronology

PURPOSE/QUESTION
Students will investigate how tree rings are formed, what causes differences in the width of rings in a given, and the relationship is between tree rings and climate change.

GRADE LEVEL
9-12

TIME TO COMPLETE
2-3 – 50 minute time periods

STANDARDS
See appendix below-page 12

LEARNING OUTCOMES
- Students will understand the importance of dendrochronology to climate science
- Students will observe and analyze tree rings
- Students will be able to predict possible weather and or natural hazards that effected tree growth during growing seasons.

STUDENT OBJECTIVES
- Recognize seasonal and annual growth in trees
- Describe and explain how tree ring appearance is affected by environmental conditions
- Collect, analyze, and interpret tree rings data, and correlate to historical climatic conditions
- Develop hypotheses as they relate to current environmental conditions in my region

TEACHER BACKGROUND
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 and are caused by variations in the annual growth of trees. Rings develop as concentric circles moving outwards from the core of the trunk with repeating patterns of light and dark wood. The lighter and wider section is known as early wood, and is laid down during times of relatively rapid growth. In temperate climates, this growth usually occurs during spring and early summer. The darker narrower section is known as late wood and is laid down later in the growing season when environmental conditions are not as favorable for growth. Because the tree is not growing as rapidly, the ring appears darker and denser than the early wood. The pattern of a light and then dark layer signifies a single year of growth and can tell us many things about the tree and its environment.

Dendrochronologists working today usually do not cut down entire trees in order to access tree ring data, but rather use a tool to extract core samples. 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. During wet, cool years, most trees grow more than during hot; dry years and the rings are wider. Drought or a severe winter can cause narrower rings. If the rings are a consistent width throughout the tree, the climate was the same year after year. Some tree species, like the Eastern Cottonwood, are relatively fast growers, and can lay down relatively wide growth rings (12-20 mm/year) while others such as the Bristlecone Pine, grow at very slow rates (often <1 mm/year). By counting the rings of a tree, we can determine, with a great deal of accuracy, the age and health of the tree and the climatic conditions present during the growing season of each year.
Computer analysis allows researchers the ability to look closer at and 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; for example, archaeologists use tree rings to date timber from logs used in structures or homes from extinct cultures by correlating the growth rings from the cut structural logs to rings in very old trees nearby. Matching these growth patterns can indicate the year in which a tree was cut, and thereby provide evidence for the age of a structure.

MATERIALS & TOOLS

- Computer with internet access
- Metric Ruler
- Hand Lens
- Microscope (Optional)
- Assignment 1-What Can Tree Rings Tell Us? Found on pg. 3
- Assignment 2-Making Sense of Tree Rings Found on pg. 5
- Assignment 3-You Are a Dendrochronologist Found on pg. 6

READING RESOURCES

- Tree Rings Tell Us a 1,100 year History of El Nino

VOCABULARY

- Dendrochronology
- Temperate Climate

ASSESSMENT TOOLS

- Concept Quiz – found on pg. 16
- Essay – found on pg. 19
- Student Assignments 1-3

REFERENCES

Adapted from Chicago Botanic Garden Climate Change Education Project

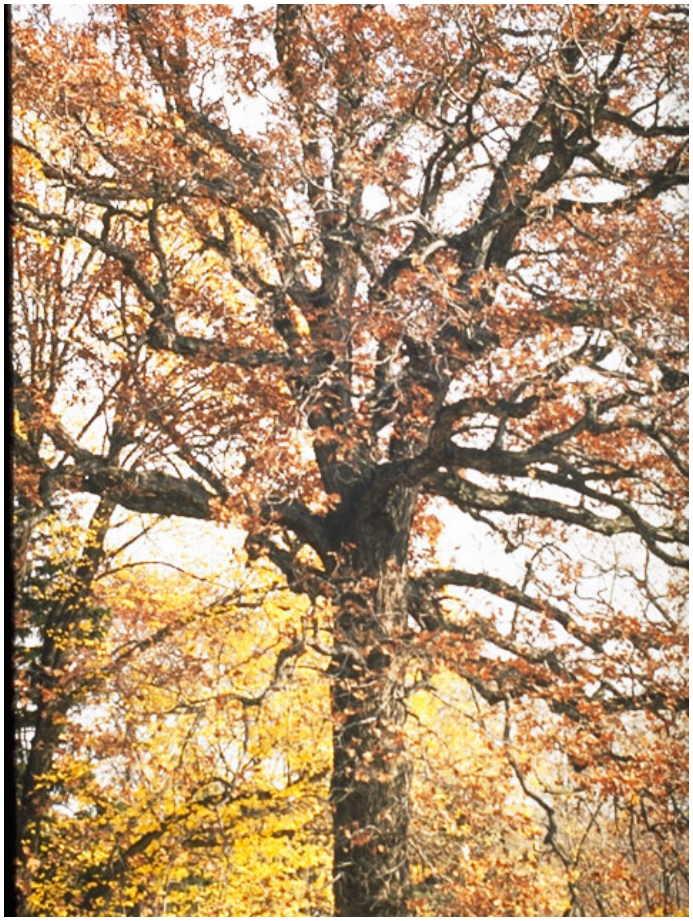

Photo credit: Albert F. W. Vick, PA, 1990.
White Oak – Ladybird Johnson Wildflower Center.

Name_____ Date_____ Class_____

What Can Tree Rings Tell Us?

Dendrochronology is the branch of science that studies growth rings in trees, and uses this information to help us understand the ecological conditions in which that tree grew over time. The word dendrochronology comes from the Greek roots dendros meaning tree, and chromos meaning time, or quite simply, the study of trees over relatively long periods of time.

From the study of tree rings, we can approximate the age of trees, as well as the varying climatic conditions in which these trees grew over the course of their lifetime. Each year, trees produce a new layer of wood under their bark. In temperate climates, trees undergo their greatest growth period in the spring and early summer, and slower growth in late summer and fall. There is little, if any growth during the cold winter months. The lighter and wider section is known as early wood, and is laid down during the times of relatively rapid growth. In temperate climates, this growth usually occurs during spring and early summer. The width of a growth ring tells us about the climate in the past because the growth rate depends primarily on precipitation and temperature during the growing season. Trees grow more during wetter years with good temperatures (wider rings) and less during colder, drier years (narrow rings). By measuring, comparing, and analyzing the growth rings of trees, we can draw fairly precise conclusions about the climate in which that tree grew.

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1. Observe and study the sample of wood. Describe the pattern, if any, that you notice in the sample. Sketch in as much detail as possible a section of the sample below.

2. Using a dissecting microscope, or a hand lens, look closely at the pattern of rings. Are there any variations within each individual ring? What might have caused this? Sketch your observations below.

3. Using a ruler, measure several of the rings. Be as accurate as possible, and measure using millimeters as your unit. Are all the growth rings the same width? List and describe at least two or more environmental factors that might have caused this. Explain why the tree's growth might be affected by these environmental factors.

4. How old was this tree when it was cut? How can you determine this? What would you need to know about this sample in order to determine when it ***began*** growing?

5. Now select at least two different samples and compare them to your original sample. In terms of growth rings, in what ways are they similar? In what ways are they different? Describe at least 4 similarities and 4 differences.

6. Based on what you know about tree rings and the way in which they are formed, rank the samples from oldest to youngest (when they were cut). Which sample had the most consistent growth? Which one had the most inconsistent growth patterns? How do you know this? What factors might have contributed to these different growth patterns?

Name_____ Date_____ Class_____

Making Sense of Tree Rings

Write a description in the space below that compares the two samples you have chosen, and demonstrates your understanding of tree rings and what they can tell us. You should include the major similarities and differences between the samples, what factors may have produced these characteristics, and what that tells us about the environment in which these trees grew. You may include drawings or sketches with your writing.

You Are a Dendrochronologist

You and your team have been given a set of "cores" that have been removed from several different species and different individual living trees, at different times over the last 100 years or so, and have come from different locations around the country. By carefully studying the patterns of growth rings displayed in each set of cores from a given location, and aligning them by common patterns found in these cores, we can construct a tree ring "time-line" that runs from the present day to as much as 115 years ago. Each core tells a part of the story of the growth conditions that the various living trees were subjected to during their lifetime. When all the cores are properly aligned, the entire record of growth and environmental conditions becomes much more apparent.

2 Days Needed To Complete

In this activity, you will align the different tree cores, record the age of each core when taken, and then by measuring and recording the width of each unique ring (mm) and graphing that data (either into a spreadsheet or by making a pencil and paper graph), observe and identify what relationship there is between precipitation amounts and tree ring growth.

Procedure

1. Your teacher will provide you with a need a set of simulated tree cores pre-marked with ring patterns.

2. Student teams should cut out the individual tree cores **(MAKE SURE TO KEEP THE LABELS ATTACHED IF YOU ARE CUTTING THEM OUT YOURSELVES!!)** and lay them out on your workspace.
    a. Record the core's name and # in Table 1.0
    b. Count and record the number of rings in each core.
    c. Based on number of growth rings, record the age of the tree when the core was taken.
    d. Measure the width in millimeters (mm) of each ring in each core, and using pencil (in case of mistakes!) record the value in the center of each ring on the samples. This serves two purposes:
        i. Allows you to have a numerical pattern to look for, as well as the visual pattern of the rings themselves
        ii. Once the cores are properly aligned, you will then have, in chronological order, a composite, long-term set of data that can then be graphed.
    e. Now look for patterns or groups of patterns in the growth rings that are common to two or more core samples, and **align the cores into chronological order from left to right (oldest to most recent).** These common patterns represent years when both trees were actively growing. **REMEMBER early growth is represented by lighter wood and later growth by darker wood**. Take your time, double check each other, and be as accurate as you can.

3. When your team group has the cores correctly aligned, you should carefully tape tem together to form one continuous composite core that represents over 100 years of tree growth within a specific region. Your team will then have over 100 years of tree ring data representing a time line of climatic (and ecological) events that can be used to relate tree growth to historical precipitation levels.

4. **Accurately and carefully record this data in an Excel spreadsheet** or your journals. Your team should choose 1 person to act as the recorder of data, and have them checked for accuracy by another member of the team.

5. Using your aligned core samples, your team should work to complete Table 1.0. **All references to years are hydrologic years (October 1st-September 30th).** This means that "Year Cut" would not be, for example 1972, but rather 1972-1973.

6. Once your team has successfully completed this part of the activity, you should rank the samples from oldest to most recent, record that data in Table 1.0. and complete the two questions at the bottom of the table. The taped cores should be carefully folded and stored. Your teacher will collect them for use later.

Day 2

1. Go to the website http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html This is the United States Historical Climatology Network and was developed over the years by a joint effort between NOAA and NASA, and offers detailed, user friendly access to climatological data from reporting stations throughout the United States. You will use it to acquire historical HY precipitation data in the form of Excel spreadsheets. Once at the site:

   A. Click **DATA ACCESS**>Click **WEB INTERFACE**

   B. This takes you to a Google style map of the United States. On the Pull-Down menu, students should select the state that their core sample came from and then

      Click **MAP SITES**

   C. A group of push pins will appear; you should select the reporting station that your core sample came from, and when you do, a bubble will appear.

   D. Click **GET MONTHLY DATA**
   Click **Create a download file of data summarized by hydrological year (Oct 1 - Sep 30)**

      Select **TOTAL PRECIPITATION**

E. You can give your file a unique name of your choosing, or simply go with the default name. The year range should be the default selection.

Click **SUBMIT**

F. This generates a link to an Excel file that you can download to your computer or flash drive. This file will contain hydrologic year (HY) precipitation amounts in inches, sorted by year.

2. Now enter your ring width data into the Excel spreadsheet, and generate line graphs comparing growth rates in their tree sample to historical HY precipitation levels. Your team should save their files, so they can be displayed electronically for class discussion, and print copies of your graphs for class display when you are finished.

Name_____ **Date**_____**Class** _____

Table 1.0 You are a dendrochronologist data collection table.

Sample Name_____

Species_____

Core Number	# of Rings in Core	Age of Tree When Core Was Taken	Year Tree Started to Grow	Year Tree Was Cut	Age Rank 1-7 (Oldest-Youngest)

Name_____ **Date**_____ **Class**_____

You Are a Dendrochronologist…

Analysis questions:

1. How many unique rings are represented by your composite sample core? _____

2. Determine the mean (average) ring width for your composite sample core. You can do this manually by adding up all the values and dividing by the number of values you have, or your teacher can show you how Excel will do it for you easily and quickly. Record the mean: _____ mm.

3. Looking at your graph, in general terms, describe the relationship between precipitation levels and tree growth.

4. Thinking about your answer to Q3, is there an exact one-to-one relationship between precipitation and tree growth. Why or why not? Explain your answer and give reasons based in your data.

5. Based on your data and graphs, and what you now know about tree rings and their development in relationship to precipitation amounts, how do you think temperature would affect the growth of tree rings? Give reasons for your answer based in your data and develop a hypothesis for the affect of temperature on tree growth.

6. Search the USHCN website for temperature data for the last 10 years for your sample area. Compare those values to your tree ring data. Describe the relationship that you notice. How does this compare to the relationship between precipitation and ring growth?

7. 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.

LESSON 14-APPENDIX

WEB ADDRESSES FOR HYPERLINKS

VOCABULARY

- **Dendrochronology**
  https://www.google.com/search?hl=en&rls=com.microsoft:*&defl=en&q=define:Dendrochronology&sa=X&ei=scvETMOuMMTflgfi4PkE&ved=0CBMQkAE
- **Temperate Climate**
  https://www.google.com/search?hl=en&rls=com.microsoft:*&defl=en&q=define:Temperate+climate&sa=X&ei=5cvETIzZOoLGlQfL8rkD&ved=0CBcQkAE

STUDENT READING RESOURCES

- **Tree Rings Tell Us a 1,000 Year History of El Nino**
  http://www.sciencedaily.com/releases/2011/05/110506093107.htm

LESSON 14-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Standard A – Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard C – Life Science

- Interdependence of organisms

Standard G – History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

Standard 3: Research and Information Fluency

- Process data and report results

Standard 6: Technology Operations and Concepts

- Understand and use technology concepts
- Select and use applications effectively and productively
- Troubleshoot systems and applications
- Transfer current knowledge to learning of new technologies

National Council of Teachers of Mathematics Standards

Algebra

- Understand patterns, relations, and functions
- Use mathematical models to represent and understand quantitative relationships
- Analyze change in various contexts

Measurement

- Understand measurable attributes

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data

Process

- Connections
  - Recognize and apply mathematics in contexts outside of mathematics
- Representation
  - Use representations to model and interpret physical, social, and mathematical phenomena

Climate Literacy Principles

Principle 2: Climate is regulated by complex interactions among components of the Earth system.
Principle 3: Life on Earth depends on, is shaped by, and affects climate.
Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling

Energy Literacy Principles

Principle 3: Biological Earth processes depend on energy flow through the earth system.

LESSON 14-ESSENTIAL QUESTIONS ANSWER KEY

What Tree Rings Can Tell Us

You should have several samples available; at least one per 3-4 students, preferably more. Samples could be a tree "cookie", a piece of fire wood, or students could be taken into the field to observe cut stumps. Local departments of forestry and parks often cut trees and are excellent sources for tree cookies, as are private landscaping and arborist companies. Any sample should display clearly visible growth rings, and the sample should be at least 10 years old. If none of these are possible, pictures of tree rings are readily available on the internet.

1. Observe and study the sample of wood. Describe the pattern, if any, that you notice in the sample. Sketch in as much detail as possible a section of the sample below.
   [Students should be able to describe the general pattern of concentric rings.]

2. Using a dissecting microscope, or a hand lens, look closely at the pattern of rings. Are there any variations within each individual ring? What might have caused this? Sketch your observations below.
   [Students should recognize the variation within each ring from lighter wood to darker wood; this caused by larger, rapidly growing cells produced during active spring growth, and smaller, darker cells produced during summer and fall. If they are careful observers, they should be able to notice this.]

3. Using a ruler, measure several of the rings. Be as accurate as possible, and measure using millimeters as your unit. Are all the growth rings the same width? List and describe at least two or more environmental factors that might have caused this. Explain why the tree's growth might be affected by these environmental factors.
   [Students' answers will vary, but should include precipitation amounts, and temperature. There are many other factors that affect ring size variability such as angle of growth, competition from other trees, fire scars, wind, age of the tree etc.]

4. How old was this tree when it was cut? How can you determine this? What would you need to know about this sample in order to determine when it ***began*** growing?
   [Age of samples will vary. By counting the number of growth rings, students can determine the age; 1 year for each ring. In order to determine when the tree started growing, you need to know when it was cut or the core was taken.]

5. Now select at least two different samples and compare them to your original sample. In terms of growth rings, in what ways are they similar? In what ways are they different? Describe at least 4 similarities and 4 differences.
   [Answers will vary.]

6. Based on what you know about tree rings and the way in which they are formed, rank the samples from oldest to youngest (when they were cut). Which sample had the most consistent growth? Which one had the most inconsistent growth patterns? How do you know this? What factors might have contributed to these different growth patterns?
   [Answers will vary.]

Making Sense of Tree Rings

Write a description in the space below that compares the two samples you have chosen, and demonstrates your understanding of tree rings and what they can tell us. You should include the major similarities and differences between the samples, what factors may have produced these characteristics, and what that tells us about the environment in which these trees grew. You may include drawings or sketches with your writing.

[Students should write an essay for the formal, final assessment]

You Are a Dendrochronologist

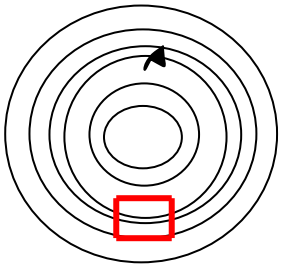
All answers will vary due to a wide variety of tree ring samples.

Name: _____ Date: _____

Science Concept Quiz
Lesson 14: Branching Out – Exploring Dendrochronolgy

Tree rings have many stories. For scientists tree rings can help them understand climate conditions or when fires or infestations occurred over the life of the tree. **In the diagram below what can you infer took place in the highlighted area?**

A. A good growth year
B. A severe drought
C. Fire
D. Insect infestation



_____ points out of 20

I. Answer

A.○ B.○ C.○ D.○

_____ points out of 15

II. What is the main concept behind the question?

1. Changes in weather patterns
2. Making inferences
3. How fires affect trees
4. Scientists who study trees

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

1.

2.

3.

4.

Use the rest of this page if more room is needed to fully communicate your thoughts.

Teacher Answer Key

1. B

2. 2

3. Answers will vary. Based on what I learned in the lesson on dendrochronology I was able to infer that when two rings are close together it generally indicates slow growth due to drought or decreased precipitation.

4. Answers will vary.

   A) Tree rings that have a significant amount of space between rings generally indicates a good growth year.

   B) This is the correct answer.

   C) Fire is indicated by dark areas on tree rings.

   D) Insects can also cause scarring similar to fire scars or you may notice a series of narrow rings.

Student Name
Teacher/Class
Date

Lesson 14: Branching Out – Investigating Dendrochronology

Explain how scientists use tree rings to “tell a story” of weather events and patterns in climate.

What Is the Expectation?

Use new lesson knowledge or student readings to support your position

Visual representations if applicable

Key vocabulary

Evidence of on grade level spelling and grammar usage