Wood Magic

A wood science curriculum for fourteen-to eighteen-year-olds

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Table of Contents

Introduction

It is important for students to gain an understanding of their environment through the use of real-world applications before they enter adulthood. Studies of environmental science reveal the negative impact humans are having on our environment. The first step towards correcting this problem is through education. Lack of education has caused many individuals to see wood science and forestry practices as one of the underlying causes of this problem. However, this is far from the truth. Wood Magic is a curriculum designed for high school students to raise awareness of how wood has become a vital part of our lives and the role of wood utilization in a sustainable future. This activity guide can easily be implemented into a formal or informal educational setting.

If used in a formal educational setting, Wood Magic can serve as a supplement to an existing science curriculum. This activity guide uses the Virginia Standards of Learning and the National Science Education Standards. Many of the activities require more than an hour to complete and some need several teachers. Each lesson is divided into introduction activities and activities; therefore, teachers can elect to do the introduction activity the day before completing the main activity. Also, many of the introduction activities can be done by the students outside of class.

The activities in Wood Magic have been designed using the experiential learning model. This model is divided into three steps: do, reflect, and apply. The first step (do) is where students perform/experience the activity. In the second step (reflect), students share and process their experience. Then in the last step (apply), students make generalizations of how the information learned in the activity applies to their own lives and they also apply the information to new situations. This approach allows students to actively engage in their own learning, thus allowing a more meaningful learning experience to occur.

Participants take part in many interactive activities and experiments. Lesson 1 introduces students to wood science and allows them to realize the extensive usage of wood in their daily lives. Lessons 2 through 8 are based on the macroscopic and microscopic structure of wood. Their purpose is to prompt students' understanding of how structure is related to function. This concept prepares them for Lessons 9 and 10 which provide students with a very hands-on approach to wood science. These two lessons are an accumulation of the concepts the students learn throughout Wood Magic. The final lesson ties all of these concepts together by showing students the impact wood science has on the environment.

Overall, Wood Magic serves to prepare students to make ethical choices dealing with wood utilization. Through education, students can understand how their actions and the actions of others impact their immediate and distant surroundings. Hopefully, students will gain an appreciation for the magic that surrounds wood and its products.

Basic Features of Wood Magic Activities

Virginia Standards of Learning

National Science Education Standards

Each activity provides corresponding Virginia Standards of Learning and National Science Education Standards. This makes implementing Wood Magic in classrooms much easier.

Content Skill

Each activity identifies the lesson objectives for students. Lesson objectives explain what the students will be learning in the lesson and how they will accomplish this task.

Life Skill

Each activity identifies the life skill that will be achieved through the process of completing the activity. These life skills are based on 4-H principles.

Success Indicator

This section gives a simple statement of what students should accomplish in the activity.

Time Needed

Each activity provides an approximation of the time needed to complete the lesson. This approximation is based on the introduction activity and main activity combined. Times may vary depending on the class size and setting.

Activity Summary

This section summarizes what students will be doing in the main activity.

Activity Materials

This section provides a list of the materials that are needed to complete the activity.

Introduction

Activity

This section describes the activity to be conducted in each lesson.

Procedures

This section summarizes the first step of the experiential learning model (do). It provides step-by-step directions for the activity.

Do

This section is the first step of the experiential learning model and is where students perform and experience the activity.

Reflect

This section is the second step of the experiential learning model where students share their results and process the information they gained from the lesson.

Apply

This section is the final step of the experiential learning model where students apply the knowledge gained during the activity to their own lives as well as new situations.

Resources

Some sections will provide a list of additional resources for teachers who want the students to explore the topic further.

DID YOU KNOW?

Some sections have a bulleted list of fun trivia facts for students.

Suggestions to Teacher/Leader

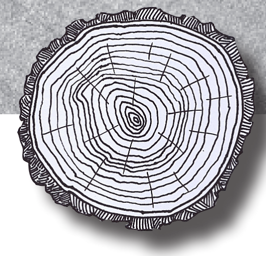
1. Students need to be reminded of safety precautions before beginning activities. Some of these activities use chemicals and/or sharp objects and students should be aware of the proper safety measures to take.
2. Students should keep either a Wood Magic portfolio or journal. Many of the introduction activities could be kept in portfolios or journals. The Reflect and Apply sections could also serve as questions to be answered in portfolios or journals. These types of assessments will be much more useful and helpful to students than traditional assessment methods. Portfolio and journals allow students to reflect on and control their own learning.
3. If time constraints are an issue, it may be easier to complete one lesson in a two-day period. Students can perform the introduction activity on the first day and then finish the lesson the next day.
4. Lessons 9 and 10 will be very time-consuming. Incorporate the lesson into your plans each day so students have an opportunity to work on the project a little bit at a time.
5. Some of the topics in this curriculum guide will be challenging for many students. It is often helpful to seek assistance from special education teachers if some students need special accommodations.
6. Some of these topics may be new to you. Review each lesson before introducing it to students. It is helpful if you perform the activity beforehand to familiarize yourself with the information. This will allow you to see if any changes need to be made to better fit your students and the classroom setting.
7. Complete the wood-drying beforehand so class time can be made as productive as possible. Several of the activities use wood that needs to be dried for several hours and this task can be accomplished the night before class in many instances.
8. Many of these lessons incorporate several different sciences and some use mathematics. If time is an issue, science and math teachers can work collaboratively to create a thematic unit on wood science so all lessons can be completed. Many of the lessons can easily fit with Math SOLs.

Supplies

Supplies for many of the activities found in Wood Magic can be obtained from the following sources:

1. Aldrich – chemicals and laboratory equipment; Milwaukee, Wisc. (800) 558-9160 *www.sigma-aldrich.com*
2. Fisher Scientific – chemicals and lab equipment; Pittsburgh, Pa. (800) 766-7000 *www.fishersci.com*
3. Carolina Biological Supply Company; Burlington, N.C. (800) 334-5551 *www.carolina.com*
4. Edmund Industrial Optics; Barrington, N.J. (800) 363-1992 *www.edmundoptics.com*
5. Sigma – Biochemicals and Reagents; St. Louis, Mo. (800) 325-3010 *www.sigma-aldrich.com*
6. Cole-Parmer Instrument Company; Vernon Hills, Ill. (800) 323-4340 *www.coleparmer.com*
7. Daigger Discount Lab Supplies; Lincolnshire, Ill. (800) 621-7193 *www.daigger.com*
8. Micro-Mark – The Small Tool Specialists; Berkeley Heights, N.J. (800) 225-1066 *www.micromark.com*
9. Grainger – everything from tools to light bulbs to soap; Charlestown, Mass. (888) 361-8649 *www.grainger.com*
10. Craftsman Power and Hand Tools; Manteno, Ill. (800) 290-1245 *www.sears.com*
11. Woodworker's Supply Inc; Casper, Wyom. (800) 645-9292 *www.woodworker.com*
12. Rockler Woodworking and Hardware; Medina, Minn. (800) 233-9359 *www.rocklerpro.com*
13. Woodworkers Library – books, videos, and plans; Linden Publishing, Fresno, Calif. (800) 345-4447 *www.lindenpub.com*
14. Manny's Woodworkers Place – books and tools; Lexington, Ky. (800) 243-0713 *www.mannyswoodworkersplace.com*
15. Garrett Wade – woodworking tools; New York, N.Y. (800) 221-2942 *www.garrettwade.com*
16. Woodcraft Supply Corp.; Parkersburg, W.Va. (800) 225-1153 *www.woodcraft.com*

Lesson 1: Made in the USA – Goods from the Woods



Content Area: Forest Products

Virginia Standards of Learning addressed:

ES.2D: The student will demonstrate scientific reasoning and logic by:

- Explaining that observation and logic are essential for reaching a conclusion

ES.7: The student will investigate and understand the differences between renewable and nonrenewable resources.

BIO.1B: The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Formulate and revise scientific explanations and models using logic and evidence

Content Standard F: All students should develop an understanding of natural resources and science and technology.

- Humans use many natural resources

Content Skills

Students will be able to:

- Define the term *raw material* and understand that wood is a natural renewable resource
- Identify examples of wood products and wood by-products
- Begin to conclude how the utilization of wood impacts the environment

Life Skill

Critical thinking

Success Indicator

Accurately identify examples of wood products and wood by-products

Time Needed

60 minutes

Lesson 1: Made in the USA – Goods from the Woods

Activity Summary

Using critical thinking skills, students will identify wood products and wood by-products found in their classroom, homes, and example pictures.

Procedures

Do (~ 5 minutes)

To identify any misconceptions that might exist, have the students consider the following:

1. Define the term *raw material* and provide two examples.

 ____

 ____

2. What raw material is used in the greatest quantity in the U.S.?

 ____

 ____

Reflect (~10 minutes)

Now have students discuss their answers with the class. Record answers on the board.

If the students defined raw materials as unprocessed products used in manufacturing, then they are correct. Examples of raw materials include wood, steel, aluminum and concrete. You may have been surprised that the answer to question 2 was wood. The following graph shows that wood is not only the most frequently used raw material, but it is also used in amounts that are roughly equal to all other industrial raw materials combined!

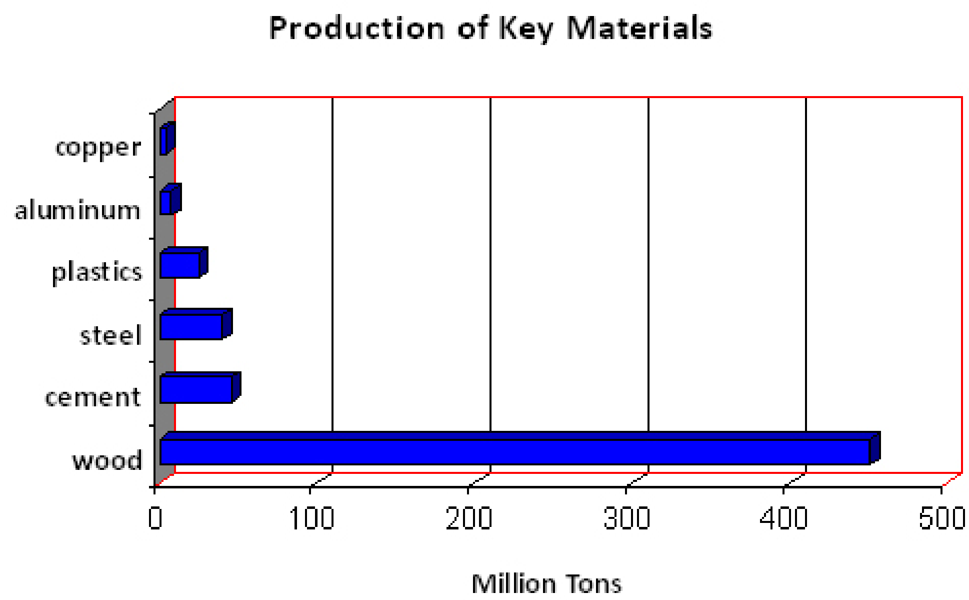


Figure 1. Production of Raw Key Materials

Apply (~ 5 minutes)

Ask the students the following questions and discuss the answers:

Why do you think wood is the most utilized raw material? What are some advantages and disadvantages to using wood as opposed to other raw materials?

Activity Materials:

Lesson 1 Work Sheets A and B are to be completed as part of this activity.

"Wood's Mysterious Products" Information Packet (3 pages)

Procedures

Do (~ 30 minutes)

1. After reading the background information, students will record examples of wood products and wood by-products that they see in the classroom.
2. Next, students will record examples of wood products and wood by-products found in their homes.
3. Each student will record his or her observations on the board.
4. The class members will discuss their observations with one another.
5. The teacher will then distribute the handout entitled "Wood's Mysterious Products" to students. Students will be given time to read the information packet to learn about the diverse uses of wood.
6. After discussing all the different types of products, students will complete Lesson 1 Work Sheets A and B individually.

Background Information

Trees are considered to be natural renewable resources (substances that can be replaced). Besides growing wood, trees have many functions including removing excess carbon from our environment, providing shade and shelter, anchoring soil, reducing water and air pollution, and providing beauty and recreation for us. Therefore, unlike fossil fuels, metals, and plastics, wood can be harvested, used, regrown, and then harvested again. This cycle can continue indefinitely as long as the trees harvested are replaced with new plantings. With proper management, our forests can provide us with thousands of products and still have plenty of trees for wildlife habitats today and in the future. Through research and advanced technology, we have learned how to convert tree fibers and paper-pulping residues into more than 5,000 products!

Reflect (~ 5 minutes)

Ask and discuss the answers to the following questions:

1. What wood product was most surprising to you? What had you originally thought the product was made from?
2. What is your personal view about the logging industry? Has your view on the logging industry been changed due to this activity? Why or why not?

Apply (~ 5 minutes)

Ask and discuss the answers to the following questions:

1. As a consumer, why is it important to understand where the products that you use come from?
2. If wood products are the most produced raw material, what are several implications that could result if trees that are harvested are not replaced?

For additional information about the use of wood in our society you are encouraged to consult the following references and the SWST website *(www.swst.org):*

Flynn, J.H. and C.D. Holder (Eds.) 2001. *A Guide to Useful Woods of the World*. Forest Products Society, Madison, Wisc. *www.forestprod.org/*.

Bowyer, J.L., R. Shmulsky, J. G., Haygreen. 2007. *Forest Products and Wood Science - An Introduction*, fifth edition. Iowa State University Press, Ames, Iowa.

Howard, J.L. 2001. U.S. timber production, trade consumption, and price statistics 1965-1999. Res. Pap. FPL-RP-595. USDA Forest Service, Forest Products Lab., Madison, Wisc. *www.fpl.fs.fed.us/welcome.htm*.

Leavell, C. 2001. *Forever Green, The History and Hope of the American Forest*. Longstreet Press, Inc., Marietta, Ga.

Lincoln, W., A. Peters, L. Leech, J. Marshall, A. Walker, and L. Hughes. 1993. *The Encyclopedia of Wood*. Quarto Publishing PLC, The Old Brewery, 6 Blundell Street, London N7 9BH, England.

Moore, P. 2000. *Trees are the Answer*. Greenspirit Enterprises Ltd. Vancouver, B.C., Canada.

DID YOU KNOW?

- Paper is the most recycled material of all those that are routinely recycled.
- In the U.S., we annually consume about 660 pounds of paper for every man, woman, and child.

Figure 2. People surrounded with yearly consumption of paper.

Approximately 97% of paper is made from wood.

Healthy growing forests do a better job for our environment than older, decaying ones. We get healthy growing forests when we apply modern forestry knowledge to the forest through tree farming and sustainable forest management practices.

From 1900 to 1990, the U.S. grew and used the equivalent of 14 billion 100-foot trees.

Name ____

Made in the USA – Goods from the Woods

Figure 3. Kitchen counter with wood products

There are 21 items in this picture that are made from wood products and wood by-products. Can you find them all?

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________
16. ____________________
17. ____________________
18. ____________________
19. ____________________
20. ____________________
21. ____________________

Name ____

Made in the USA – Goods from the Woods

Figure 4. Identifying wood products

There are six different types of wood products shown in this picture. Can you find them?

1. ____

2. ____

3. ____

4. ____

5. ____

6. ____

Wood's Mysterious Products

Many of you probably recognized several common products made from wood such as **paper**, **lumber**, and **plywood**. Lumber is the principal framing material used in house construction. It is solid wood that has been cut into different shapes. It is also used to make cabinets, furniture, and sporting goods. Plywood is made by cutting thin veneers and then gluing them together with the grain direction of adjacent veneers at right angles to one another.

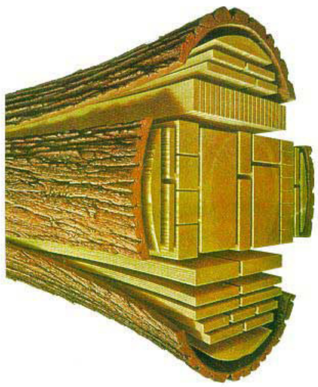


Figure 5. Lumber sections

Figure 6. Plywood

Some of you may have even listed **particleboard**, which is a product made by gluing small flakes, shavings, or splinters of wood together using heat and pressure to form larger panels.

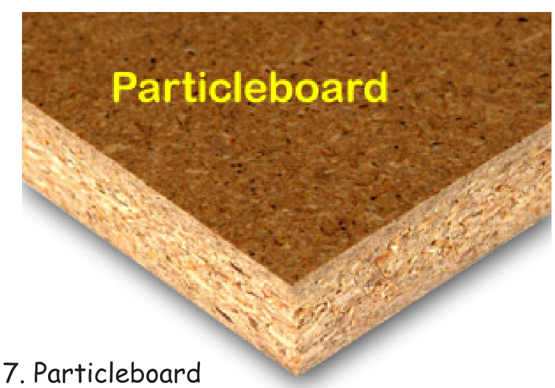


Figure 7. Particleboard

However, most people are unaware of the origins of many wood products and wood by-products. Examples of products used in manufacturing are:

Hardboard is made from wood that has been reduced to pulp. Fibers are formed into a mat and pressed using very high temperatures and pressures. Pegboard is a type of hardboard that has holes punched in it and is often found on garage or workshop walls and on the back of televisions.

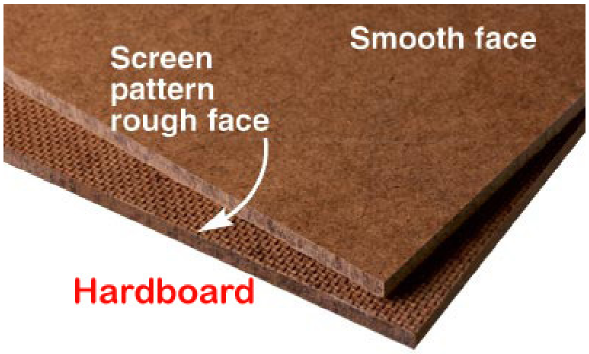


Figure 8. Hardboard

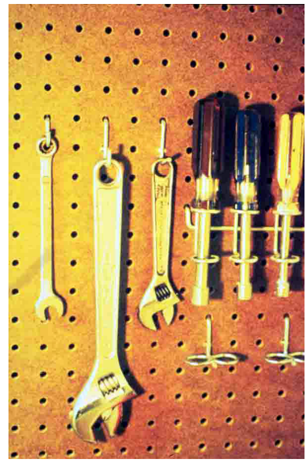


Figure 9. Pegboard with tools

Insulation board is made in a process similar to hardboard. This product goes in walls of buildings, under the siding of buildings, and is used for acoustical ceiling tile.

Figure 10. Insulation board

There are several products that you probably use everyday that are made from wood products and by-products and you don't even realize it. Below is a *short* list of some of these products. Remember, there are over 5,000 products made from wood and its by-products!

Rayon is made from wood that is broken down into constituent molecules, followed by controlled regeneration of cellulose-like polymers. Curtains, bedspreads, clothing, and other fabric goods are often made with rayon. It is even used to make tires and light-weight skin for jet airliners.

Lignosulfonates are created from spent sulfite pulping liquid. It is a major ingredient in artificial vanilla, which is a product used in making ice cream, cookies, and cakes. Lignosulfonates are also found in cleaning products, pharmaceuticals, insecticides, hair spray, deodorant, and laundry stain remover.

The **bark** of a tree is used in anticancer drugs, shoe polish, cosmetics, spices, and garden mulch.

Cellulose, a component of plant material that cannot be broken down by humans' digestive systems, is used in numerous products. Some of these products include Scotch tape, toothpaste, football helmets, computer cases, sandwich bags, and instant hot chocolate.

Terpenes, which are derived from wood, are used to make licorice flavor as well as to sweeten the spearmint or peppermint flavor of many toothpastes, mouthwashes, and chewing gums.

Esters, which are derivatives of trees, are used to ensure a uniform distribution of citrus flavor throughout drinks and are found in many soft drinks.

Many **medicines** are made from wood or its by-products. Aspirin tablets are held together with **lignin**, which is a natural component of wood. The essential elements of aspirin come from the **bark** of willow trees. Medicines used for treating high blood pressure and Parkinson's disease contain various wood derivatives.

Hard resins, which come from trees, are used to make glues and other adhesive products.

Carnauba wax, a resin produced by the leaves of the carnauba tree, is used in making crayons, lipstick, and the finish coating on furniture. It is also found in apples and pears.

Torula yeast, which is made from wood sugars recovered during the pulping process, is found in baby food, imitation bacon, cereals, beverages, and baked goods.

For additional information visit *www.woodmagic.vt.edu/PDF/GoodsWoods.pdf*.

Lesson 2: Seeing the Big Picture
Content: Macroscopic Structure of Wood

Virginia Standards of Learning addressed:

BIO.4A and 4B: The student will investigate and understand relationships between cell structure and function. Key concepts include:

- Characteristics of eukaryotic cells
- Exploring the diversity and variation of eukaryotes

BIO.7: The student will investigate and understand the basis for modern classification systems. Key concepts include:

- Structural similarities among organisms

National Science Education Standards addressed:

Content C: All students should develop an understanding of the cell:

- Cells have particular structures that underlie their function
- Cells can differentiate and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells

Content Skills

Students will be able to:

- Compare and contrast softwoods and hardwoods
- Recognize that the structure of wood determines its function

Life Skill

Teaching others – teaches others new skills

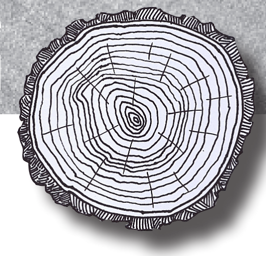
Success Indicator

Successfully explains designated topic to the class and demonstrates comprehension of the material

Time Needed

65 minutes

Lesson 2: Seeing the Big Picture
Content: Macroscopic Structure of Wood



Activity Summary

Students will work cooperatively in groups to interpret new information about the macroscopic structure of wood. They will then be responsible for teaching the class about their designated topic.

Procedures

Do (~5 minutes)

To identify any misconceptions that might exist, please consider the following questions:

1. Are all trees alike? Do they all have the same structures?

2. Based on the products discussed in Lesson 1, do you believe the structure of wood plays a role in how wood can and cannot be used?

Reflect (~10 minutes)

Each student will discuss his or her responses with the class. The teacher will need to explain the correct answers in order for students to answer the questions in the Apply section.

Apply (~5 minutes)

Now that you understand the correct answers to the questions in the Do section, identify a few structures that are not found in or on all plants.

Lesson 2: Seeing the Big Picture
Content: Macroscopic Structure of Wood

Activity Materials:

3 information packets for the stations

Procedures

Do (~15 minutes)

1. Have students read the background information.
2. Divide the class into three groups and assign each group one of the following stations:
   - Heartwood and Sapwood
   - Direction of Wood
   - Softwoods and Hardwoods
3. Allow students to read and discuss the information packet provided at their stations.

Background Information

A tree stem consists of three areas that include the pith, xylem, and bark. The central pith (F) is usually barely visible and does not increase in size throughout the life of the tree. A cylinder of wood, known scientifically as xylem, is comprised of (D) sapwood and (E) heartwood. It varies in diameter with age and rate of growth. And finally, the bark sheath can be subdivided into inner bark (B) (also know as phloem), which conducts sugars, and outer bark (C) that serves as a protective layer. New wood and inner bark are added each year by the (A) cambium, which is located between the inner bark and sapwood. The cambium is a layer of dividing cells. New bark production is relatively small compared with new wood production, and bark is continually being shed to the outside of the stem; thus in older trees the greatest volume of the stem is wood. Since new wood is added to the outside of existing wood, the oldest wood is close to the pith, and the most recent is close to the bark. [Note: G, the fine radiating "spokes," are the wood rays].

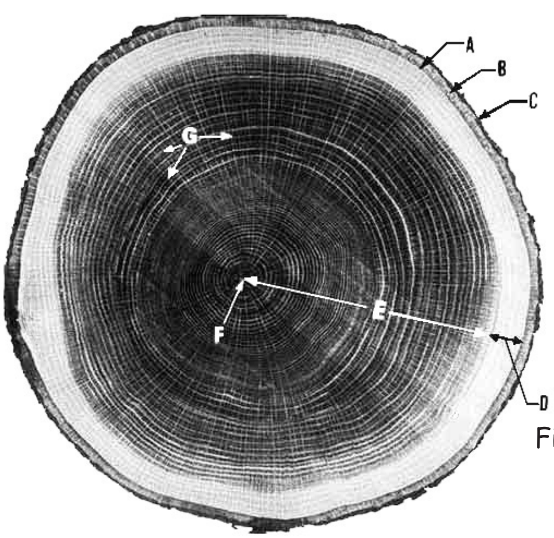


Figure 11. Wood disk cross-section

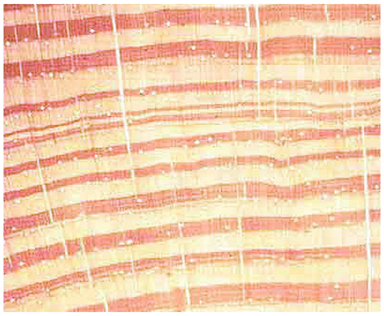


Figure 12. Pine cross-section

In the north temperate zones, cutting any tree stem surface will show the wood to be composed of a series of concentric bands. These bands are referred to as growth rings, and in temperate zone trees, one ring is commonly formed each year. Growth rings actually extend vertically along the stem as a series of concentric cylinders. If the numbers of growth rings on the two ends of a log are counted, more rings will be found on the lower end of the log than on the upper end.

Each year a tree grows in height from its tip, although new wood is added along the length of the stem, no previous growth rings are present at the top of the stem. The number of growth rings increases down the stem according to the number of annual height increments. The appearance of growth rings is due to changes in the structure of wood produced through the growing season.

Reflect (~25 minutes):

Each group will teach the class about its topic. Other students will be encouraged to ask each group questions. At all of the presentations, the teacher will clarify on any information that is still unclear to students. **Note to students:** YOU CANNOT READ STRAIGHT FROM THE INFORMATION PACKET WHEN TEACHING!

Apply (~5 minutes):

Based on what you have learned during this lesson, please answer the following questions:

1. Who would find macroscopic structure of wood useful? For example, what careers would use this type of information? Do you feel this information is relevant to your own life?

Heartwood and Sapwood

Wood that is functional in water transport is referred to as sapwood, and it occupies the outer or more recently formed growth rings. In the diagram below, this region is represented by the yellowish zone. Wood that is no longer functional in conducting water is referred to as heartwood (here, the orange-brown zone), and it occupies the central stem core.

Figure 13. Eastern redcedar disk

Each year that new wood is formed, some inner-most sapwood becomes nonfunctional in water transport. This causes the outer boundary of the heartwood core to continually move outward. In general, an approximate balance is maintained between new wood formation and conversion of sapwood to heartwood. This balance ensures that there will always be adequate conducting tissue.

The conversion of sapwood to heartwood is commonly associated with a color change that is due to the deposition of chemical compounds known as extractives. The color change varies among species according to the composition of the wood. Some have a rich and beautiful appearance. In other species, the color change may be only very slight and in yet other species, there may be no evidence of color change. The extractives give durability to the wood against fungal decay and insect attack. The degree of durability varies widely among different species.

Direction of Wood

Important Terms:

1. Cross section cut: A section cut perpendicular to the grain (cells); typically observed at the end of a log or stump.
2. Radial cut: A section that is cut parallel to the wood rays in the tree stem.
3. Tangential cut: A section that is cut tangent to the growth rings in the tree stem.

Three orthogonal planes (e.g., mutually perpendicular) are recognized in wood, although the stem can be cut in any number of intermediate planes. (1) A horizontal, or transverse cut, through the stem will reveal the growth rings as concentric circles. In structural lumber, partial growth rings are evident at the ends of lumber and the surface is known as end grain. (2) A longitudinal cut in a plane through the pith exposes a radial-longitudinal surface. In species with distinct growth rings, this surface will appear to have a series of more or less parallel lines. A board cut to expose a radial-longitudinal surface is known as a quarter sawn board. (3) A longitudinal cut in a plane at a tangent to the surface of the stem exposes a tangential-longitudinal surface. Growth rings here will appear as a series of wavy lines or cones stacked on top of one another. A board cut to expose a tangential-longitudinal surface is known as a plain (or flat) sawn board.

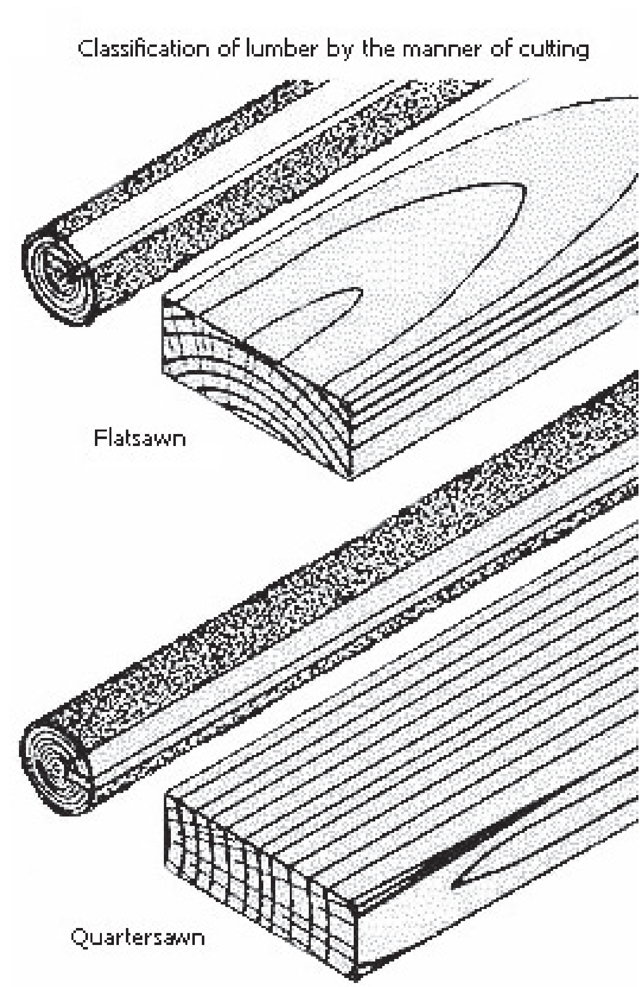


Figure 14. Flat and quartersawn lumber

Softwoods and Hardwoods

Trees for timber production are classified as softwoods and hardwoods. **Hardwoods** are the more diverse group; they contain both the heaviest and lightest timber examples found in nature. **Softwoods** include the conifers that belong to the more primitive group of plants called the **Gymnosperms**. Interestingly, this group of plants is almost entirely composed of trees. Hardwoods belong to the botanical group called the Dicotyledenous **Angiosperms**. This is a very large group of plants including vegetable and fruit plants, herbaceous flowering plants, weeds, and trees.

Figure 15. Hardwoods and softwoods

One of the major botanical distinctions between softwoods and hardwoods lies in the structure of their wood. In softwoods, the cells that serve to transport water also provide the mechanical support for the stem. In hardwoods, some division of labor has evolved, with some cells specializing in water transport, and others specializing in mechanical support.

In hardwoods, the water conducting cells, known as vessels, are commonly very much larger in diameter than the cells, known as tracheids, in softwoods. The vessels can frequently be seen with the naked eye as a number of pinholes in the cross section surface of the wood. As a result, hardwoods are commonly referred to as porous woods, and softwoods as nonporous woods. The differences in the anatomical structure of these two groups can be seen in the following pictures (20 X).

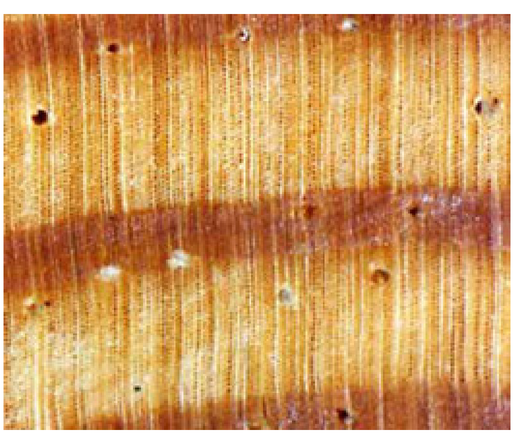


Figure 16. Pine cross-section (Softwood)

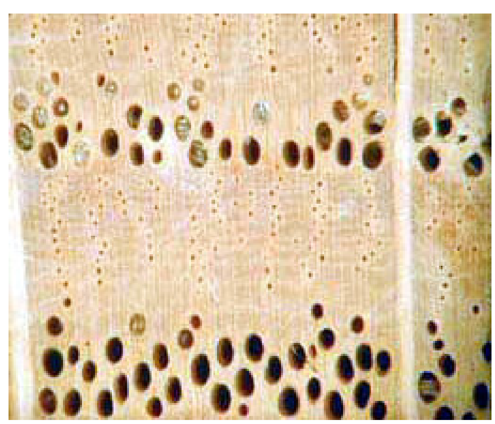


Figure 17. Red oak cross-section (Hardwood)

Lesson 3: More than the Naked Eye Can See
Content Area: Microscopic Structure of Wood

Virginia Standards of Learning addressed:

BIO.1B and 1M: The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observation and information from scientific literature
- A scientific viewpoint is constructed and defended

BIO.4A and 4B: The student will investigate and understand relationships between cell structure and function. Key concepts include:

- Characteristics of eukaryotic cells
- Exploring the diversity and variation of eukaryotes

BIO.5A: The student will investigate and understand life functions of plants. Key concepts include:

- How their structures and functions vary between and within kingdoms

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Formulate and revise scientific explanations and models using logic and evidence
- Communicate and defend a scientific argument

Content Standard C: Students should develop an understanding of the cell:

- Cells have particular structures that underlie their functions.

Content Skills

Students will be able to:

- Demonstrate their ability to accurately identify examples of softwood and hardwoods using microscopic structures
- Perform a scientific investigation to observe structures of wood using a light microscope

Life Skill

Acquiring and evaluating information

Success Indicator

Obtaining and interpreting results from a scientific investigation.

Lesson 3: More than the Naked Eye Can See
Content Area: Microscopic Structure of Wood

Time Needed
Approximately 2 days, including cell preparation

Activity Summary
Students will conduct a scientific investigation to view microscopic structures of wood using a light microscope.

Introduction Activity Materials
Provided transparencies of examples of softwoods and hardwoods.

Procedures
Do (~10 minutes)
The teacher will show students example slides of softwoods and hardwoods. Working together as a class, students will draw on the previous knowledge they gained from Lesson 2 to predict if each slide is a softwood or a hardwood. Students will discuss their reasoning with one another and then the teacher will take a vote to see what the majority of the class predicts. The teacher will then explain the answer to the class before moving on to the next slide.

Reflect (~5 minutes)
Ask the students the following questions and discuss the answers:

1. Did your personal predictions frequently match the correct answers? If not, why do you think you are having problems distinguishing the difference between softwoods and hardwoods?

   ____

   ____

2. Brainstorm some possible methods you could use to help you remember the differences between softwoods and hardwoods.

   ____

   ____

Apply (~5 minutes)
1. Now that you know the structural differences between softwoods and hardwoods, make a prediction of how each of these types of wood is used (what products it produces).

Slide #1

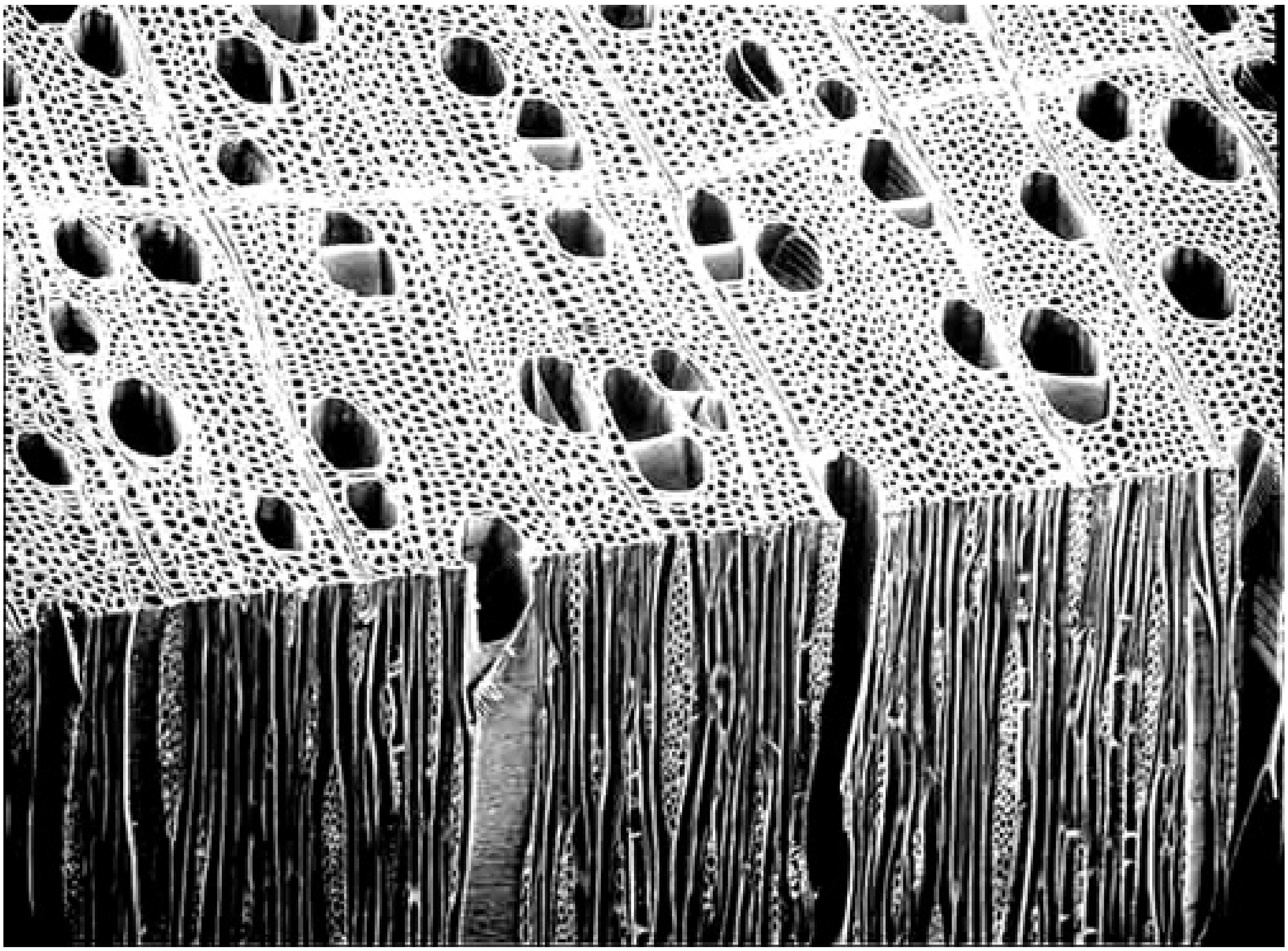


Figure 18. SEM of yellow-poplar
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

Class Prediction ______________________________

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Correct Answer ______________________________

Slide #2

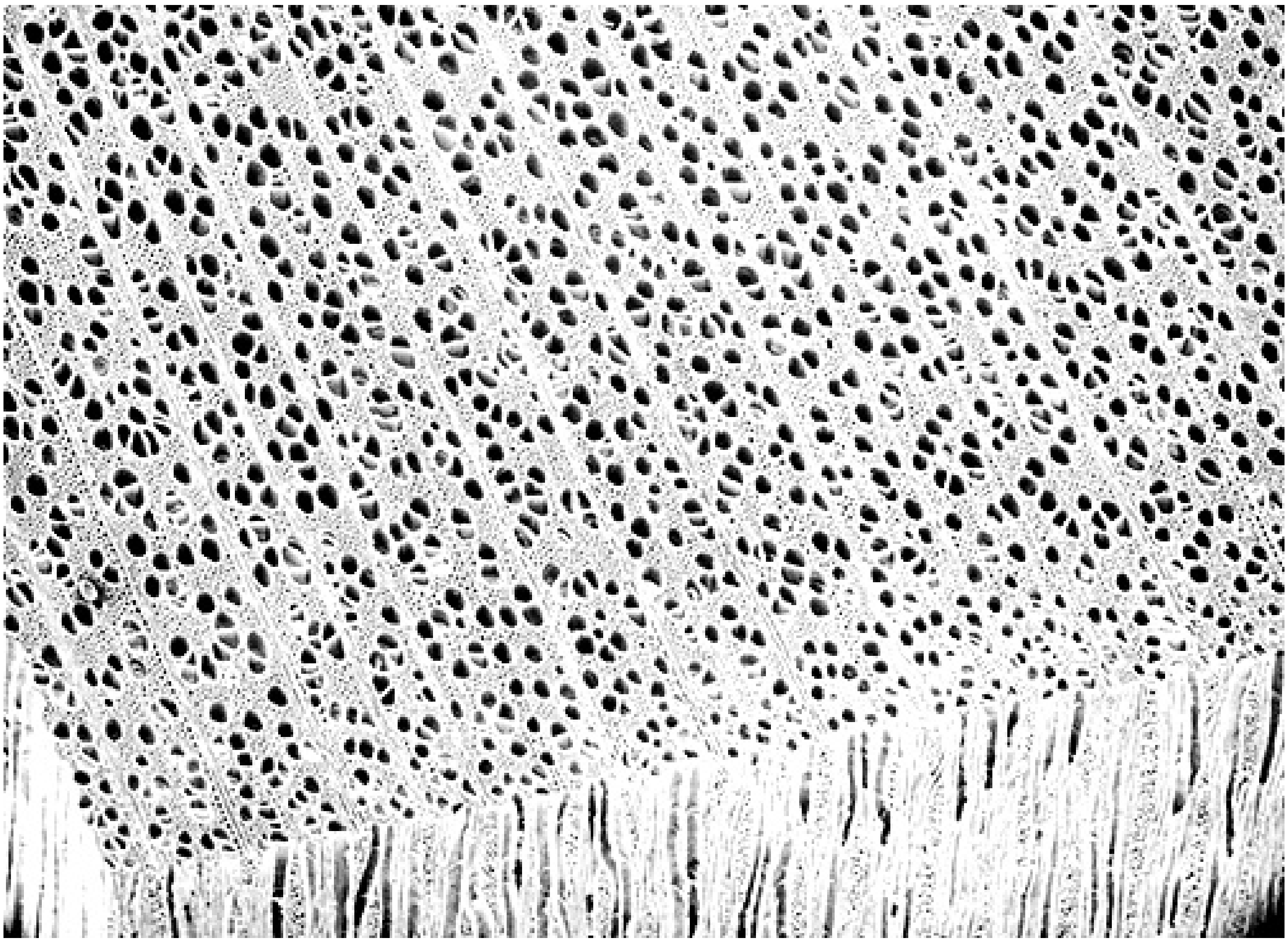

Figure 19. SEM of basswood
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

Class Prediction ______________________________

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Correct Answer ______________________________

Slide #3

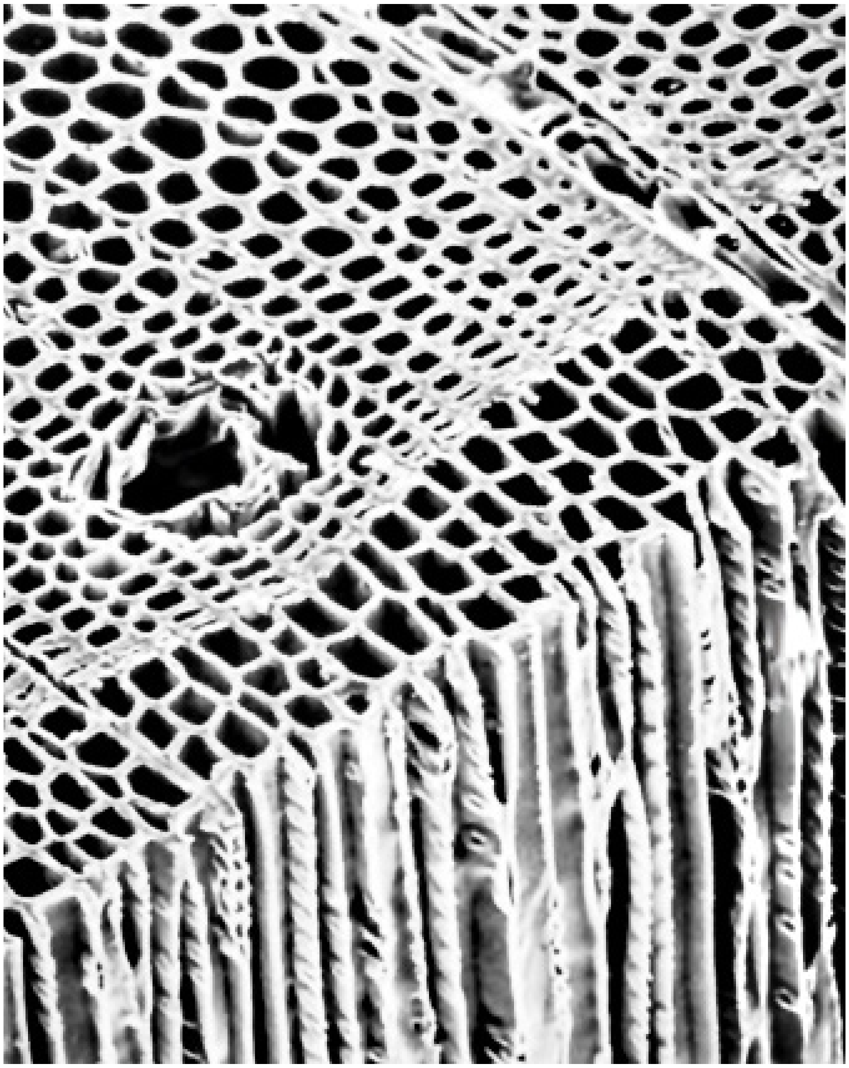

Figure 20. SEM of eastern spruce
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

Class Prediction ____________________

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Correct Answer ____________________

Slide #4

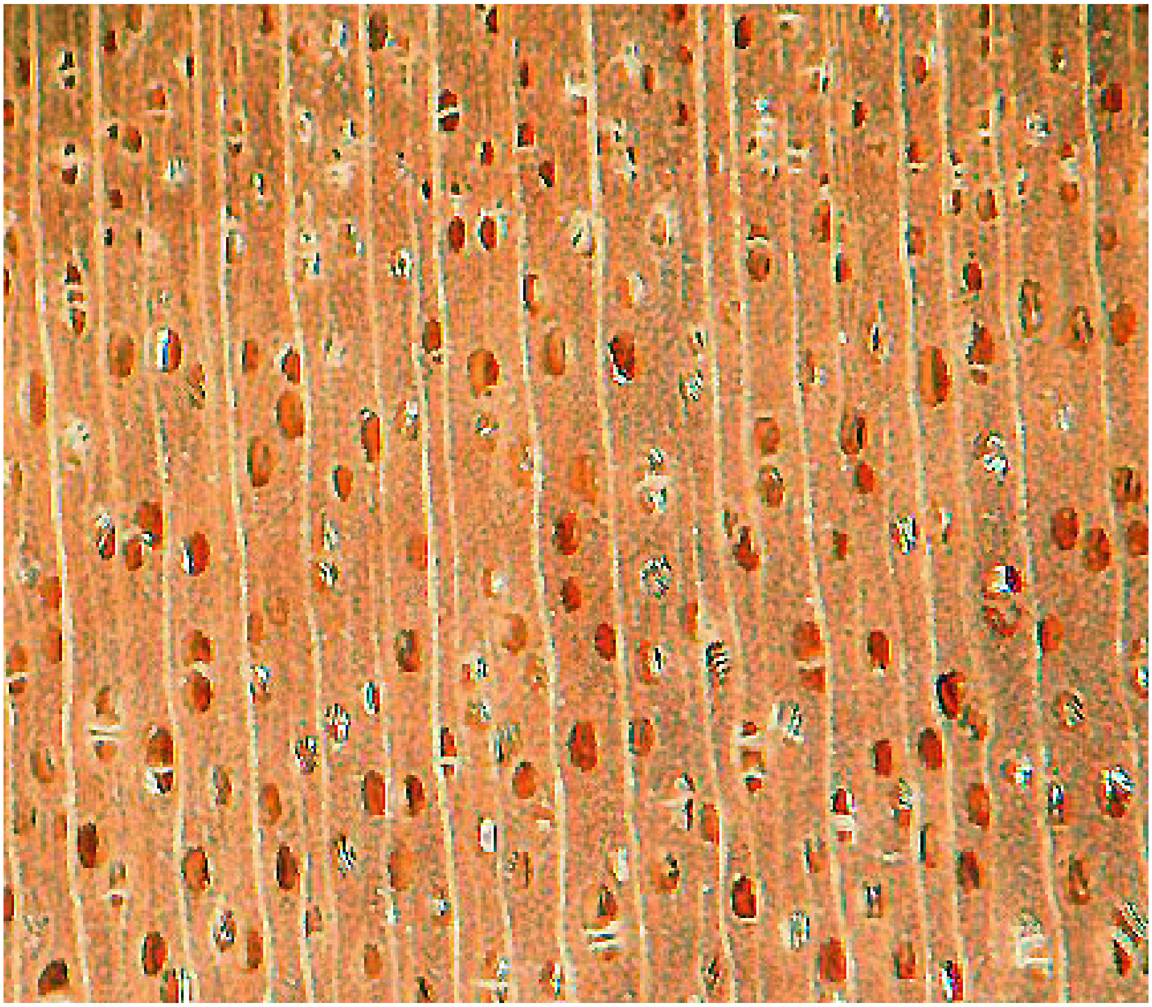

Figure 21. Macroscopic image of yellow-poplar
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, VA.

Class Prediction ____

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Correct Answer ____

Slide #5

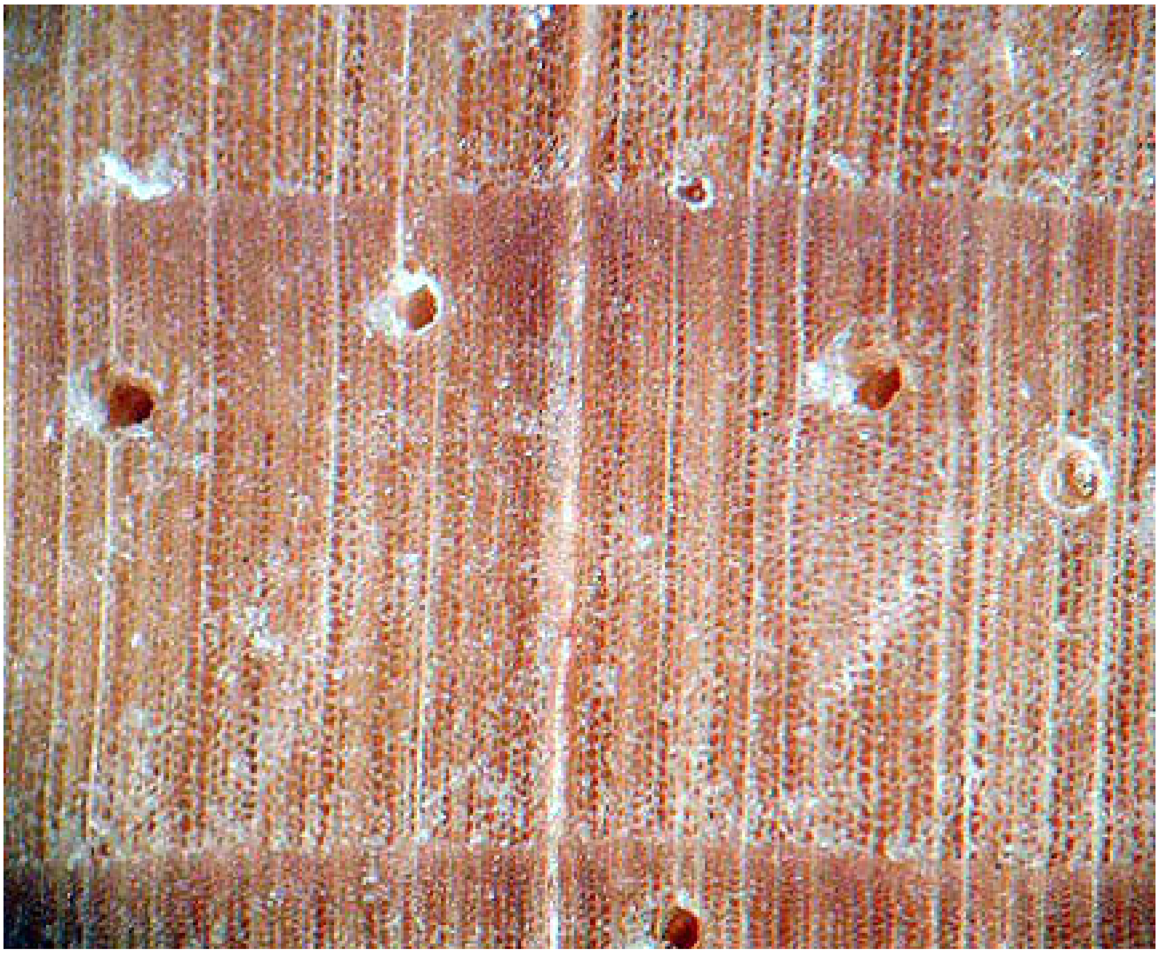

Figure 22. Macroscopic image of pine
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, VA.

Class Prediction

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Correct Answer ____

Identification of Softwoods and Hardwoods

Activity Materials

- Small specimens of softwood (such as pine, spruce, fir, cedar) and hardwoods (such as oak, ash, maple, hickory, cherry,) 1/2 inch long
- Knife or razor blades for splitting wood
- Equal amounts glacial acetic acid and 30% hydrogen peroxide (enough to cover the splinters in a test tube to about twice their depth)
- Test tubes and corks or screw tops
- Cheesecloth
- Oven capable of heating to 60°C (140°F) (Do not use an oven in which food will later be cooked.)
- Food coloring or dye such as light green, methyl green, or safranin
- Light microscope
- Microscope slides and cover glasses
- Eye dropper (pipette)
- Glass rod
- Dissecting needles
- Glycerin (optional)

Procedures

Do (best to do this activity in a fume hood and use gloves)

1. Have the students read and discuss the background information before beginning the experiment.
2. Split off small toothpick-size slivers of wood from a 1/2-inch long block (if pieces are split off along the grain, more cells will remain whole than if cut across the grain).
3. Place several pieces in a test tube and cover with a mixture that contains equal amounts of glacial acetic acid and hydrogen peroxide.
4. Close the tube and place in an oven at 60°C (140°F) for 24 hours.
5. Remove the tube from the oven and stir the contents with a glass rod – the wood should break into individual cells; if separation is not complete then allow the wood to cook a little longer.
6. When separation is satisfactory, allow the cells to settle to the bottom of test tube.
7. Cover the open end of the test tube with cheesecloth and pour off the liquid or remove the liquid with an eye dropper.

8. Then wash the pulp free of acid under lots of cold running water. (Be careful not to lose too many cells!)
9. The cells may be stained for better viewing by adding a few drops of dye to the last wash.
10. Put small amounts of the cell mixture on glass slides with an eye dropper and carefully pull the mixture apart with dissecting needles into a uniform dispersion. Add a drop of glycerin if available and place a cover slip on top.
11. View the slide with a microscope.

Background Information

The diagram below shows a scanning electron micrograph of an eastern spruce wood block, which is a softwood. Most cells run longitudinally, but some cells run horizontally. The big hole is called a **resin canal (rc)**. The majority of the cells shown here are called **longitudinal tracheids**. On different surfaces, the wood structure appears differently. This is called anisotropic structure; this concept will be further discussed in Lesson 6. This unique structure differs from other raw material such as metal, plastic, concrete, and rocks.

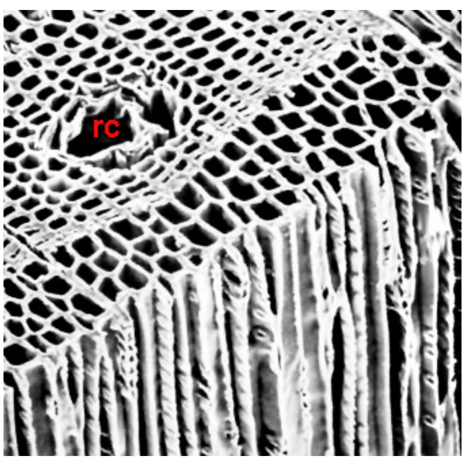


Figure 23. SEM of eastern spruce
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

In contrast to softwood, the structure of hardwood is much more complicated because more cell types exist in hardwoods. Below is a 3-D picture of a yellow-poplar wood block. The large holes represent vessel elements. The small ones are fibers. The lines between the vessel elements on the top of the block are bundles of ray cells called multiseriate rays.

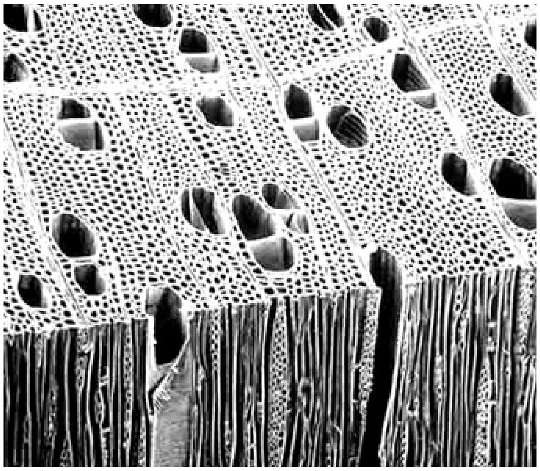


Figure 24. SEM of yellow-poplar
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

The picture below shows a cross-section of redwood. It is enlarged 100X through a light microscope. As you learned in Lesson 2, a tree produces a ring annually. This ring is composed of two zones called earlywood (light colored area) and latewood (dark colored area). The earlywood is produced at the beginning of a growing season with a relatively thin cell wall and a large diameter. The latewood is formed late in the growing season with a relatively thick cell wall and small cavity. This picture also shows that the zones from the earlywood to latewood change distinctively. This is called an abrupt transition. Some species possess this distinct feature, while it is more gradual in other species.

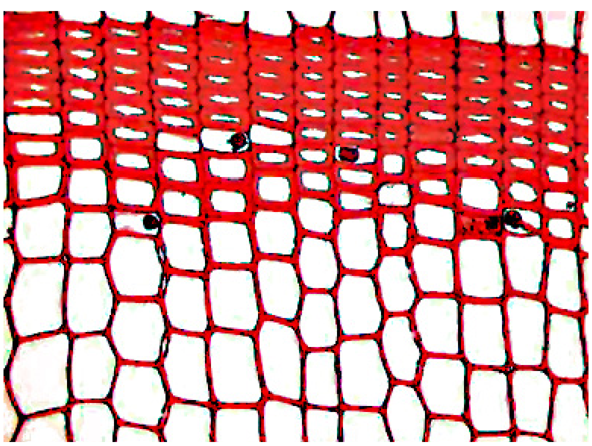


Figure 25. Light microscopic image of redwood (100X)
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, Va.

The micrograph below shows a cross-sectional view of red oak (20X). The largest diameter holes in the earlywood zone are cross-sectional views of vessel elements. In latewood, these vessel elements are small and sometimes grouped together. Because of this distinctive size and arrangement of the vessel elements, the growth ring is very clear and distinctive. This type of hardwood is called a ring-porous wood.

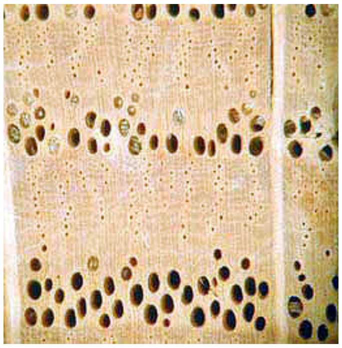


Figure 26. Macroscopic image of red oak
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, Va.

However, in some hardwoods, size of vessel elements does not change very much throughout a growing season. A good example of this arrangement is seen in the sugar maple. The large circles are vessel elements. Wood possessing this type of even-sized vessel elements is called diffuse porous wood.

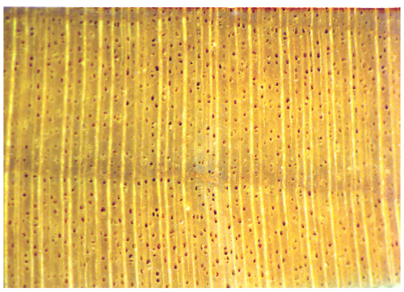


Figure 27. Macroscopic image of sugar maple
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, Va.

In other hardwoods, the size of vessel elements changes gradually from the early growing season to the late growing season. This type of wood is called semi-ring-porous wood. A good example of this type of wood is walnut. Large vessel earlywood is at the bottom of the picture and smaller vessel latewood is at the top (20X).

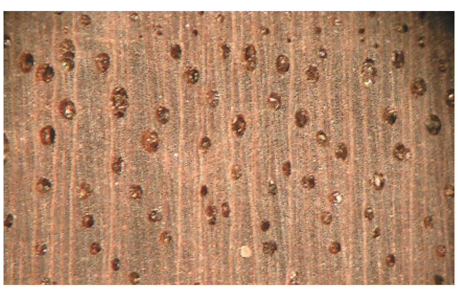


Figure 28. Macroscopic image of walnut
Quantitative Wood Anatomy Lab, Virginia Tech, Blacksburg, Va.

Figure 29 shows some of the cell types in softwoods and hardwoods. The long cell (e) is called a longitudinal tracheid and accounts for over 90% of the wood volume of softwoods. The tracheids are approximately 3 to 5 mm in length and 30 to 50 micrometers in diameter. These long cells, often referred to in the trade as “fibers,” are the main cell type that makes up writing paper and brown paper bags. In hardwoods, more cell types are found; vessel elements are (b) earlywood and (d) latewood. (c) represents a hardwood fiber. Hardwood fibers are somewhat similar to softwood tracheids, but are much shorter. The fibers are approximately 1 to 2 mm in length and 20 to 30 micrometers in diameter. Kodak color paper is mainly made of maple and beech fibers. Toilet paper, napkins, and Kleenex are made of poplar fibers.

As previously stated, hardwood structure is more complicated than softwood. Therefore, softwood lumber has a uniform appearance. Different softwoods will appear somewhat similar. However, hardwoods will vary in appearance.

Now you know that the structure of wood is quite complicated, especially the structure of hardwoods. The structure of softwoods is much simpler. Here is a close look at pine wood. Most of the cells run vertically and resemble long, straight tubes, which are the tracheids. The block-like holes on top of the specimen are cross sectional views of tracheids. Wood rays are perpendicular to the tracheids.

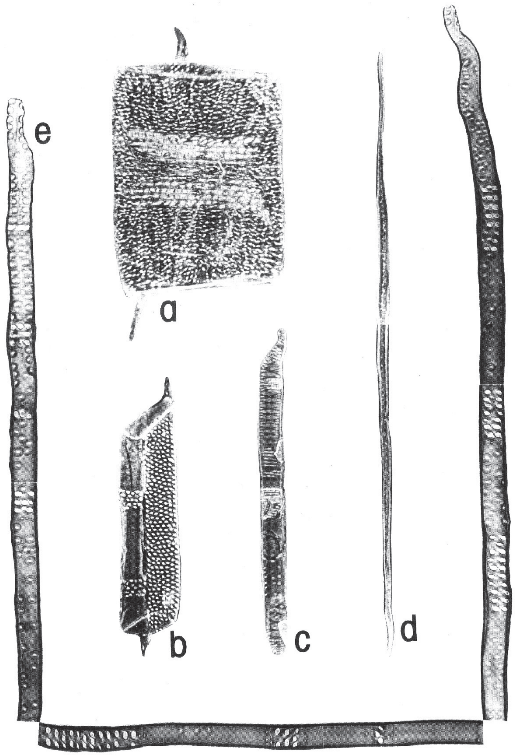


Figure 29. Light micrograph of cell types
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

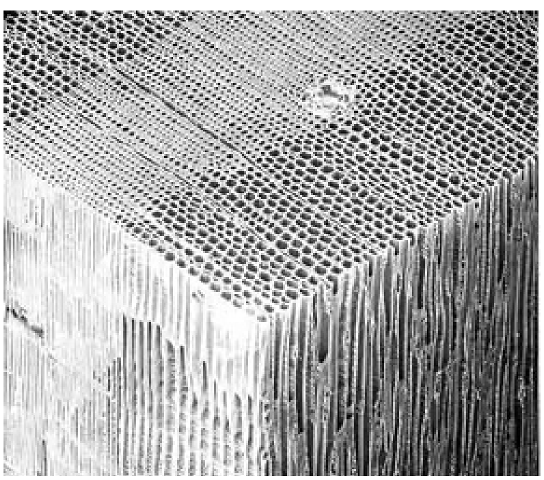


Figure 30. SEM of resinous softwood
Center for Ultrastructure Studies, SUNY-CESF, Syracuse, N.Y.

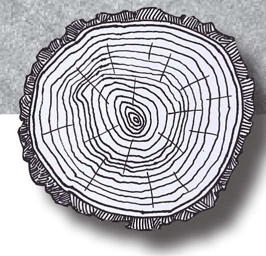
Reflect (~10 minutes)

Recalling observations made during the laboratory exercise, have the students record answers to the questions on the Lesson 2 Work Sheet.

Apply (~5 minutes)

1. Using their answers from Work Sheet 2, have students explain in their own words why the unique structure of wood determines its function. Use examples from softwoods and hardwoods to support your reasoning.

Identification of Softwoods and Hardwoods



Name ____

Recall the observations you made during the laboratory exercise, and then record your answers to the following questions:

1. What cell structures are clearly present on the slides containing softwood specimens?

____

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2. What cell structures are clearly present on the slides containing hardwood specimens?

____

____

____

3. What cell structures are present in both? Which structures are distinctively unique?

____

____

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Lesson 4: Chem Time!
Content Area: Wood Chemistry

Virginia Standards of Learning addressed:

BIO.1B and **1E:** The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- Conclusions are formed based on recorded quantitative and qualitative data

BIO.3B: The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include:

- The structure and function of macromolecules

CH.1A and **1B:** The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include:

- Designated laboratory techniques
- Safe use of chemicals and equipment

National Science Education Standards addressed:

Content Standard B: Students should develop an understanding of:

- Structure and properties of matter

Content Skills

Students will be able to:

- Identify the major organic molecules found in wood
- Differentiate between organic and inorganic molecules
- Recognize the structural formulas of various organic molecules
- Define the term *extractive* and interpret if these unique structures are present in various samples of wood

Life Skill

Acquiring and evaluating information

Success Indicator

Recognizing the effect of extractives and understanding the unique properties these components give to wood.

Lesson 4: Chem Time!
Content Area: Wood Chemistry

Time Needed

Two days, including prep time

Activity Summary

Students will conduct a scientific investigation to determine if fluorescent extractives are present in various wood samples.

Procedures

Do (~5 minutes)

Answer the following questions:

1. What do you think are the major elements found in wood?

2. Do you believe wood is an organic or inorganic material?

Reflect (~10 minutes)

Students should now discuss their answers with one another. As a collaborative effort, students should come to an agreement about what the three major elements of wood are and if each is an organic or inorganic material. The teacher should record the majority's answers on the board and then have students read the background information presented on the next page.

Apply (~5 minutes)

Answer the following questions:

1. Was the majority of the class correct with their responses about the major elements and chemical classification of wood? If so, what previous knowledge helped the class determine the correct answers? If not, where do you believe the classes' misconceptions originated?

2. Why do you think it is important to understand the chemical structure of wood? How would its chemical composition affect how it could be harvested and used?

Background Information

Wood contains both organic and inorganic molecules; however, the main part of wood is comprised of organic molecules. The three major elements of wood are carbon, oxygen, and hydrogen. They are combined in complex molecules that are then joined into polymers, which are large molecules formed by the repetitive combination of many smaller molecules. The structural integrity of wood is a direct result of these polymers.

Element	Percent by Weight
Carbon	49
Oxygen	44
Hydrogen	6
Other	1

Figure 31. Chart of chemical elements

These polymers can be classified into one of the three following categories: cellulose, hemicellulose, and lignin.

Polymer	Percent of Dry Weight
Cellulose	40 - 50
Hemicellulose	20 - 35
Lignin	15 - 35

Figure 32. Chemical polymers chart

****Note: The percentage of these polymers can vary among species.**

Cellulose is the most important polymer found in wood because it provides strength. It is a product of photosynthesis created by the following process:

Glucose and other sugars are produced from the reaction between water and carbon dioxide. Glucose is first chemically altered to glucose anhydride by the removal of one molecule of water from each glucose unit. These units of glucose anhydride are then polymerized into long-chain cellulose molecules that contain 5,000 to 10,000 glucose units. In this resulting structure, there are repeating units. Two glucose anhydride units are called a cellobiose unit (see diagram below).

Cellulose polymers are then arranged in a crystalline (refers to the geometric arrangement of atoms in a solid) form where adjacent polymers are bonded together laterally by hydroxyl groups (OH) that occur in each cellobiose unit. These bonds are what give wood its strength.

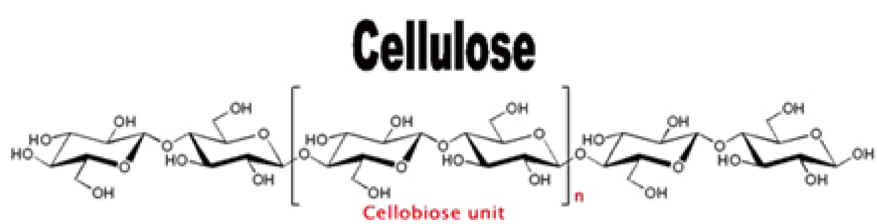


Figure 33. Cellulose structure

Hemicellulose is very similar to cellulose. It differs from cellulose in that hemicellulose has a lower molecule weight. The number of repeating molecules averages 150 in hemicellulose compared to the 5,000 to 10,000 found in cellulose. Hemicellulose is comprised of glucose as well as other sugars such as galactose, mannose, xylose, and arabinose, which are all produced during photosynthesis. An example structural formula for a hemicellulose is displayed in the following diagram.

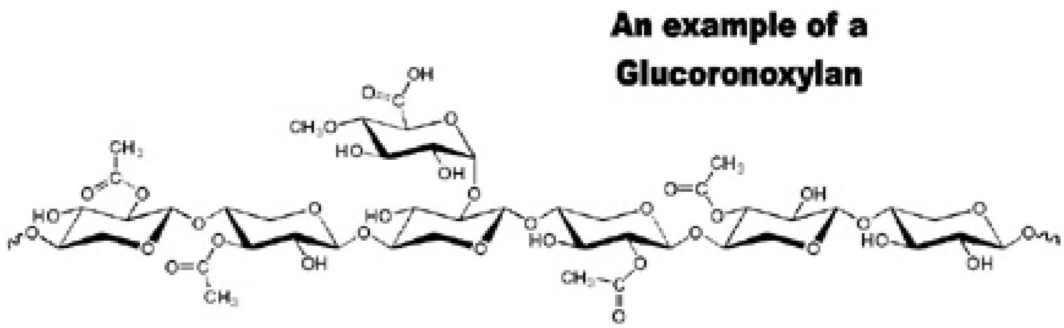


Figure 34. An example of a hemicellulose

Lignin is a class of complex, high molecular weight polymers. Their exact structures vary and they act as a binding agent that holds cells together. They give cell walls rigidity. An example of structural formula for lignin is shown in the following diagram.

Another diverse group of organic chemicals that are present in wood is called extractives. Extractives are "nonstructural polymers" because they do not contribute to the structural framework of wood. However, extractives provide wood with many unique properties. The types of extractives found in wood vary with the species of the tree. For example, redwood is naturally resistant to decay because the extractives present in the wood are toxic to insects and fungi.

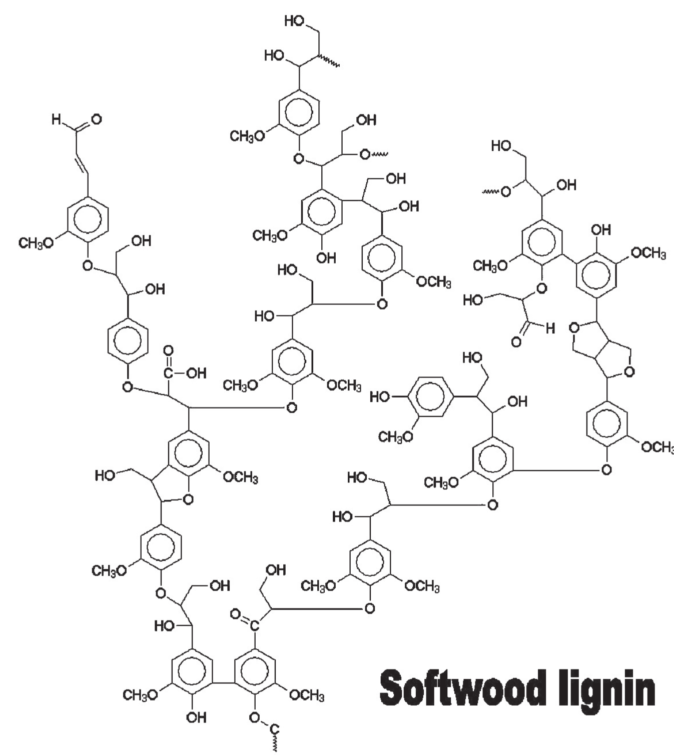


Figure 35. Lignin

*Original source: Adler, E. 1977. Lignin Chemistry-Past, Present, and Future. Wood Science Technology 11, 169-218.

Lesson 4: Chem Time!
Content Area: Wood Chemistry

Activity Materials

Small blocks (at least 1 inch square and 3 inches long) of black locust wood (*Robinia pseudoacacia*), honeylocust (*Gleditsia triacanthos*), pine (*Pinus* spp.), spruce (*Picea* spp.), and walnut (*Juglans nigra*). Any wood type will work in this activity, but both the black locust and honeylocust fluoresce quite well and should be included in this activity. You can get the more common ones at home improvement and lumber stores, but the black locust and honeylocust will probably have to come from specialty stores or woodworking catalogs such as Woodworkers Supply (800) 645-9292. Also, check the Internet for other sources such as *www.woodworker.com, www.colonialhardwoods.com*, and *www.woodweb.com*.

- File, rasp, or hand plane
- Chemical solvents acetone, water, ethanol (ethyl alcohol), and cyclohexane (hexahydrobenzene)
- Beakers
- Small vials or flat-bottom bottles
- Small funnel
- Taper-point paint brushes – 1 for each participant
- Notebook paper
- Long wave (~365 nanometers) ultraviolet light ("black" light) found at most hardware, home improvement, and discount stores.

Procedures

Do

****Note: You should perform the extraction in a fume hood if one is available. If a fume hood is not available, try to get as much ventilation in the room as possible.**

1. File or rasp a portion of each block into sawdust or plane off some shavings.
2. Prepare a mixture of 90% acetone and 10% water; about 100 ml to start with (10 ml of water plus 90 ml of acetone.)
3. Place the sawdust or planer shavings from each block of wood in a separate labeled beaker and cover with enough acetone/water solvent to equal about twice the volume of the wood.
4. Soak the sawdust or planer shavings in the solvent for 6 hours or overnight (extraction can be improved by using a magnetic stir rod).
5. Prepare a mixture of 50% ethanol and 50% cyclohexane.

6. Remove the acetone/water mixture from each beaker and replace it with the 50/50 ethanol/cyclohexane; soak the blocks 6 hours or overnight.
7. Label vials for each wood type.
8. Pour off some of the extractive solution into the vials.
9. Dip a paint brush into the solution in one of the vials and then paint your name on a piece of notebook paper. Allow it to dry so that your name becomes invisible. Now place your paper under long-wave ultraviolet light. Do this for each wood type.

Reflect (~5 minutes):

Ask the students the following questions and discuss the answers:

1. What did you observe when you put each sample of wood under the long-wave ultraviolet light?
2. Of the organic molecules discussed in this lecture, which one do you think was responsible for producing the results you obtained?

Apply (~5 min):

Ask the students the following questions and discuss the answers:

1. If you took the original blocks of wood that have not been extracted using the organic solvents and placed them under the long-wave ultraviolet light, what do you think you would see?
2. Fluorescence is used in many products and is also used as an identification tool as this laboratory exercise demonstrated. Can you think of any other examples where fluorescence is used?
3. Why do you think it is important to be able to identify what species a certain sample of wood is? Who would find this information useful?

Lesson 5: Wood Identification Techniques
Content Area: Wood Structure

Virginia Standards of Learning addressed:

BIO.1B and **1H**: The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- Chemicals and equipment are used in a safe manner

BIO.4A and **4B:** The student will investigate and understand the relationships between cell structure and function. Key concepts include:

- Characteristics of eukaryotic cells
- Exploring the diversity and variation of eukaryotes

BIO.5A: The student will investigate and understand the life functions of plants. Key concepts include:

- How their structures and functions vary between and within the kingdoms

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Formulate and revise scientific explanations and models using logic and evidence

Content Standard C: All students should develop an understanding of the cell

- Cells have particular structures that underlie their function

Content Skills

Students will be able to:

- Identify the type of wood by examining a wood sample using a hand lens
- Demonstrate wood identification techniques using equipment in an appropriate and safe manner

Life Skill

Acquiring and evaluating information

Success Indicator

Understanding how to correctly perform wood identification techniques using the proper equipment.

Time Needed

65 minutes

Activity Summary

Using wood identification techniques and equipment, students will examine six different wood samples and then identify the type of tree based on the analysis of the wood samples.

Procedures

Do (~10 minutes)

Students will need to review Lessons 2 and 3 before completing the main activity. Teachers may use the following game as an interactive way for students to review the microscopic structures of wood. The following game frame was developed by Terry Graham, a professor at Virginia Tech.

Asterisking Game

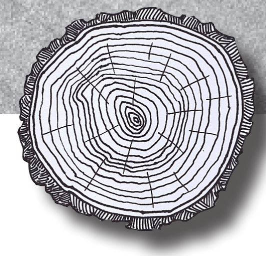
Explanation of Formatting and Rules

Asterisking is a game designed to show students the relationships between certain words. A sample format is as follows:

- comfortable
- cheerful
- happy
- feelings
- sad
- angry
- embarrassed

Teachers

It is very simple to construct an asterisking game. In the above example, the fourth line is the center and contains the main or connecting word. The connecting word shows the relationship between all of the words used in the game. Then words that are opposites are placed on each side of the center word. For example, softwoods could be placed on line 3 from the top and hardwoods could be placed on line 3 from the bottom. All of the words to the right of the center word should have opposite meanings/examples from the words to the left of the center word. The purpose is to build a chain of words that relate to the same topic but each side of the chain should be opposite in meaning/theme. As you can see in the above example, all of the words are certain feelings; the feelings at the top of the center word are positive feelings while the bottom words are negative feelings. Another chain could be formed by using feelings as the center word to create four corners instead of two.



Students

Students attempt to figure out the pattern found in the words by filling in the blanks. The first student or team can guess the first letter in the word located on the top left or bottom right. If the student/team guesses correctly, they continue until they guess a letter incorrectly. Students can not guess the center word (fourth line on above example) until all other words have been filled in.

For this introduction activity, teachers will need to design an asterisking game using the bold-faced words found in Lessons 2 and 3. One side of the chain should be based on softwoods and the other side should be based on hardwoods. After the students complete the game, teachers should have them recall the definitions of the terms used in the game. If some of the words are structures, students should be able to identify them in example slides.

Reflect (~5 minutes)

Ask the students the following questions and discuss the answers:

1. What was the purpose of the asterisking game? What relationship did it show?
2. If you are still having difficulty recalling some of the definitions of terms used in this game, brainstorm some ideas that may help you recall the information more easily.

Apply (~5 minutes)

Ask the students the following questions and discuss the answers:

How can one can determine the species of a wood sample? What equipment do you think you would need? How would this information be useful?

Lesson 5: Wood Identification Techniques
Content Area: Wood Structure

Activity Materials

6 wood samples from the following types: red oak (*Quercus* spp.), white ash (*Fraxinus* spp.), yellow-poplar (*Liriodendron tulipifera*), southern yellow pine (*Pinus* spp.), spruce (*Abies* spp.), and redwood (*Sequoia sempervirons*).

- Hand lens (hand-held magnifying glass), 10X to 15X
- Single-edge razor blades
- Bench clamp (vise)
- Water in squeeze bottles
- Paper towels

**Note: Teachers can purchase a wood block set containing these six species of trees from Society of Wood Science and Technology; see *www.swst.org*.

Procedures

Do (~30 minutes)

1. Students need to read the background information and safety precautions before beginning the investigation.
2. Students should lightly moisten the surface of the wood block that is going to be cut (Do not wet the whole wood block).
3. Secure a block in the bench vise and using their razor blades, students will need to cut their wood samples to obtain end grain surfaces.
4. Using the hand lens, students will observe and record the structures they see present in each wood sample.

Background Information

Wood identification is based on examination of the anatomical features of a wood specimen using a hand lens (10X to 15X). These anatomical features (microscopic structures) were discussed in Lessons 2 and 3. The first step in wood identification begins with cutting the wood sample to obtain an end grain surface. An end grain surface is also known as the cross-sectional surface of a block of wood. This is the surface that is exposed when the wood cells are cut perpendicular to their length (at a right angle to the tree stem axis). On this particular cut, growth rings appear as arcs. Wood cells are seen as circles and holes, like looking at the ends of straws or tubes.

Safety Precautions

Before we cut any wood, we need to go over some safety precautions. Cutting wood samples can be very dangerous if the proper safety precautions are not followed. The razor blades used in this activity are very sharp and therefore they can easily cut skin! Proper technique and following directions can minimize the risk of injury.

The first step in specimen preparation is to identify the end grain surface or cross-sectional surface. It is shown below as the surface with the "X."

When cutting your specimen, always use a fresh, sharp razor blade so that you do not have to exert excessive force to push (or pull) the blade through the wood. While used blades may look sharp, microscopic nicks and rounding of the edge make the blades dull. Therefore, make only a few cuts per blade. Be sure to dispose of used razor blades properly in a rigid, sealable container. Do not throw them in the trash.

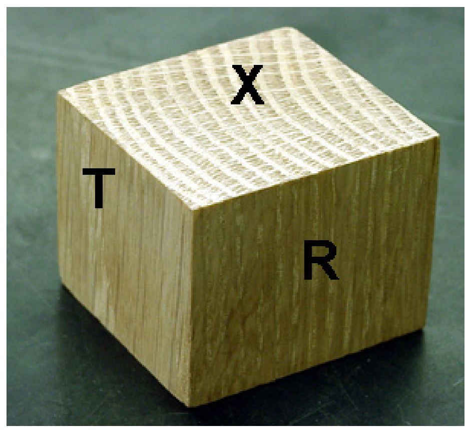


Figure 36. Oak wood cube

See the arcs!

X = Cross-sectional surface

R = Radial surface

T = Tangential surface

Secure the block tightly in the vise or grasp the block firmly in your hand so that the cross section is up. See the picture below.

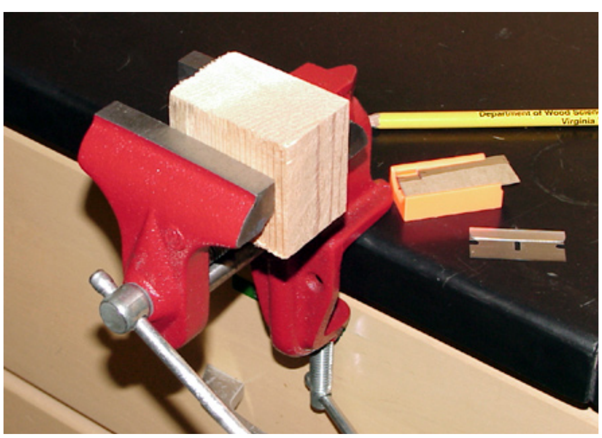


Figure 37. Securing the wood block in a vise.

If holding the block by hand, **BE SURE** to keep all your fingers **BELOW** the cutting surface and anticipate the blade's direction of travel.

Figure 38. How to cut wood

Figure 39. How to cut fingers

When making your first cut, do not angle the blade too much and make sure to pull the blade toward you in a flat slicing motion. A thin, clean cut will expose the needed surface, which is an area that contains at least one growth ring. Once you have obtained the proper cut, you are ready to view the specimen with your hand lens. Bring the hand lens up to your eye and then bring the wood block that you have cut near the lens. Move the block closer to and further away from your eyes until the wood surface is in focus.

Identification Characteristics

Here are some identification features to look for in the wood blocks that are included in this lesson:

- Oak and ash are both ring-porous hardwoods, with different latewood vessel patterns and differing ray widths. Oak has some VERY wide rays and some narrow rays, while ash does not.
- Yellow-poplar is a diffuse porous hardwood. Vessels are almost the same size throughout the growth rings.
- Pine and spruce are softwoods with resin canals, but the canals differ in their size (diameter). Pine has large, numerous resin canals, while spruce has small, sparse resin canals.
- Redwood is a softwood with no resin canals. It has very large cells (tracheids) for a softwood and lives up to its name – it's red (or least dark brown).

Reflect (~10 minutes)

Recall the observations you made during the laboratory exercise, and record your observations and drawings on the Lesson 5 Work Sheet.

Apply (~5 minutes)

Using what the students have learned in this activity, have them answer the questions on the Lesson 5 Work Sheet.

A number of books are available on the topic of wood identification. A couple of recommended references are:

Core, H.A., W.A. Cote, and A.C. Day. 1979. *Wood Structure and Identification*, 2nd ed. Syracuse University Press, Syracuse, N.Y. **Note:** This book is out of print but occasionally available at used book stores and via the Internet.

Flynn, J.H., and C.D. Holder (Eds.) 2001. *A Guide to Useful Woods of the World*. Forest Products Society, Madison, Wisc. *www.forestprod.org/*

Hoadley, R.B. 1990. *Identifying Wood: Accurate Results with Simple Tools*. Taunton Press, Newtown, Conn.

Milius, S. 2002. The Wood Detective. *Science News* Vol. 162 No. 12 pages 184-185 *www.sciencenews.org*

Panshin, A.J., and C. deZeeuw. 1980. *Textbook of Wood Technology*, 4th ed. McGraw Hill Book Company, New York

USDA Forest Products Lab, Center for Wood Anatomy. *www2.fpl.fs.fed.us/Menu.ssi*

Lesson 5 Work Sheet B
Wood Identification Techniques

Name ____

In the circles below, draw in all visible cell features and structures that your hand lens allowed you to see. In the blanks beneath each circle, record your prediction as to what type each specimen is, choosing your answer from the six types discussed in the background information section. Each type will only be used once.

Sample #1 ______________________________

Sample #2 ______________________________

Sample #3 ______________________________

Sample #4 ______________________________

Sample #5 ______________________________

Sample #6 ______________________________

Lesson 5 Work Sheet B
Wood Identification Techniques

Answer the following questions;

1. Lesson 4 demonstrated how fluorescence can be used to determine the species of a wood sample. This lesson demonstrated that the species of a wood sample can be determined by the analysis of its microscopic structure. Which method do you think is more accurate? Why?

2. Both Lessons 4 and 5 gave you information on identification characteristics for determining the species. How would you find this information on your own? Would you need all of the information that was given to you for each species in the background information section? What would be the most important characteristic you would need to assist you in analyzing the wood sample?

3. What other physical characteristics (that were not discussed in this lesson) of wood could be useful in wood identification?

Lesson 6: Hygroscopicity
Content Area: Wood Properties

Virginia Standards of Learning addressed:

BIO.1B, 1D, 1E, and **1H**: The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- Graphing and arithmetic calculations are used as tools in data analysis
- Conclusions are formed based on recorded quantitative and qualitative data
- Chemicals and equipment are used in a safe manner

BIO.3A: The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include:

- Water chemistry and its impact on life processes

BIO.5C: The student will investigate and understand life functions of plants. Key concepts include:

- Analyses of their responses to the environment

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry.

- Formulate and revise scientific explanations and models using logic and evidence
- Use technology and mathematics to improve investigations and communications

Content Skills

Students will be able to:

- Define the term *hygroscopicity* and describe its purpose and functional mechanisms.
- Use mathematical calculations to determine the hygroscopicity of wood samples.
- Relate how environmental conditions affect the hygroscopicity of wood.

Life Skill

Acquiring and evaluating information

Success Indicator

Performing and evaluating a scientific investigation to determine the hygroscopicity of various wood samples.

Lesson 6: Hygroscopicity
Content Area: Wood Properties

Time Needed
Several days

Activity Summary
Students will conduct a scientific investigation to determine the hygroscopicity of four wood samples. They will use mathematical calculations and graphing to help them determine the results of the experiment.

Procedures
Do (~5 minutes)
Ask the following questions and discuss the answers with the students to determine if there are any misperceptions.

1. How much water do you think wood contains?
2. How is this water obtained from the environment?
3. What purposes is this water used for?

Reflect (~10 minutes)
Students will discuss their responses with the class. After students have shared their thoughts, the teacher will need to go over the correct answers.

Apply (~5 minutes)
Ask the students how the fact that wood can obtain moisture from its surroundings influence how it is manufactured, stored, and used in everyday life?

Activity Materials

4 different aqueous salt solutions with a concentration that will give the desired vapor pressure of water in a closed container held at 20ºC (68ºF). Use the following chemicals to achieve the desired relative humidity at 20ºC:

- $MgCl_2$ for 33% RH (Magnesium Chloride crystals)
- $MnCl_2$ for 54% RH (Manganese Chloride crystals)
- NaCl for 76% RH (Sodium Chloride crystals or granular)
- KNO_3 for 95% RH (Potassium Nitrate crystals)
- 4 glass containers or bottles with lids
- 4 wood blocks (about 1 inch x 1 inch square and 2 inches long), all the same kind and from the same board if possible
- Laboratory oven to dry wood blocks (needs to reach 105°C (220ºF) but do not use an oven in which food is cooked.
- Balance
- String or cord

Procedures

Do

1. Students will read the background information before beginning the experiment (it is suggested that the students read this section for homework because it is lengthy).
2. Students will prepare four containers, each of which will contain a chemical solution that creates a different moisture environment inside the container.
3. Dry the wood blocks in an oven at 105°C (220ºF) for 24 hours and record the dry weights (DW) in the chart.
4. Prepare the saturated salt solutions by mixing the salt crystals with water. Keep adding salt until it no longer dissolves in the water. Then add another small amount to be sure you have a saturated solution.
5. Fill each glass container about half full with one of the salt solutions and label with the target relative humidity.
6. Tightly tie a string around a wood block and suspend the block over the solution. Allow the string to extend over the container rim and then close the container. Be sure the wood block does not contact the solution.
7. Remove and weigh the blocks every day for several days. Record this weight as the wet weight (WW) in the chart.

8. At the end of the week (or equilibration period if the weight is still changing), remove each sample from its container, and record the final weight.
9. Using the %MC equation, the "wet weights" (WW) which you recorded for a week, and the "dry weights" (DW) which you determined at the start of the experiment, calculate the %MC of each sample as it has equilibrated in the container.

Background Information

Adsorption is a process by which the surface of a material attracts moisture from the air. It differs from absorption which is the uptake of liquid due to physical contact with the liquid (like a sponge). Adsorption causes wood to have hygroscopicity, which means the ability to attract moisture from the air. See the figure 40 below for a representative illustration of the hygroscopicity of wood.

Figure 40. Hygroscopicity of wood

All wood contains a considerable amount of water; this water is used during photosynthesis and to aid the tree in its growth. The water found in wood is referred to as sap. Sap contains other materials in solution although it is mainly comprised of water. Wood contains water in two different forms. It is either present as bound water or free water. Bound water is held within cell walls by the bonding forces between water and cellulose molecules. Free water is contained in cell cavities and is not held by any forces. See figure 41 on the next page for an illustration of these two different types of water molecules found in wood.

Section of wood cell

The amount of water in wood is expressed as the percent of dry weight, which is called Moisture Content (%MC). It is calculated by using the following equation:

$$\%MC = \frac{\text{weight of wood with water - weight of dry wood}}{\text{weight of dry wood}} \times 100$$

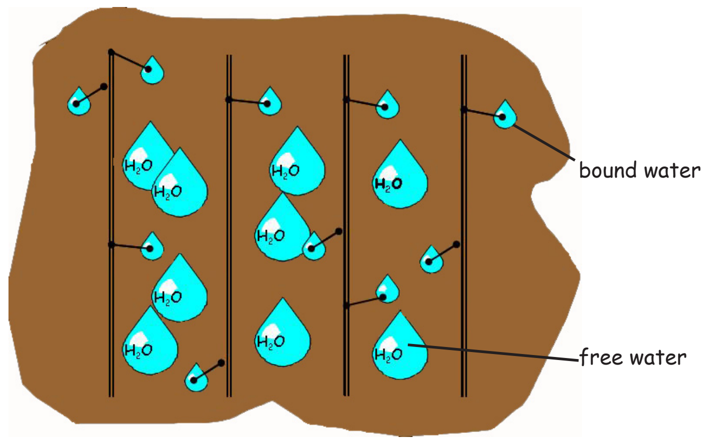


Illustration 41. Types of water in wood

Water movement is important in two ways for those who use wood. First, we need to be concerned about the drying that occurs before manufacturing and after the finished product is produced. Our second concern is the gain and loss of water vapor in response to changes in environmental conditions that impact the moisture content of wood. In the first situation, water normally moves from higher to lower zones of moisture concentration, although extreme changes in temperature can affect this normal pattern of movement.

Water moves through wood in two different physical states; it moves as liquid as well as vapor. Water molecules travel through several kinds of pathways including the cell cavities of fibers and vessels, ray cells, pit chambers, and the cell walls themselves. Water movement along the wood grain is much faster than water movement across the wood grain.

Free water moves through cell cavities and pit openings. During the drying process, this type of water molecule is moved by capillary forces that exert a pull on the free water found deeper in the wood. On the contrary, bound water moves as vapor through empty cell cavities, pit openings, and cell walls. The most common cause for bound water movement is attributed to the difference in water vapor that is caused by relative humidity, moisture content, and temperature differences in the environment.

Once wood has been dried below its fiber saturation point (the point when the cell walls are still fully saturated but there is no free water remaining), the wood rarely gets back any free water that could increase the moisture content above the current level. Only prolonged soaking of the wood in water will do so.

Bound water is lost or gained by wood until the amount that the wood contains is in balance with that of the surrounding environment. This amount of bound water that is equal to the surrounding environment is called the equilibrium moisture content (EMC). The EMC is always below 30% and is greatly influenced by the relative humidity and temperature of the surrounding air.

Water movement plays a large part in the shrinkage and swelling of wood. Shrinkage and swelling cause many problems during the manufacturing, storing, and usage of wood and its by-products. Splitting, warping, and open joints are examples of problems that are associated with uneven shrinkage of wood. The diagram below shows an example illustration of warping.

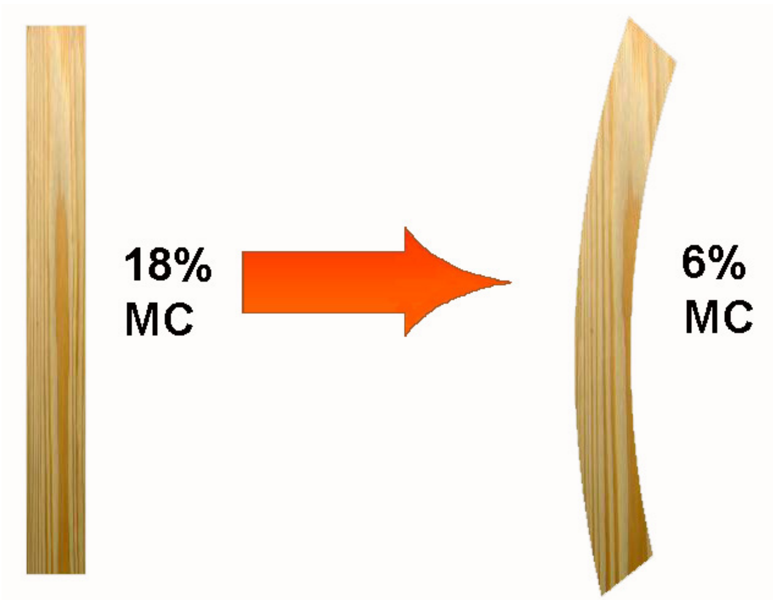


Figure 42. Warped board

Shrinkage occurs when water begins to leave the cell wall at the fiber saturation point. Even after drying has been completed during manufacturing, wood will still shrink and swell as relative humidity fluctuates and as water enters or leaves the cell walls. This causes stress to the wood and the problems mentioned above (splitting, warping, and open joints) are a result of this added stress. Shrinkage and swelling are defined by the following mathematical equations:

1. $$\textbf{Shrinkage}\ \% = \frac{\text{wet dimension} - \text{dry dimension}}{\text{wet dimension}} \times 100$$

2. $$\textbf{Swelling}\ \% = \frac{\text{wet dimension} - \text{dry dimension}}{\text{dry dimension}} \times 100$$

Reflect (~5 minutes)

Record your observations and calculations on the Lesson 6 Work Sheet.

Apply (~5 minutes)

Ask the students the following questions and discuss their answers:

1. How do you think wood is prevented/delayed from shrinking and swelling during manufacturing of products and their storage before reaching consumers?
2. How does the hygroscopic characteristic of wood affect people's daily lives, including yours?

Lesson 6 Work Sheet
Hygroscopicity

Name ____

Recall your observations made during the laboratory exercise, and record your observations in the chart below. In the space below the chart, provide an example of how you calculated all of your results for one sample. (Remember that WW is the "wet weight" or simply the weight of the wood (which contains adsorbed water) at a condition other than oven dry; and DW is the oven-dry weight of the wood determined by drying the wood in an oven at 105º C (220ºF) until no water remains and the weight of the block no longer changes).

			Wet Weights (WW)					
Sample	RH%	DW	1	2	3	4	5	%MC
1	33							
2	54							
3	76							
4	95							

Sample Calculations:

Now, sketch a graph of RH% vs. %MC to see their relationship. Share your results with the rest of the class.

Were the results for individuals (or groups) similar across the entire class? Why or why not?

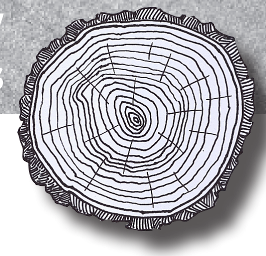
____

____

____

____

Lesson 7: Anisotropy
Content Area: Wood Properties



Virginia Standards of Learning addressed:

BIO.1A, 1D, and **1E**: The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- Graphing and arithmetic calculations are used as tools in data analysis
- Conclusions are formed based on recorded quantitative and qualitative data

BIO.3A: The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include:

- Water chemistry and its impact on life processes.

BIO.5C: The student will investigate and understand life functions of plants. Key concepts include:

- Analyses of their responses to the environment

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence

Content Skills

Students will be able to:

- define the term anisotropy and explain its effect on wood properties
- conduct a scientific investigation to determine if the % shrinkage is affected by wood direction

Life Skill

Acquiring and evaluating information

Success Indicator

Performing and evaluating a scientific investigation to determine the anisotropy of the three structural directions of wood

Time Needed

Several days

Activity Summary

Student will conduct a scientific investigation to determine the anisotropy of the longitudinal, radial, and tangential structural directions of wood.

Procedures

Do (~5 minutes)

Examine the following graph and record any observations you have pertaining to the information shown on the graph.

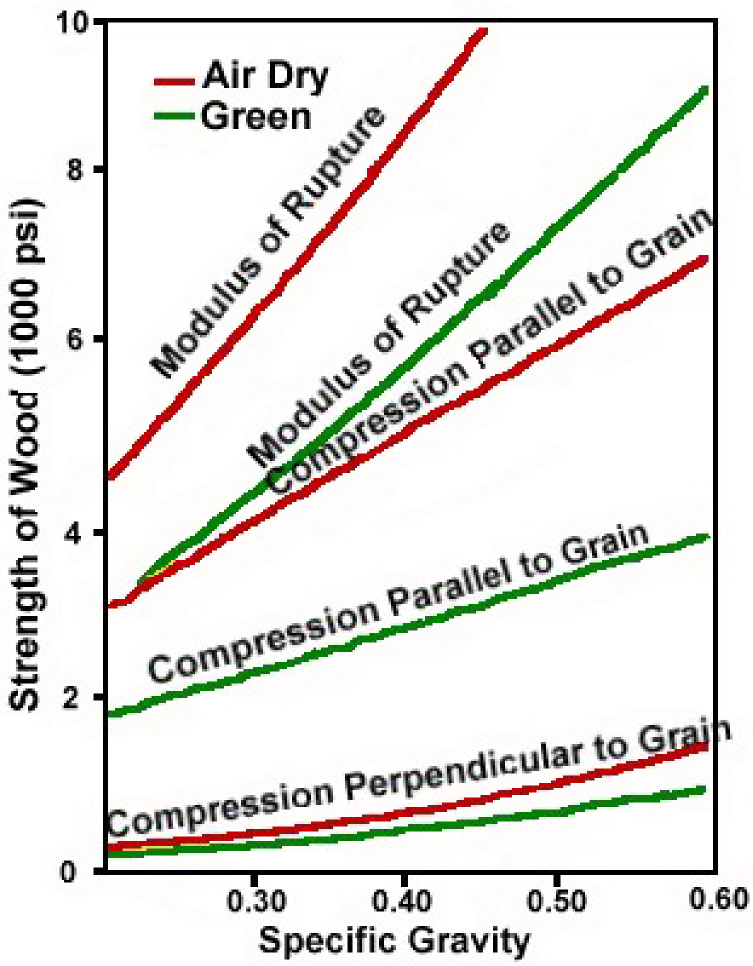


Figure 43. Strength v. SG chart

Reflect (~10 minutes)

Students should discuss their answers with the class and form a consensus on the meaning of the graph.

Apply (~5 minutes)

Ask the students the following questions and discuss their answers:

1. Based on the information from the graph, do you believe the direction of wood grain can play a role in how wood and its products can be used? If so, how does this affect the forest products industry and consumers of wood products?

Activity Materials

Samples of a variety of high and low density woods, 2 inches x 2 inches x 2 inches, cut so that the 3 primary surfaces of wood are parallel with each side of the wood cube (see Figure 44 below)

- Rulers
- Basin of water
- Oven for drying the wood (capable of reaching 105ºC [220ºF]) (Do not use an oven in which food will later be cooked.)

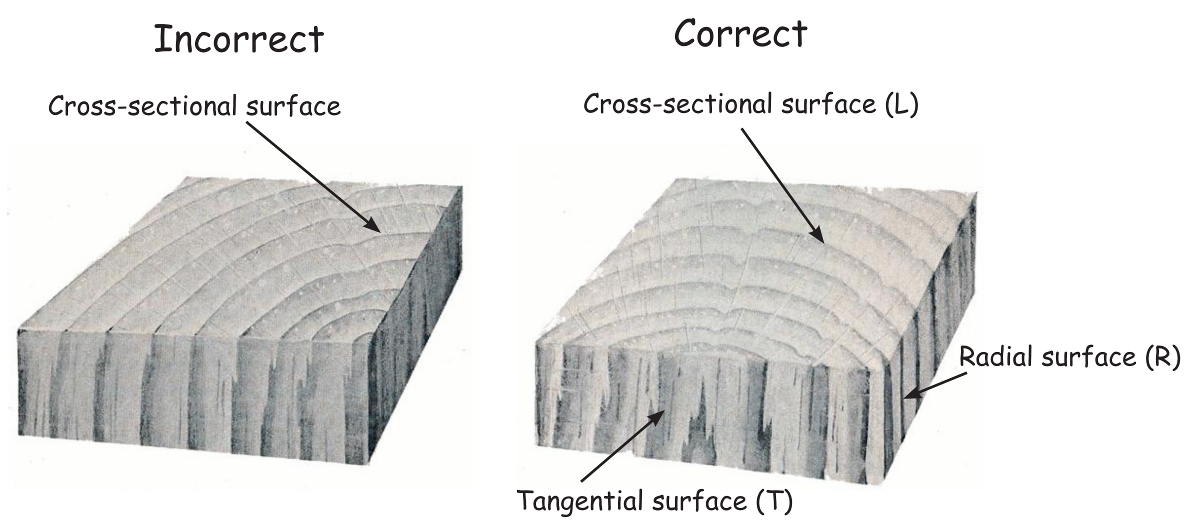


Figure 44. Incorrect and correct ways to prepare wood blocks

Procedures

Do

1. Thoroughly soak the specimens in water for 48 hours.
2. Wipe with a cloth, weigh, and measure the dimensions in each of the 3 directions (R, T, and L) (see background information for directions on how to measure the dimensions.)
3. Record the wet dimensions in the chart on the Lesson 7 Work Sheet.
4. Next place the specimens in an oven and dry for 24 hours at 105°C (220ºF) or until they reach a constant weight.
5. Measure and record the dry dimensions in the chart on the Lesson 7 Work Sheet.

Background Information

Wood is described as being an anisotropic material. Anisotropic means that wood's structure and properties vary in different directions. In contrast, other materials such as steel, concrete, and plastic are isotropic, meaning that their structure and properties remain the same in all directions.

There are three primary directions found in wood – longitudinal, radial, and tangential. If you were to look at the end of a log you would see the cross-sectional surface of the wood. If you then peeled the bark off from the side of the log, you would see the tangential surface. If you were to slice the log like a pie, the pie-shaped wedge of wood would reveal the radial surface of the wood. See the diagram below for further explanation.

The three different directions are a result of the way cells form in tree stems. The longitudinal direction is parallel to the wood cells and is known as the grain direction. The radial direction is parallel to the wood rays (review lessons on microscopic structures). The tangential direction is parallel to the growth rings.

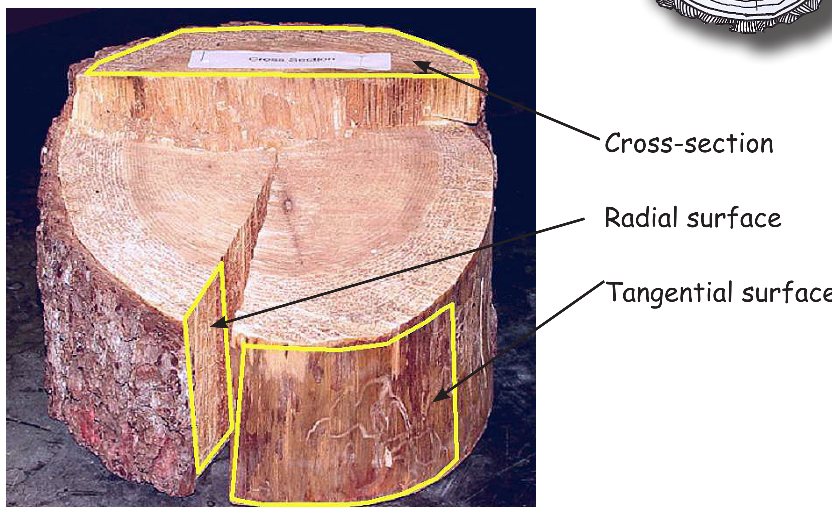


Figure 45. Tree cut away view

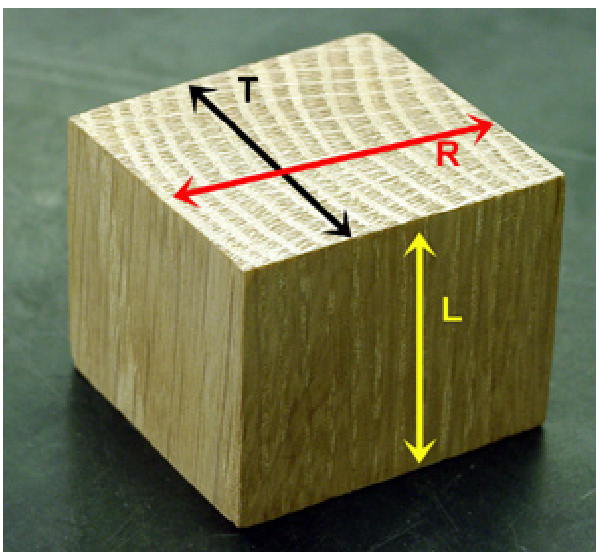


Figure 46. Oak cube

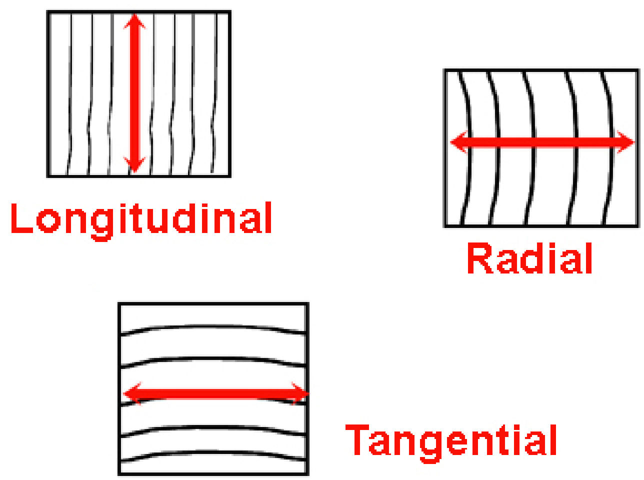


Figure 47. Three directional wood structure

In this exercise, you will be measuring wet and dry dimensions. Figures 46 and 47 demonstrates how to perform this task.

Arrows indicate what surface and distance to measure for each dimension.

Reflect (~10 minutes)

Complete the observational chart on the Lesson 7 Work Sheet. Share your results with the class.

Apply (~5 minutes)

Answer the questions on the Lesson 7 Work Sheet based on the data obtained from your laboratory experiment.

Anisotropy

Name ______________________________

Recall your observations made during the laboratory exercise, and then record answers in the chart:

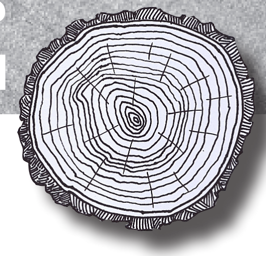
Sample Direction	Wet dimension (mm)	Dry dimension (mm)	Shrinkage (%)
Longitudinal			
Tangential			
Radial			

Answer the following questions based on the data obtained from your laboratory experiment.

1. Does the % shrinkage vary with the wood direction? What are some possible explanations for these differences?

2. Can you think of any advantages or disadvantages to wood being anisotropic?

3. Do you think that % shrinkage varies in different species of wood? If so, why?



Virginia Standards of Learning addressed:

PH.7C: The student will investigate and understand properties of fluids. Key concepts include:

- Archimedes' principle of buoyancy.

BIO.1D and **1E**: The student will plan and conduct investigations in which:

- Graphing and arithmetic calculations are used as tools in data analysis
- Conclusions are formed based on recorded quantitative and qualitative data

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence

Content Skills: Students will be able to

- explain the impact of the density and specific gravity of wood on its processing and usage
- conduct a scientific investigation to determine the specific gravity of particular wood specimens

Life Skill

Acquiring and evaluating information

Success Indicator

Completing scientific investigation dealing with specific gravity

Time Needed

Several days

Activity Summary

Students will conduct a scientific investigation to determine the specific gravity of particular specimens.

Lesson 8: Sink or Float?
Content Area: Density and Specific Gravity of Wood

Introduction Activity

Procedures

Do (~5 minutes)

Discuss the following questions with the students to determine any misconceptions that might exist.

1. Many of you have gone to a lake and noticed a huge log floating in the water. How is this possible?

Reflect (~10 minutes)

Students will discuss their responses with the class. Afterwards, the teacher should explain the correct answer.

Apply (~5 minutes)

Answer the following question:

1. How do you think the density of wood affects how it is manufactured and used?

____

____

____

Lesson 8: Sink or Float?
Content Area: Density and Specific Gravity of Wood

Activity Materials

- Wood specimens 1 inch x 1 inch x 10 inches of white pine, southern pine, oak, and aspen (or a variety of high and low density woods; see background information)
- 500-cc graduated cylinders
- Drying oven (capable of reaching 105ºC [220ºF]) (Do not use an oven in which food will later be cooked.)
- Balances (scale)
- Rulers

Procedures

Do

1. Students should read the background information before beginning the investigation.
2. Dry the wood samples overnight in an oven at 105ºC.
3. Remove each specimen, weigh, and record the data in the observational chart.
4. Place the samples back into the oven for another 2 hours.
5. Reweigh and record the data in the observational chart.
6. Repeat until each specimen reaches a constant weight (i.e. all moisture has been removed).
7. Gently lower each specimen into the water (do not submerge the whole specimen).
8. When it has reached its floating level, withdraw the specimen from the water and measure the length of the sample that was under water.

Background Information

Density of a material is defined to be the mass per unit volume and is calculated using the following equation:

Density = mass/volume

Most woods have a density of less than 1 g/cm^3. Density of a sample of wood is usually calculated as the weight density instead of mass by using the following equation:

$$\text{Wt. density} = \frac{\text{weight of wood with moisture}}{\text{volume of wood with moisture}}$$

The concept of specific gravity comes from Archimedes' principal that showed that an object floating in water was being held up by a force equal to the weight of water displaced.

Lesson 8: Sink or Float?
Content Area: Density and Specific Gravity of Wood

Specific gravity is a measure of the amount of solid cell-wall substance and is also known as "relative density." It is a ratio of the density of a substance to the density of water (1 g/cm^3). With wood, it provides a relative value for describing the amount of cell-wall material present in a particular volume of wood. This is particularly helpful since wood obtains its properties from the cell-wall characteristics (including the relative amount of wall and lumen space). Specific gravity is a good predictor of all other physical properties found in a particular specimen of wood. It is defined by the following mathematical equation:

$$SG = \frac{\text{OD weight of wood}}{\text{Weight of an equal volume of water}}$$

OD = oven dry (no moisture in the wood)

There are three factors that can influence the specific gravity of wood. First, moisture content can have an affect on specific gravity. A higher moisture content (up to the fiber saturation point) causes a lower specific gravity. When the moisture content is above the fiber saturation point, there is no change in specific gravity with changes in moisture content. Specific gravity is highest when the moisture content is equal to zero. The second factor is the proportion of wood volume that is made of various kinds of cell types and thicknesses. Specific gravity is high when there are many types of thick cells. The final factor is the size of cells and cell lumens. Large cells with large lumens cause a lower specific gravity.

Most commercial woods produced in the United States have specific gravities that range from 0.35 to 0.65. However, commercial woods produced in other parts of the world have a much larger range of specific gravities; this range is from 0.04 to 1.40.

Reflect (~10 minutes)

Have the students record their data in the observational chart and show their work in the specific gravity column on the Lesson 8 Work Sheet. Compare and discuss your data with the rest of the class.

Apply (~10 minutes)

Have the students answer the questions on the Lesson 8 Work Sheet.

Virginia Standards of Learning addressed:

PH.4A: The student will investigate and understand how applications of physics affect the world. Key concepts include:

- Examples from the real world

PH.8A: The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include:

- Transformation of energy among forms including mechanical, thermal, electrical, gravitational, chemical, and nuclear

BIO.1B and **1E:** The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- Conclusions are formed based on recorded quantitative and qualitative data

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry.

- Formulate and revise scientific explanations and models using logic and evidence

Content Skills

Students will be able to:

- acquire knowledge pertaining to the mechanical, thermal, electrical, and acoustical properties of wood
- recognize some of the sturdiest arrangements of wood by conducting two different experiments that demonstrate the mechanical properties of wood

Life Skill

Acquiring and evaluating information

Success Indicator

Understanding the principles of mechanical, thermal, electrical, and acoustical properties of wood

Time Needed

65 minutes

Lesson 9: Engineering with Wood
Content Area: Wood Properties

Activity Summary

Students will become familiar with the mechanical, thermal, electrical, and acoustical properties of wood. They will conduct two different investigations that demonstrate the mechanical properties of wood.

Introduction Activity Materials

- 9 strips of softwood (1/4 x 1 x 18 inches)
- Hammer
- Small nails
- Glue (ordinary wood glue will work fine)
- Clamps
- 2 supports
- Light colored cardboard backdrop
- 5000-gram weight (about 11.0 pounds)

Procedures

Do (~20 minutes)

1. Take 3 strips of wood, place them on top of one another, and nail them together using 4 or 5 nails equally spaced along the length.
2. Take 3 other strips of wood, place them on top of one another, then glue and clamp them together.
3. Take the last 3 strips of wood and place them on top of one another. Then place them across the two supports and position the 5,000 gram weight in the center of the strips. Mark the level of the bottom of the strips on the backdrop (see the diagram below). Measure the distance from the bottom of the backdrop to the bottom of the strips of wood.
4. Record your observations in the chart on the Lesson 9 Work Sheet A provided in the Reflect section of this activity.
5. Repeat steps 3 and 4 for both the nailed beam and the glued beam.

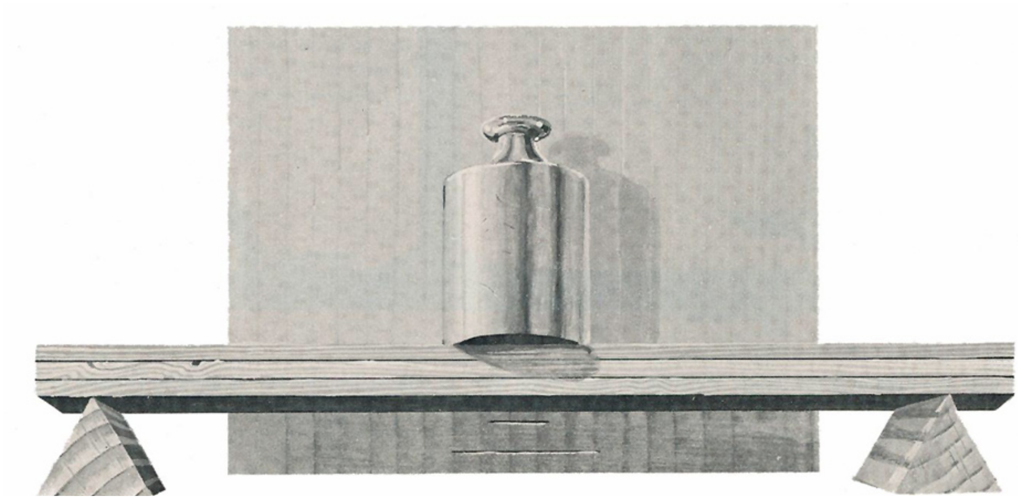


Figure 48. Weight on wood beam

Reflect (~5 minutes)

Have the students recall their observations during this activity and complete the Lesson 9 Work Sheet A.

Apply (~5 minutes)

Have the students answer the question in the Lesson 9 Work Sheet A.

Activity Materials

- 5 strips of oak veneer (1/8 x 3 x 3 inches - oak veneer is available at home improvement stores, hardware stores, or from catalogs)
- 2 pieces of solid oak (5/8 x 3 x 3 inches)
- Waterproof glue
- Hammer
- Clamp
- Sharp-pointed nails
- Basin of water
- Caliper or dial gauge

Procedures

Do (~30 minutes)

1. Students need to read the background information before beginning the activity (it is lengthy!).
2. Glue the 5 thin sheets of oak together with waterproof glue, making sure that the grain directions run at right angles to each other in adjoining sheets. See diagram below.

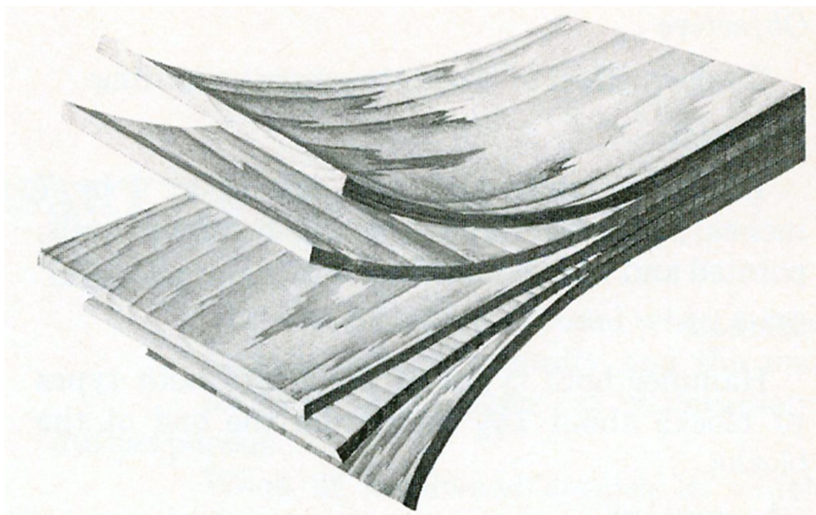


Figure 49. Plywood layers

3. Clamp and allow the plywood to set completely following the manufacturer's instructions.
4. Hammer nails near an edge of the plywood and do the same with one of the solid oak pieces. Observe if splits occur when nailing for both the plywood and solid oak block.
5. Measure the 3 dimensions (thickness, width, and length) with a caliper or dial gauge and note the size of the dry plywood and the solid oak block; record these dry dimensions in the chart provided in the Lesson 9 Work Sheet B.
6. Thoroughly soak both for at least 6 hours and remeasure the dimensions. Record the wet dimensions in the chart and compare the dimensions before and after soaking.

Background Information

Mechanical properties of wood deals with the behavior of wood under applied forces. Examples of mechanical properties include strength, stress, strain, toughness, stiffness, and elasticity. As we discussed in Lesson 7, shrinking and swelling of wood varies in the tangential, longitudinal, and radial directions. This also applies to mechanical properties; the mechanical properties of wood can vary depending on the direction. Therefore, wood is anisotropic in both its hygroscopic behavior as well as its mechanical behavior.

The strength of wood is important to know when using wood as a construction material. Wood is an elastic material, which is bent, but not broken, when the load (weight) applied is small.

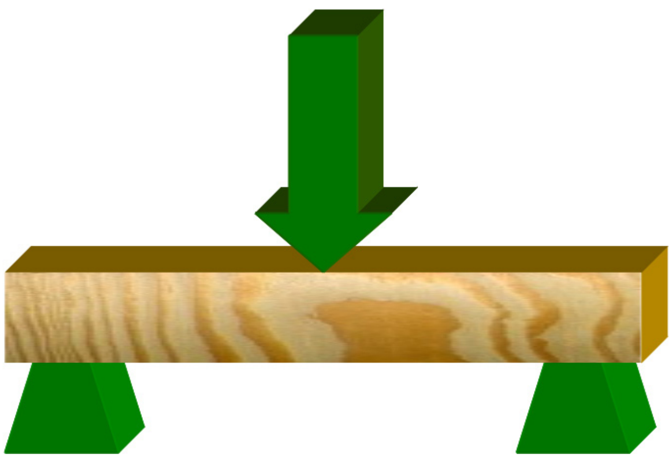


Figure 50. Unloaded beam

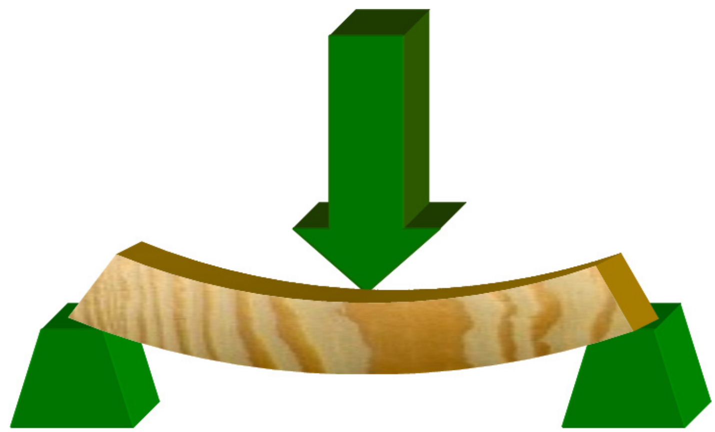


Figure 51. Loaded beam

However, if the load is too great, the wood will eventually break. This is represented in the following diagram.

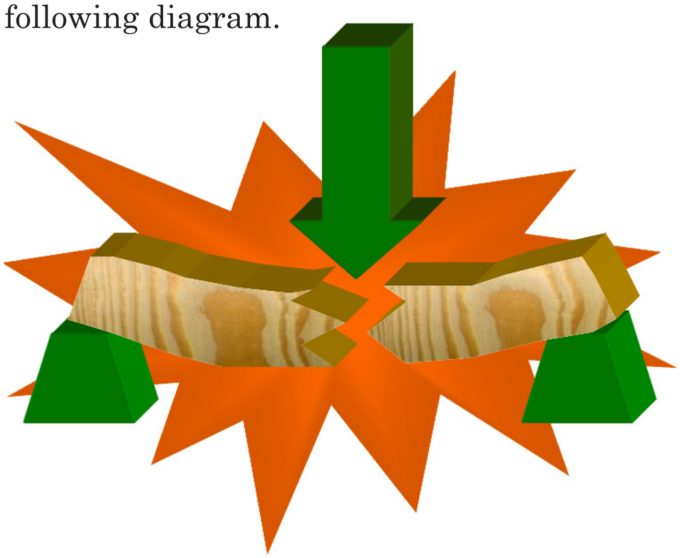


Figure 52. Failed beam

The elastic nature of wood is illustrated in the graph below. The degree of deformation that a piece of wood will undergo is proportional to the amount of load applied. Wood is elastic up to a point, called the **elastic** or **proportional limit**. If loads are applied below the elastic limit and then removed, the wood will go, or spring, back to its original shape. If a load is applied that exceeds the elastic limit and is then removed, the wood will go back only partially to its original shape. This is because the load applied was too much for the wood to stand and damage to the wood occurred. If the applied load greatly exceeds the proportional limit, the wood is no longer able to support this heavy load and the wood breaks, as was demonstrated in the Figure above. In general, wood is stronger when loads are applied parallel to the grain instead of perpendicular to the grain of the wood.

Three important mechanical properties of wood are used as a measure of its strength. These properties are **compression, tension,** and **bending.** Compression is defined as two forces or loads acting along the same axis that are trying to shorten a dimension or reduce the volume of a particular piece of wood. Compressive forces can act on the wood parallel to the grain or perpendicular to the grain. Compressive strength parallel to the grain is greater than compressive strength perpendicular to the grain.

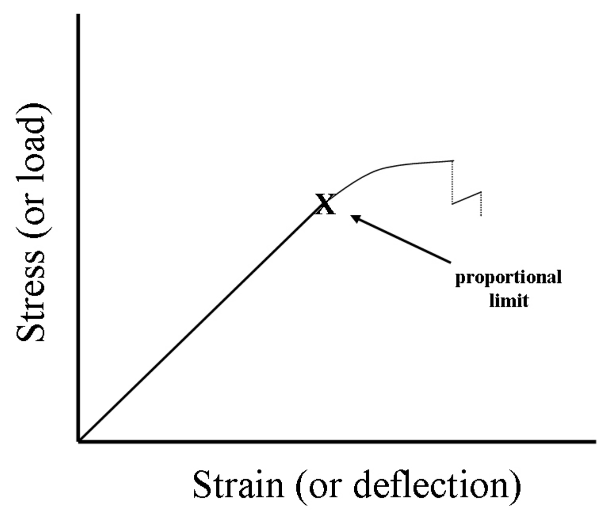


Figure 53. Stress/strain curve

Tension is defined as two forces or loads acting along the same axis that are trying to lengthen a dimension or increase the volume of a particular piece of wood. Wood is the strongest in tension parallel to the grain due to the orientation of wood fibers. Wood is not strong in tension perpendicular to the grain.

Bending strength is expressed as a degree of deflection with a given force or load on a wood beam. A test of bending strength was demonstrated in the introduction activity. Bending strength is a measure of the resistance to failing. Stiffness is a measure of the ability to bend freely and regain normal shape.

Wood also has unique thermal properties. Thermal conductivity (K) is a measure of the rate of heat flow in response to a temperature gradient. In wood, this rate depends on the direction of heat flow with respect to the grain orientation. Thermal conductivity is about equal in the radial and tangential directions. However, K is 2 to 3X greater parallel to the grain of the wood which means heat will flow 2 to 3 times faster along the grain than across it.

Thermal conductivity is influenced by moisture content and density. The higher the moisture content, the greater the thermal conductivity will be. Thermal conductivity is linearly proportional to density and, therefore, denser woods have a greater K.

Thermal insulating value (better known as the R value) is the reciprocal of thermal conductivity. It is represented by the following mathematical equation:

$R = 1/K$

Just like thermal conductivity, R values depend on wood structure direction, and it is also influenced by density and moisture content. Since R is the inverse of K, insulating value is lower along the grain. It is also lower for higher density woods and lower for higher moisture content. Values of K and R for various materials are shown in the following chart.

Material	K	R
Air	0.16	6.25
Water	4	0.25
Glass	5	0.20
Brick	4.5	0.22
Concrete	7.5	0.13
Steel	310	0.003
Aluminum	1,400	0.0007
Wood 12% moisture content	0.4-1.2	0.8-2.5

Thermal expansion is a measure of dimensional changes caused by changes in surrounding temperature. In wood, the amount of thermal expansion varies with density in a linear relationship. For example, higher density woods have higher thermal expansion. Thermal expansion varies with wood structure direction. Expansion parallel to the grain is very small compared with other common solid materials; it is about 1/2,000,000 inch per degree F temperature change. Steel, however, would shrink 3 times that amount and aluminum more than 7 times.

The ignition temperature of wood is usually given as about 275°C (525°F). This is actually the temperature at which wood begins to decompose exothermically, i.e., with liberation of heat. The speed with which combustion is initiated depends upon the rate of accumulation of heat at the surface. Several factors influence the accumulation of heat at the structure's surface: size of the piece, rate of heat loss from the surface, presence of thin outstanding edges, and rate at which heat is supplied. Small pieces with sharp projecting edges, such as match sticks, ignite easily because a small amount of heat is needed to raise the temperature of the whole stick to the ignition point. Large pieces with rounded edges, like poles and logs in log homes, are much slower to catch fire because conduction of heat into the interior keeps the surface below ignition temperature for some time. This is why wood construction materials maintain their strength during fires which cause failure of steel products designed to carry the same loads. Large wood materials burn slowly and then only if there is a continuous supply of heat, and the low thermal conductivity of wood delays weakening on the unburned interior.

Now we will move on to wood's electrical properties. The direct current (DC) properties of materials are measured by resistivity or by its reciprocal, conductivity. In wood, any electrical conductivity occurs primarily by migration of metallic ions which are found in wood as impurities. There aren't very many of these, so air-dry wood is an excellent electrical insulator. This is one of the reasons why utility poles are made from wood. For woods with higher moisture contents, the dc resistivity is lower (water is a VERY good conductor of electricity!). Also, when the temperature is increased, the electrical resistivity is decreased. dc conductivity is 2.3 to 4.5 times greater along the grain than across it for softwoods (gymnosperms – trees with needles and cones) and 2.5 to 8.0 times greater along the grain than across it for hardwoods (angiosperms – trees with broad leaves).

Finally, we will discuss the acoustical properties of wood. Many of you may play a musical instrument. Of those who do, many of you have probably never thought about why your instrument was designed from wood. The velocity of sound waves traveling parallel to the grain in wood is directly proportional to the wood's elasticity (E) and inversely proportional to the density (D). But, since the ratio of E to D tends to be constant, speed tends to be constant along the grain. Sound velocity is slower across the grain because the transverse E is much less that than parallel to the grain (about 1/20th less). So, speed across the grain is 1/5 to 1/3 that along the grain. As MC or temperature increases, speed of sound decreases. Because the velocity of sound waves in wood is quite slow, wood is a very good insulator for sound.

A piece of wood (or parts of it) vibrates when periodic forces act upon it. When the driving force is removed, the successive amplitudes of vibration will decrease – this is called damping. Energy is dissipated partly by radiation of sound and partly in the form of heat by internal friction. Damping due to sound radiation depends mainly on the ratio of sound velocity to material density. You probably didn't realize that your musical instrument had so much to do with physics!

Reflect (~5 minutes)

Have the students complete the Lesson 9 Work Sheet B.

Apply (~5 minutes)

Have the students answer the questions on the Lesson 9 Work Sheet B.

Lesson 9: Engineering with Wood
Content Area: Wood Properties

Resource

The following resources apply to Lessons 6 through 9. A number of books are available on the topic of wood structure and properties. A couple of recommend references are:

Bowyer, J.L., R. Shmulsky, J.G., Haygreen. 2007. Forest Products and Wood Science - An Introduction, 5th ed. Iowa State University Press, Ames, Iowa.

Hoadley, R. B. 1980. Understanding Wood: A Craftsman's Guide to Wood Technology. Taunton Press, Newtown, Conn.

Panshin, A.J. and C. deZeeuw. 1980. Textbook of Wood Technology, 4th ed. McGraw Hill Book Company, New York.

The Nature of Wood and Wood Products. 1996. CD ROM, Forest Products Society, Madison, Wisc. www.forestprod.org/

Wood Handbook: Wood as an Engineering Material. 1999. Forest Products Society, Madison, Wisc. www.forestprod.org/

Wood Reference Handbook. A Guide to the Architectural Use of Wood in Building Construction. 1991. Canadian Wood Council, Ottawa, Ontario, Canada.

DID YOU KNOW?

- A piece of air-dry Douglas-fir wood an inch square on the cross-section and 3 inches in length can support 4900 psi (pounds per square inch) which is strong enough to support a police car.
- Using wood for fuel is the number one largest single use of wood in the world.
- Spruce is used in violins because it has exceptional resonant qualities and it is favored for soundboards.
- African blackwood (rosewood) and ebony (white ebony or persimmon) is used in woodwind instruments and castanets.
- It is traditional for the sharp/flat keys of a piano to be ebony to contrast with the ivories. This is to symbolize forces of good and evil in everyday life.
- Fiddleback sycamore and maple are traditionally used for the backs of violins and cellos.

Lesson 9 Work Sheet A
Engineering with Wood

Name ____

Record your observations in the chart below.

Beam type	Deflection
separate pieces	
nailed beam	
glued beam	

Answer the following questions:

Are your observations similar to the rest of the class's observations? Why or why not?

____

____

____

1. Rank the deflection of the three beams you created in this activity from least to greatest. Based on this conclusion, which arrangement produced the sturdiest structure?

____

____

____

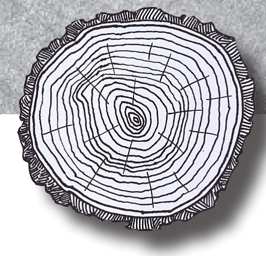
2. Why do you think these results occurred? Use the principles of wood structure and properties that we have discussed to provide evidence for your reasoning.

____

____

____

Lesson 9 Work Sheet B
Engineering with Wood - Plywood



Name ____

Record your observations about plywood in the chart on Work Sheet 9B. Show your work in the space provided in the chart. You will need to use the following equation for your calculations:

$$\text{Percent swelling} = \frac{\text{wet dimension} - \text{dry dimension}}{\text{dry dimension}} \times 100$$

Sample type	Wet dimension	Dry dimension	Swelling (%)
solid wood			
plywood			

Answer the following questions:

1. The plywood does not split when nailed although the solid wood block does (this should have been observed during the activity.) Why do you think this occurs?

2. Plywood is a good example of taking wood apart and putting it back together to make a more useful product. Can you think of an instance where it would be more useful to use plywood than solid wood?

Lesson 10: Deterioration of Wood Products
Content Area: Wood Properties and Wood Quality

Virginia Standards of Learning addressed:

BIO.1: The student will plan and conduct investigations in which:

- Observations of living organisms are recorded in the lab and in the field

BIO.5: The student will investigate and understand life functions of bacteria, monerans, protists, fungi, plants, and animals including humans. Key concepts include:

- Analyses of their responses to the environment

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Identify questions and concepts that guide scientific investigations
- Formulate and revise scientific explanations and models using logic and evidence

Content Skill

Students will be able to:

- Classify wood samples/trees based on the type of deterioration that is present on the specimens
- Explain one cause of wood deterioration through a formal presentation to the class.

Life Skill

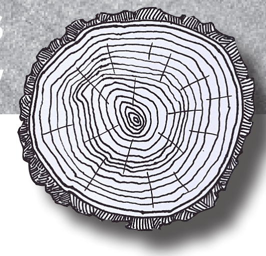
Reasoning

Success Indicator

Draws logical conclusions based on given specimens and explains one cause of wood deterioration through formal presentation.

Time Needed

90+ minutes (time will vary depending on class size)



Activity Summary

The main activity is divided into two parts. First, students will observe wood deterioration in several different specimens and make logical conclusions for the cause of the deterioration. Second, students will choose to research one type of wood deterioration and its causes and effects on wood properties and quality and give a formal presentation to the class about their findings.

Procedures

Do (~5 minutes)

Ask the following questions to identify any misconceptions that might exist:

1. List factors that cause the deterioration of wood and wood products.
2. Do you think some species of trees are more susceptible to some forms of wood deterioration than other species?

Reflect (~10 minutes)

Students should share their responses and discuss the correct answers.

Apply (~5 minutes)

Ask and discuss the following questions:

1. Do you think wood deterioration is of economic significance to the industry?
2. What would you recommend to someone who has wood deterioration that is attributed to insects?

Activity Materials

Wood specimens that have deterioration caused by weather, fungi, borers, insects, and bacteria

(**Note: Teachers can either go on a "scavenger hunt" to locate these specimens or they could check with a local representative from the forest products industry or wood science industry to see about borrowing specimens.)

Lesson 10: Deterioration of Wood Products
Content Area: Wood Properties and Wood Quality

Procedures 1

Do (~30 minutes)

1. Students need to read the background information.
2. Students will go outside to find trees that have been affected by wood deterioration.
3. If students find any trees with visual deterioration, have them make predictions about what caused the wood to deteriorate.
4. Then, students will view wood specimens that represent different types of wood deterioration.
5. Students should analyze the specimens and make predictions about what caused the wood to deteriorate.
6. Students will discuss their predictions and as a class they should determine the correct answers.

Procedures 2

Do (~30 minutes)

1. Each student will research one cause of wood deterioration of their choosing.
2. Each will make a formal presentation that discusses the effects of the deterioration on the visual and physiological conditions of the tree and possible ways to eradicate or control the problem.

Background Information

Since wood is an organic material, it can be subject to decay, fungi, bacteria, insect infestation, fire, and surface weathering. These factors can cause the useful life of wood and wood products to be greatly reduced. Biological agents such as fungi, bacteria, wood boring beetles, termites, carpenter ants, and marine borers are the major causes of wood deterioration. Of these biological agents, fungi cause the most economic losses. Nonbiological deterioration is caused by fire and surface weathering, which is caused by ultraviolet light and mechanical abrasion. Fire is by far the most costly form of nonbiological deterioration.

Figure 54. Decay on a door frame

Figure 55. Decay in a log

Reflect (times will vary)

Students will present their research findings to the class.

After all presentations are completed, have the students answer the following questions:

1. List the visual signs of wood deterioration caused by the major types of biological deterioration (fungi, bacteria, and insects).
2. Why are fungi the most prevalent cause of wood deterioration?

Apply (~10 minutes)

Ask and discuss the following questions:

1. What climates do you think have the most problems with fungi and bacteria? Why?
2. Based on what you learned about moisture content in previous lessons, what environmental conditions do you think must be present in order for wood to begin decaying?
3. Based on wood structure and properties discussed in previous lessons, why do you think some species of trees are more susceptible to biological deterioration?

Resource

Bowyer J. L., R. Shmulsky, and J. G. Haygreen. 2007. *Forest Products and Wood Science*, 5th edition. Iowa State University Press, Ames, Iowa

Lesson 11: Preservation of Wood
Content Area: Deterioration of Wood

Virginia Standards of Learning addressed:

BIO.5A and **5C:** The student will investigate and understand life functions of bacteria, monerans, protists, fungi, plants, and animals including humans. Key concepts include:

- How their structures and functions vary between and within kingdoms
- Analyses of their response to the environment

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Identify questions and concepts that guide scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.

Content Standard C: All students should develop an understanding of:

- Interdependence of organisms
- Behavior of organisms

Content Skill

Students will be able to:

- Develop a hypothesis that predicts the causes for wood deterioration in provided scenarios.
- Determine what types of preservation techniques are needed for wood used in various situations and environments.

Life Skill

Solving problems

Success Indicator

Determining the cause of wood deterioration in provided scenarios and recognizing the correct preservation technique needed to correct the existing problem.

Time Needed

90 minutes

Lesson 11: Preservation of Wood
Content Area: Deterioration of Wood

Activity Summary

Students will determine the cause of wood deterioration in provided scenarios by researching on the Internet. They will then use the knowledge gained from their findings to generate solutions to the existing problems discussed in the scenarios.

Procedures

Do (~5 minutes)

Ask and answer the following questions:

1. How do you think wood is preserved?
2. Do you think the method of preservation depends on the cause of wood deterioration? Why or why not?

Reflect (~10 minutes)

Students should discuss their responses with the class and the teacher should record the answers on the board.

Students should then answer the following questions:

1. After listening to the class discussion, have any of your responses changed? What caused you to modify your answers?

Apply (~5 minutes)

Ask the students the following questions and discuss their answers:

1. How do you think the environmental conditions of an area contribute to the likelihood of wood decaying/deteriorating in that particular environment? (Hint: think about the properties of wood!)
2. Based on your previous knowledge of biological evolution, do you think some groups of insects and termites have become resistant to wood preservation techniques? If so, how do you think this resistance occurs?

Activity Materials

- Scenario Cards (cards on which the three different scenarios shown below have been written)
- Computer Access

Procedures

Do (~40 minutes)

1. Students should read the background material before moving on with the activity.
2. Students will be divided into three groups and each group will be given one of the following scenarios:
   - You are a home owner living in Pennsylvania and you begin to notice winged insects flying around in your basement. At first you think the insects are flying ants, but as you look closer you see that the insects are white! It seems as though the insects are flying in and out of wood pieces in the basement. You immediately panic because you can't identify the pests that seem to be taking over your basement and therefore, you turn to the Internet to find some answers.
   - You are a Florida business owner and you begin to notice that some of the wood in your buildings appears to have damage. It appears as though the wood has been cut across the grain and something has dug large chambers that are connected by small tunnels throughout the wood member. You don't have money to seek professional advice, so you turn to the Internet to find out what could be causing damage to the wood in the structures on your property.
   - You are a log home owner in California and you begin to notice reddish brown insects on your property. As time goes on, you notice that some of the logs on the outside of your home have tiny holes in them. As you inspect your property further, you find these holes in your hardwood flooring and some of your furniture. You are immediately worried about your house and search the Internet to find out what the insects are and if they are the cause of the mysterious holes.
3. Students will need to write a hypothesis that states the cause of the wood deterioration.
4. Students will then need to search the Internet to find out what is causing the wood deterioration in their assigned scenarios. They will need to make sure to answer the following questions:
   - What is the cause of the wood deterioration? (Include both the scientific name and common name if applicable.)
   - If the damage is caused by insects, including termites, provide a brief description of the organism's physical appearance, life cycle, what areas of the country it lives in, and type of damage it causes.
   - What type of preservation technique would be used to eliminate the problem and why?

Background Information

There are three general approaches to preventing wood decay. The first, and the simplest, is to keep the wood product dry. This approach is the best and least expensive way to preserve wood. In wood buildings that are located in temperate regions, the equilibrium moisture content is never high enough to maintain wood at 20% moisture content unless water condensation or leaks are present. The second approach is to treat wood with chemicals that are toxic to fungi. The final approach is to use naturally decay-resistant species of wood. However, only the heartwood of these species can be used and there is a limited supply of these species. This approach can also be very costly and therefore it is used when both durability and appearance are a priority.

Today, there are two types of wood preservatives for commercial use: oil-soluble chemicals and waterborne salts. The fundamental difference between these two chemicals is the type of liquid used to carry the toxic chemicals into the wood structure. The advantage of using oil preservatives is that it can be used in wet-use situations because the oil retards water movement. However, these chemicals cause the wood surface to become oily and therefore it is difficult or, often times, impossible to paint or finish. If waterborne salts are used, it may be necessary to re-dry the wood to maintain structural properties. Waterborne salts are commonly used because the surface is not altered by the treatment, thereby allowing usage to be more practical and easier.

There are several environmental concerns about using preservatives. Since all preservatives have some degree of toxicity to living organisms, most are not available for public use. The Environmental Protection Agency monitors the use of preservatives to ensure the health and safety of industry personnel, the public, and the environment.

Reflect (~25 minutes)

Students will present their findings to the class in a brief presentation (~8 minutes)

Have the students answer the following questions after all groups have presented:

1. Was your hypothesis correct? If not, why do you think your original thinking was flawed? What previous knowledge did you use to formulate your hypothesis?
2. When would it be best to use an oil-soluble chemical for wood preservation?

Apply (~5 minutes)

Have the students discuss the following questions:

1. In the future if you suspect that your residence has termites, what are three pieces of evidence that you would need to collect/consider before determining the species of the termite causing the damage?
2. What are two reasons why the forest products and wood manufacturing industries need to preserve wood?
3. How does the usage of wood preservatives play a role in reaching a sustainable future for our forest resources?

Resources

Bowyer, J.L., R. Shmulsky and J.G. Haygreen. 2007. *Forest Products and Wood Science*, 5th edition. Iowa State University Press, Ames, Iowa

Visit the following websites, among others:

Professional Pest Control Products, *www.pestproducts.com/termites.htm*

Penn State Cooperative Extension, *www.ento.psu.edu/extension/factsheets/termite.htm*

Iowa State University, *www.ipm.iastate.edu/ipm/iiin/bpowderpo.html*

Lesson 12: Constructing Popsicle-Stick Bridges
Content Area: Wood Structure and Properties

Virginia Standards of Learning addressed:

PH.4A: The student will investigate and understand how applications of physics affect the world. Key concepts include:

- Examples from the real world

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Design and conduct scientific investigations.

Content Standard E: All students should develop:

- Abilities of technological design
- Understandings about science and technology

Content Skill

Students will be able to:

- Recognize common structural designs of bridges and recall the advantages and disadvantages of using each design when constructing a particular bridge.
- Understand the four forces that act on bridges' structural integrity.
- Work collaboratively with classmates to design and construct a popsicle-stick bridge to demonstrate their knowledge and understanding of wood structure and properties.

Life Skill

Thinking creatively

Success Indicator

Collaboratively working with classmates to design and construct a completed popsicle stick bridge.

Time Needed

Two hours

Lesson 12: Constructing Popsicle-Stick Bridges
Content Area: Wood Structure and Properties

Activity Summary

Students will collaboratively work with one another to creatively design and construct a popsicle stick bridge using the knowledge they have gained from Lessons 1 through 9.

Introduction Activity Materials

Bridge structure information paragraphs (text boxes in the following pages)

Procedures

Do (~10 minutes)

Students will be divided into five groups to learn about a certain type of bridge structure (beam, arch, truss, suspension, and cablestay.) In each group, students will read and discuss their bridge structure information paragraphs.

Reflect (~15 minutes)

Each group will be responsible for explaining their designated bridge structure to the class. After all groups have presented, the class will work together to list the advantages and disadvantages of each structure. Then the class will vote on what type of bridge they want to try to build.

Apply (~5 minutes)

Ask and discuss the following questions:

1. Using the structure that the class has chosen to build, can you think of any bridges locally, nationally, or globally that were built using this structural design?
2. What do you think engineers base their decision on when choosing the design of a particular bridge?

Group 1 Bridge Structure Information Handout

Beam Structure

A beam bridge is the simplest and most inexpensive bridge to build. It is very strong over short distances. Its structure consists of a horizontal beam that is supported by piers that are located at each end of the bridge. The weight of the beams pushes straight down on the piers. Therefore, piers that are farther apart cause the beams to weaken. Due to this problem, beam bridges are rarely longer than 250 feet. However, beam bridges can be chained together to create a structure that spans great distances. In fact, the world's longest bridge (Lake Ponchartrain Causeway, 24 miles) is several beam bridges that have been connected together!

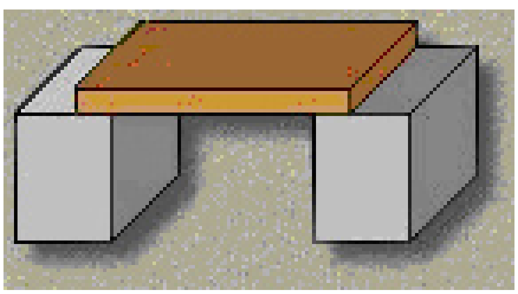


Figure 56. Beam bridge

Group 2 Bridge Structure Information Handout

Arch Bridge

Arch bridges were designed by the Ancient Romans and were originally made from stone. Today, they are generally made from steel or concrete. Many of the Roman bridges were made without mortar and some still stand today! Arch bridges usually span up to 800 feet. They are very difficult to build because they are completely unstable until the two ends of the bridge are locked together in the middle of the bridge. This is very dangerous for construction workers and engineers have created an easier way for these bridges to be constructed. In earlier years, engineers used a technique called centering. This technique uses a wooden support to help stabilize the bridge while it was being built. Now a newer method exists where cables are anchored to the ground on either side of the bridge to add additional support to the unfinished bridge.

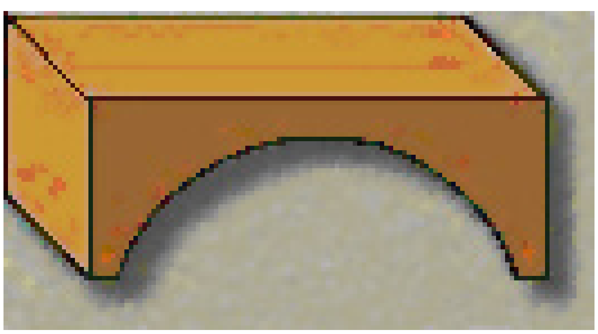


Figure 57. Arch bridge

Group 3 Bridge Structure Information Handout

Truss Bridge

The truss bridge is a series of triangles; triangles have the most stable structure because their shape cannot be distorted. Truss bridges can support very heavy loads compared to their own weight. They are usually constructed from a series of straight, steel bars. They are sturdy and have aesthetic value. There are several types of truss bridges; this picture represents the Warren truss bridge design.

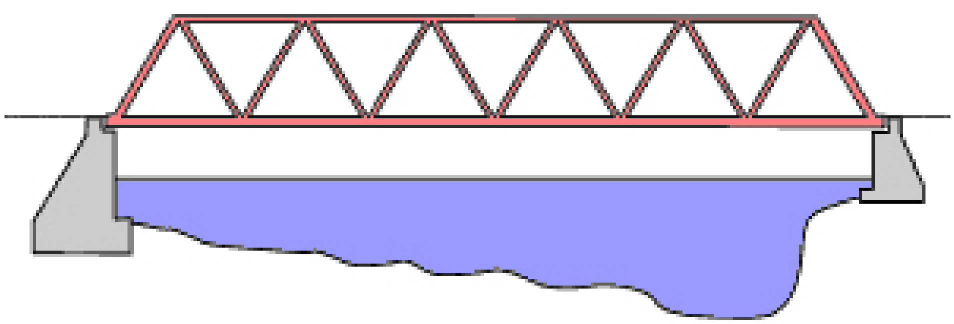


Figure 58. Truss bridge

Group 4 Bridge Structure Information Handout

Suspension Bridge

Suspension bridges are the longest bridges that can be constructed and, therefore, they are generally the most expensive type of bridge. They can span from 2,000 feet to 7,000 feet! These types of bridges hang from cables that are anchored at each end of the bridge. There are evenly spaced towers that span across the bridge to provide extra support. Most suspension bridges have a truss system beneath the roadway that helps stabilize the structure.

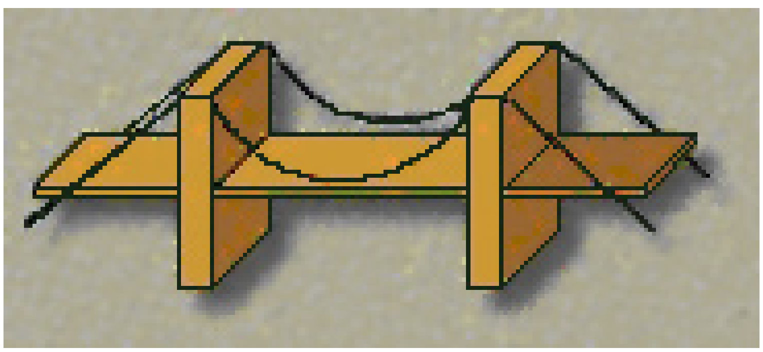


Figure 59. Suspension bridge

Group 5 Bridge Structure Information Handout

Cablestay Bridge

The bottom of a cablestay bridge is supported by cables that are attached to a central tower. These bridges can be very long and the roadway is constructed on both sides of the tower. This placement of the roadway evenly applies the stress caused from the weight of the cars traveling along the bridge.

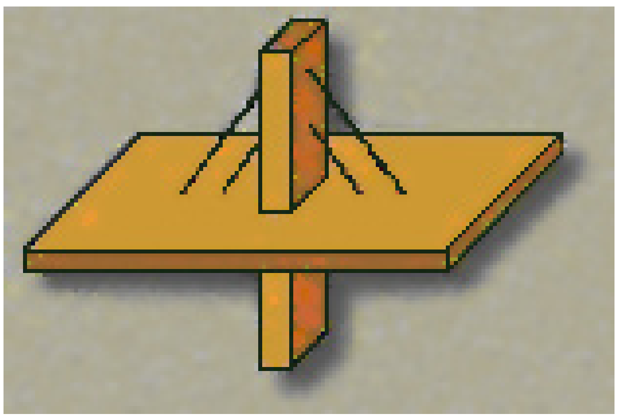


Figure 60. Cablestay bridge

Lesson 12: Constructing Popsicle-Stick Bridges
Content Area: Wood Structure and Properties

Activity Materials

- Lots of popsicle sticks! (each bridge may take 100 or more)
- Elmer's white glue
- Set of weights (in grams)
- 5 pieces of plywood (~ 3 feet long each)
- String

Procedures

Do

1. Students will stay in their assigned groups from the introduction activity to build their bridges.
2. First, students should create a team (company) name and choose a name for their bridge.
3. Students should read and discuss the background information before designing their bridge.
4. Using graph paper, students should collaboratively design their bridge based on the class's chosen bridge structure and draw a rough sketch of their bridge.
5. Students should weigh their piece of plywood before constructing their bridge. Record the weight on the rough sketch of the bridge.
6. Then, using only popsicle sticks and glue, students will construct their bridge. The final structure must be free-standing, be at least 2 feet long, and be sitting on a piece of plywood that has a hole in the center large enough so the weights can be applied after completion of the bridge. (Hint: Examine each popsicle stick! Do not use sticks that have knots or ones that do not have grain structure that is parallel to the stick. Knots and perpendicular grain structure will weaken your bridge!)
7. After all groups have completed their bridges, the teacher should evaluate each bridge's structural integrity using the following efficiency rating:

$$\text{Efficiency} = \frac{\text{mass supported (in grams)}}{\text{weight of bridge (in grams)}}$$

Lesson 12: Constructing Popsicle-Stick Bridges
Content Area: Wood Structure and Properties

Background Information
There are four main forces that act on bridges: compression, tension, torsion, and shear. Compression is a pushing force that squeezes material together. In general, compression causes a material to become shorter. Wood that is shorter can withstand more compression than a long piece of wood can. Compression can be seen in everyday life by looking at the lower columns of a skyscraper that is being built. These columns are squeezed together due to the weight above them. Tension is the opposite of compression; it is a force that stretches material. Wood is very strong in tension when it is parallel to the grain, but extremely weak when tension is applied perpendicular to the grain. The cables of suspension bridges are always in tension from the weight of the cars traveling along the bridge. Torsion is simply twisting of material. For example, when you wring out a cloth, you are applying torsion to the cloth. Torsion can be very catastrophic to bridges. Many natural occurrences such as storms, tornados, and hurricanes have produced enough torsion to rip bridges in half! Shear is known as a sliding force that causes parts of a material to slide past one another in the opposite direction. It usually occurs horizontally. Earthquakes can cause shear to occur on bridges.

Reflect (~5 minutes)
Consider your experiences in this exercise and answer the questions on the Lesson 12 Work Sheet.

Apply (~5 minutes)
Answer the questions on the Lesson 12 Work Sheet.

Resources
Visit the following websites for more information about bridge structure and design.

Public Broadcasting System, Building Big Bridges, *www.pbs.org/wgbh/buildingbig/bridge/*

Public Broadcasting System, Nova, *www.pbs.org/wgbh/nova/*

Lesson 12 Work Sheet
Constructing Popsicle-Stick Bridges

Name ______________________________

Group's Efficiency Rating ______________________________

1. What was the most difficult part in designing/constructing your bridge?

____
____
____

2. How did your group's efficiency rating compare to the rest of the groups' ratings? What do you think your group did differently that helped and/or harmed your group's progress and success?

____
____
____

3. After the testing of your bridge's structural integrity, would you have done anything differently when designing/constructing your bridge?

____
____
____

Answer the following questions:

1. What are the advantages and disadvantages to using wood to build bridges instead of other raw materials?

____
____
____

2. Why is it important for architects and engineers to understand the properties and structure of wood?

____
____
____

Virginia Standards of Learning addressed:

BIO.4A and **4B:** The student will investigate and understand relationships between cell structure and function. Key concepts include:

- Characteristics of eukaryotic cells
- Exploring the diversity and variation of eukaryotes

BIO.5A: The student will investigate and understand life functions of plants. Key concepts include:

- How their structures and functions vary between and within the kingdoms

PH.4A: The student will investigate and understand how applications of physics affect the world. Key concepts include:

- Examples from the real world

National Science Education Standards addressed:

Content Standard A: Abilities necessary to do scientific inquiry:

- Design and conduct scientific investigations
- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence

Content Standard C: All students should develop understanding of the cell:

- Cells have particular structures that underlie their functions

Content Standard E: Abilities of technological design

Content Standard F: All students should develop understanding of natural resources:

- Human populations use resources in the environment in order to maintain and improve their existence

Content Skills

Students will be able to:

- Design and construct a room in a model house using their prior knowledge of wood structure and properties gained during Lessons 1 through 10.
- Demonstrate the knowledge and understanding they have gained from the Wood Magic curriculum guide.
- Collaboratively work with their classmates to complete a long-term project.

Lesson 13: Knock on Wood – House Design Project
Content Area: Wood Structure and Properties

Life Skill

Performing as a team member

Success Indicator

Designing and constructing a room in a model house by identifying the proper wood materials and products that would be needed to build the room in a real-world context.

Time Needed

Long-term project (time will vary depending on class size and construction option chosen.)

Activity Summary

Students will collaboratively work as a class to design and construct a model house using the knowledge they have gained through the completion of Lessons 1 through 10.

Procedures

Do (~10 minutes)

Divide the class into five groups and assign each group one of the following rooms of a house:

Kitchen

Bathroom

Living room

Bedroom #1 (adult)

Bedroom #2 (infant)

Each group will then need to brainstorm a list of products that are made from wood and wood by-products that would be needed to build and decorate their designated room.

Reflect (~ minutes)

Each group will then present their list of materials to the class. Other class members will help the presenting group identify any missing materials that the room would need.

Lesson 13: Knock on Wood – House Design Project
Content Area: Wood Structure and Properties

Apply (~10 minutes)

Once each group has a completed list of possible wood materials/products, they will need to discuss within their group the reasons why each material/product is used in this particular type of room and why the material/product's structure and properties allow it to be used for this specific function/purpose.

Activity Materials

**Note to teachers: There are several ways students can complete this project. They can draw plans of their house by hand, use software to draw the plans of the house, or construct a scale-model house. Therefore, materials will vary depending on which option you choose.

Procedures

Do (Time will vary depending on construction option that is chosen.)

1. Students will need to draw a rough sketch of their room using graph paper. All wood materials/products should be clearly and neatly labeled.
2. The rough sketch should be checked and approved by the teacher before students move on with the project.
3. Once all groups have completed their designs, they should combine their rooms and begin constructing a class model house using one of the construction options discussed in the Activity Materials section above.
4. Each group will be responsible for writing a research paper that discusses each of the materials/products used in building and decorating of their room. The discussion should include a detailed explanation of how the material/product's structure relates to its function, a rough estimate of how much of the material/product would be needed to complete the room, and a concise description of how the material/product is made and manufactured. The reports should be approximately three to five typed, double-spaced pages. A complete list of at least five references must be included in the report. Reputable Internet sites, books, magazine and newspaper articles, journals, and one interview with a professional in the field of forest products or wood science may be used.

Reflect (~60 minutes)

Each group will make a 10 minute presentation on their completed room and research paper. Teachers should create a presentation rubric that is designed to fit the needs of their class. After all groups have presented, the class should discuss their observations about similarities and differences found among the five rooms.

Apply (~10 minutes)

Ask and discuss the following questions:

1. How could the knowledge you have gained from Wood Magic be applied to your life now and in the future?
2. Make a list of all the individuals (professional and nonprofessional) you can think of who use wood and wood by-products in some way that would need to know the structure and properties of wood.
3. Now that you are aware of all the wood products and by-products that are found in a typical house, do you feel that the general public could benefit from being introduced to such information? Why or why not?

DID YOU KNOW?

- Over 90% of all homes in the U.S. are built with wood-frame walls and roofs.
- Home building, remodeling, and home improvement projects are collectively the largest use of wood products.
- Advances in technology allow the forest products industry to use nearly 100% of a tree!

Lesson 13: Knock on Wood – House Design Project
Content Area: Wood Structure and Properties

Virginia Standards of Learning addressed:

ES.2A, 2B, and **2D**: The student will demonstrate scientific reasoning and logic by:

- Analyzing how science explains and predicts the interactions and dynamics of complex Earth systems
- Recognizing that evidence is required to evaluate hypotheses and explanations
- Explaining that observation and logic are essential for reaching a conclusion

ES.7D and **7E:** The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include:

- Making informed judgments related to resource use and its effects on Earth systems
- Environmental costs and benefits

BIO.1B and **1M:** The student will plan and conduct investigations in which:

- Hypotheses are formulated based on direct observations and information from scientific literature
- A scientific viewpoint is constructed and defended (the nature of science)

BIO.9D: The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include:

- The effects of natural events and human activities on ecosystems

National Science Education Standards addressed:

Content Standard A: Abilities to do scientific inquiry:

- Recognize and analyze alternative explanations and models
- Communicate and defend a scientific argument

Content Standard F: All students should develop an understanding of:

- Natural resources

Content Skills

Students will be able to:

- Identify the costs and benefits of using wood and its by-products
- Explain their personal beliefs about the forest products industry and its practices
- Defend a position dealing with a controversial topic using scientific literature to support their reasoning
- Strengthen their research skills and continue analyzing scientific literature

Lesson 14: Ethical Choices Forum
Content Area: Environmental Science

Life Skills
Communicating with others – speaking

Success Indicator
Actively participating in a classroom debate using logic and reasoning based on scientific information/literature.

Time Needed
Two 60-minute sessions or 120 minutes

Activity Summary
After researching an assigned position on the issue of the practices of the forest products industry, students will conduct a classroom debate where they will be required to defend their position using the evidence and opinions found during their research process.

Procedures
Do (~50 minutes)
1. Divide the class into two groups and assign each group one of the following positions:
   - The practices of the forest products industry are ethical and should continue.
   - The practices of the forest products industry are not ethical and changes need to be made to the industry.

**Note: Many students will be placed in a group that does not convey their own personal beliefs. Teachers should explain to students that it is important to listen and be able to understand other viewpoints and that debating a topic that does not necessarily mesh with their own views allows them to gain more knowledge about the topic while also strengthening their critical thinking and communication skills. It is crucial to understand both viewpoints to fully comprehend the topic.

2. Next, students should research their assigned debate position to acquire information that will help defend their argument. Each student will be required to find two references (one Internet site and one scientific journal) that have not been found by their other group members. Students in the “not ethical” group may find that they have to rely more on scientific journals written in the past to find their arguments. The groups will need to discuss their findings and prepare for the debate.

Reflect (~5 minutes)

After the debate, the students should complete the Lesson 14 Work Sheet A.

Apply (~5 minutes)

Answer the questions on the Lesson 14 Work Sheet A.

Activity Materials

Research found by students in the introduction activity.

Procedures

Do (~50 minutes)

1. The teacher will be responsible for facilitating a traditional debate between the two groups assigned during the introduction activity.
2. Students must actively participate in the debate and their arguments should be based from the evidence provided in their resources found during the introduction activity. All students should be required to speak at least once during the debate.

Reflect (~5 minutes)

After the debate, ask and discuss with the students the following questions:

1. Overall, which group do you feel defended its position better after the completion of the debate? Do you feel that group had any advantages?
2. Was there any information shared during the debate that surprised you? If so, why were you surprised by the information?
3. Do you believe the information shared during the debate is common knowledge to the general public? If not, what steps do you think need to be taken to make this information more easily accessible to the public?

Apply (~5 minutes)

After the debate, ask and discuss with the students the to complete the Lesson 14 Work Sheet B.

Lesson 14: Ethical Choices Forum
Content Area: Environmental Science

Name ____

Answer the following questions:

1. Were you placed in a group that does not convey your own personal beliefs about the forest products industry and its practices? If so, how did you or will you overcome this obstacle?

____

____

____

____

2. Did you have any difficulty finding your two resources? If so, please explain your problem(s) and why you feel they occurred.

____

____

____

____

3. What was your opinion about the forest products industry and its practices BEFORE participating in Wood Magic? How and why do you think you developed this viewpoint?

____

____

____

____

4. What has been your opinion about the forest products industry and its practices DURING your participation in Wood Magic? If your viewpoint has changed from your answer in question 3, explain when and why your viewpoint changed.

____

____

____

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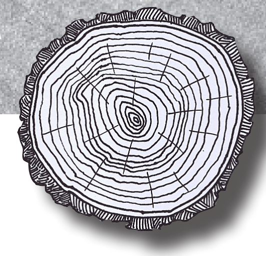

Name ____

Answer the following questions:

1. What is your opinion about the forest products industry and its practices **AFTER** your participation in the Wood Magic program? If your opinion has changed, what aspects of this curriculum guide caused your viewpoint to change? If your opinion has not changed, what aspects of this curriculum guide caused you to maintain your initial viewpoint?

____

____

____

____

2. Explain three pieces of information, concepts, and/or beliefs that you have gained from your participation in Wood Magic. How do you think this knowledge will/can be applied to your daily lives in the future?

____

____

____

____

3. Although the forest products industry is working diligently to create a sustainable future for our forests, it is crucial for the public to help them with this goal. List several ways in which you can help create a sustainable future for our forests.

____

____

____

____

Virginia Standards of Learning addressed:

- No SOLs specifically addressed

National Science Education Standards addressed:

Content Standard G: All students should develop understanding of science as a human endeavor.

- Pursuing science as a career

Content Skill

Students will be able to:

- Identify several careers in wood science
- Class regarding a specific career in wood science and technology.

Life Skill

Communicating with others – speaking

Success Indicator

Researching a career in wood science and technology and creatively presenting the information to the class.

Time Needed

Two hours or 120 minutes (can easily be divided)

Activity Summary

Students will work in cooperative learning groups to research a career in wood science and technology and then they will give a creative presentation to the class about their findings.

Procedures 1

Do (~ 5 minutes)

Answer the following question:

1. Brainstorm a list of careers in wood science and technology.

____

____

____

____

Reflect (~10 minutes)

Have students share their list with the class. Allow students to predict how much education/training each career requires.

Apply (~5 minutes)

Answer the following question:

1. Do you think a career in wood science and technology would be interesting? Do you plan to pursue a career in this field of study?

Procedures 2

Do (~40 minutes)

1. Allow students to choose a career in wood science and technology that they would like to research. Students may work individually, in pairs, or in groups. Below is a short list of example careers in wood science and technology that students could choose from:
   - Wood Products Specialist
   - Truss Designer
   - Chemist
   - Environmental Engineer
   - Mill Supervisor
   - Process Technician
   - Researcher

2. Allow students to research their careers using a variety of resources such as the internet, newspapers, journals, primary interviews, etc. They should make sure to include the following information:
   - Required education/training
   - Yearly salary
   - Job responsibilities/duties/daily activities
   - Colleges that offer programs for the career (if applicable)

3. Students should design a creative presentation to give to the class. Options could include putting on a skit to demonstrate the daily life of a person who has that particular career, they could interview someone that has that particular job title, etc. The presentation should be 5 to 10 minutes.

Reflect (~55 min. but will vary depending on number of groups)

Students will give their presentations to the class. If time permits, teachers should discuss some other careers that were not discussed by the students.

Apply (~5 minutes)

After the presentations and discussion, have the students complete the Lesson 15 Work Sheet.

Lesson 15: Looking Toward Your Future
Content Area: Careers in Wood Science and Technology

Name ________________________________

Answer the following questions:

1. After hearing your classmates present many different careers in wood science and technology, would you consider pursuing one of these careers, and if so, which one?

2. Were the class predictions about the needed education/training for jobs in wood science and technology correct? Why do you think these jobs require so much education/training?

3. How do you think careers in wood science and technology benefit society? What contributions has this type of knowledge and technology made to society?

**Note: Pamphlets discussing careers in wood science and technology can be obtained from the Department of Wood Sciences and Forest Products at Virginia Tech and from the Society of Wood Science and Technology at the following addresses.

1. Department of Wood Science and Forest Products
   Virginia Tech 230 Cheatham Hall
   Blacksburg, VA 24061
   www.woodscience.vt.edu

2. Society of Wood Science and Technology
   One Gifford Pinchot Drive
   Madison, WI 53726-2398
   www.swst.org