Wood, Cork, Fibers & Humans

Beyond food, your life is built upon the woody, corky, and fibrous parts of plants which provide us with the construction materials for shelters, the cordage for ropes and twine, the fibers for paper and textiles, and the cork for construction materials, baseballs, and wine bottling. In this lab we will make a study of these materials, from their anatomy and natural occurrence in plants, to the various ways in which they are used.

A. Wood

Our understanding of the strengths and limitations of wood as a natural product requires a basic understanding of the anatomy and development of wood. The following exercises will accomplish this task and ask you to apply your new-found knowledge.

1. Anatomy of 1-yr and 3-yr old woody stems (with compound light microscope).

a. Prepared slide: *Tilia* 1-yr old stem x-section. This basswood (*Tilia*) stem was 1 year old when cut. Examine it for the following tissues in this sequence from the center to periphery:

Pith – the center of the stem retains the original pith of the primary stem.

1) What type of tissue is present here (parenchyma, collenchyma, or sclerenchyma)?

Xylem – there is one ring of secondary xylem (wood) that has formed here. Note the large-diameter cells lacking cytoplasm and nuclei (vessel elements, assembled into vessels), the narrower cells without cytoplasm or nuclei (which are either tracheids or fibers), and the thin-walled cells with cytoplasm and nuclei (these are parenchyma cells). All mature vessel elements, tracheids, and fibers will have relatively thick walls because of secondary thickening and will typically stain red at maturity b/c of lignin deposition. Only the parenchyma cells will not stain very red b/c they are not lignified.

2) *Name two primary functions of secondary xylem.*

Vascular cambium – locate the position of the vascular cambium between the secondary xylem and secondary phloem. Look for a zone ca. 1-4 cell layers wide of small diameter, undifferentiated cells.

3) *How can you tell visually that this cambium is meristematic? Answer: the cambial cells are smaller than surrounding cells and have thin cell walls b/c they had recently divided or were in the process of dividing when the tissue was sectioned. Moreover, the cambial cells (initials) give rise to radial files of cells.*

Phloem – There is one ring of secondary phloem which has formed here. In this species you'll find sieve tube members (large diameter cells) with their companion cells (smaller diameter, nucleate), fibers (thick-walled, narrow-lumened cells) and parenchyma. The cell walls of sieve tube members, companion cells, and parenchyma should be thin because they are not secondarily thickened and their walls should be blue-staining b/c they lack lignin. The walls of fibers should be very thick and stain red at maturity due to lignification.

4) Name the primary function of secondary phloem?

5) *Do you think that the phloem fibers aid the xylem in mechanical support of the stem?*

Rays – Note the radially oriented series of nucleated parenchyma cells extending through the secondary xylem and into the phloem.

*6) What is the function of rays: **a.** radial transport **b.** axial transport?*
Transport of what?

Cortex – The parenchyma ground tissue between the phloem and epidermis.

Epidermis – The epidermis is surely still intact in a stem still in the very early stages of secondary growth.

b. Prepared *Tilia* 3-yr old stem x-section slides. Compare this 3-yr old stem to the 1-yr old stem.

1) Can you see the 3 annual rings (i.e., the 3 rings of secondary xylem)?

2) Can you also see three rings of secondary phloem too? Why or why not?

3) Although you may see a few years of phloem accumulation, why are you not likely to see many (e.g., 100) years of phloem accumulation in an old tree?

4) Note how the rays in the xylem are narrow, whereas they are dialated (expanded) in the older (outer) layers of phloem. Indeed, the parenchyma of the phloem rays divide anticlinally as the secondary xylem and vascular cambium grow outward, resulting in the widening of the phloem-portion of the rays as they age. *Do you think that the ability of the phloem rays to expand extends the functional life of secondary phloem?* Explain. (Hint: what would happen to the phloem and phloem ray tissue if they could not produce new cells laterally?)

5) Are vessel elements and tracheids from the spring (early) wood larger or smaller than such cells from the summer (late) wood?

Answer this right and you'll now be able to explain why we can discern annual rings in wood.

2. Development of the vascular cambium.

Within the first year of a stem's life, the residual undifferentiated procambium between the xylem and phloem of each vascular bundle (yellow line bisecting each bundle, below left) again becomes meristematic. This meristematic activity then spreads to the parenchyma between the bundles to complete the formation of the vascular cambium (yellow ring, below right). Subsequent action of the vascular cambium results in concentric rings of secondary xylem to the inside and secondary phloem to the outside.

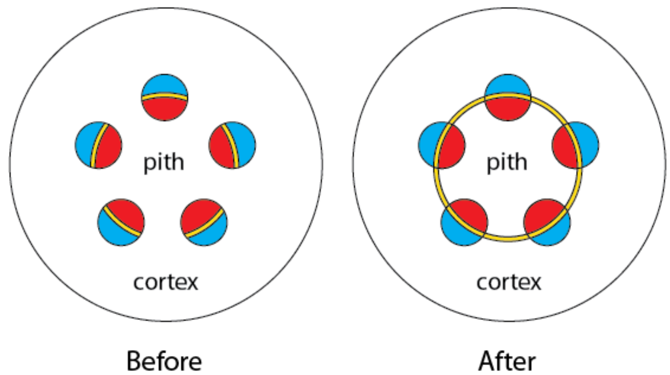


Figure above: Stem x-sections before and after the formation of the vascular cambium.

a. <u>Prepared *Medicago* 3 stem stages slide</u>. Examine this slide which has stem x-sections of three different ages. Alternatively, a *Medicago* slide depicting only two stages may be available. Determine which section represents the youngest and which the oldest. Often, the youngest is the smallest but size is not always a reliable indicator: the degree to which the vascular cambium is formed is the best indicator of age.

Draw the youngest, middle-aged, and oldest stem.

1) Can you find evidence of the first periclinal divisions in the parenchyma between the bundles? What does this evidence look like? **Note:** It is primarily <u>periclinal</u> cell division (cell division along a plane parallel to surface of the plant) of cambial cells that add girth to the plant. In order for the expanding cambium to keep up with the increasing girth of the stem, occasional <u>anticlinal</u> cell division adds cells to the circumference of the cambium.

2) In which section have the bundles been united by the vascular cambium?

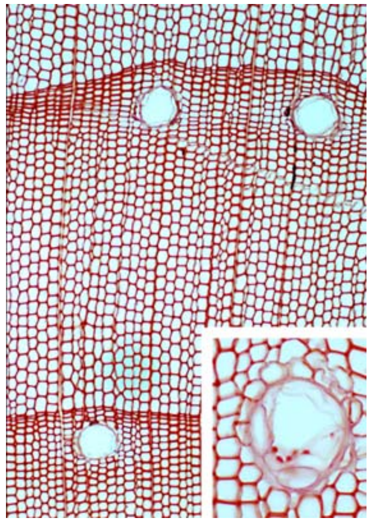
3) What will happen to the phloem and the xylem halves of the primary vascular bundles as secondary growth continues? a. they will stay together b. the phloem half will be pushed out and away from the xylem half.

3. Hardwoods vs. Softwoods.

Folks in the flooring and timber industries frequently refer to hardwoods and softwoods. Today the distinction between hardwoods and softwoods is a taxonomic one: hardwoods are from angiosperms (particularly woody dicots since monocots and herbaceous dicots do not form wood) and softwoods are from gymnosperms (particularly conifers). Although softwoods tend to lie towards the bottom of the hardness scale and hardwoods towards the top, this is not always the case (Appendix 1) and so use of the prefixes "hard" and "soft" is misleading. For example, wood from the South American balsa tree (an angiosperm) is softer than most gymnosperm woods yet balsa is technically a "hardwood" b/c it is an angiosperm.

Obtain the **Prepared Slide of** a typical softwood, ***Pinus strobus*** **(white pine)**, that has transverse, radial, and tangential sections on it.

> Examine only the transverse section (see figure below) and find the axially oriented <u>tracheids</u> and the radially oriented <u>ray parenchyma</u>. Also note the occurrence of larger "holes" which are the <u>resin canals</u>. As viewed in transverse section, the resin canal is actually a lacuna (hole or intercellular space) surrounded by parenchyma cells which manufacture and secrete the aromatic resin into the canals.



The transverse section (= x-section) is the one that looks like this.

Now obtain a **Prepared Slide** of a typical hardwood, ***Quercus*** **(oak)**, that has the 3 types of section on it. Look at the transverse section and compare it to that of pine. Recall that pine wood had 1) tracheids, 2) ray parenchyma, and 3) resin canals. Draw a portion of a growth ring, large enough to easily diagram and label the following: vessel element, tracheid, fiber, and ray parenchyma. In addition to the added complexity of angiosperm wood, note the absence of resin canals.

a) Does the oak appear more or less dense than the pine (a higher density would result from a higher cell wall-to-lumen ratio in the wood)?

b) Density is the single most important predictor of hardness in wood. Thus, do you think that the oak is harder or softer than the pine?

c) How would you rank the fiber abundance in oak: rare or abundant? Do you think that fibers would contribute to the widely recognized hardness of oak wood?

4. Gross Morphology of Tree Trunks.

Inspect the various trunk cuts in the room and identify the extent and location of the 1) pith, 2) heartwood, 3) sapwood, 4) vascular cambium, 5) inner bark (secondary phloem) and 6) outerbark (periderm or periderms plus any included old phloem; this is mostly cork, however). Use the definitions below to help.

a. Heartwood vs. Sapwood. Heartwood is the older, innermost portion of a plant's wood. It has accumulated gums, resins, oils, and tannins (generally plant metabolic waste) over the years which 1) clogs the conducting cells, preventing them from conducting, 2) often discolors the heartwood, and 3) may even make the heartwood aromatic. Sapwood is the outermost portion of the wood that is still involved in water conduction; often lighter than heartwood in color.

b. Spring (Early) Wood vs. Summer (Late) Wood. Springwood is the first-formed wood of an annual ring (i.e., of a growing season). Cell diameters are larger here and wood here is therefore less dense, softer and more "porous". Summerwood is the latter-formed wood in an annual ring; consists of smaller-diameter cells and is therefore denser than springwood. The alternation of spring and summer woods in a woody stem is responsible for the annual rings seen in x-section.

c. Bark. "Bark" is an old but still technical term for everything to the outside of the vascular cambium, including the phloem; it is what is typically stripped off of a woody plant rather easily. Some botanists distinguish between <u>outer bark</u> (from the cork cambium out - consisting mostly of cork) and <u>inner bark</u> (consisting of secondary phloem and any other remnant tissue between the vascular cambium and the cork cambium).

5. Interpreting Grain Patterns in Lumber.

Lumber for boards in construction is not cut randomly, but in an orderly manner with maximizing the number the useable "board feet" per tree. The way in which each board is sawed determines its strength and appearance (the "grain" of the wood) in particular orientations.

Lumber is never cut <u>transversely</u> from trees because of two reasons: 1) the lumber would break easily and 2) it would be difficult to get long boards from all but the oldest, largest trees (think about it). Sawing a tree <u>longitudinally</u> into boards is typically done one of two ways: <u>plane-sawing</u> and <u>quarter-sawing</u> (as explained below). After reading the description of plane- and quarter sawing techniques below, visit the wood boards and blocks in the room and use their grain patterns to accurately reconstruct their pre-cut orientation in the tree trunk (identifying the direction of the center and outside of the stem) and, if they are boards rather than blocks, whether or not they were plane-sawed or quarter-sawed.

Plane-sawed boards are from a trunk cut tangentially, leaving the end grain appearance of loops and growth "swirls" on the broad, flat surface. This is fastest and most common sawing process.

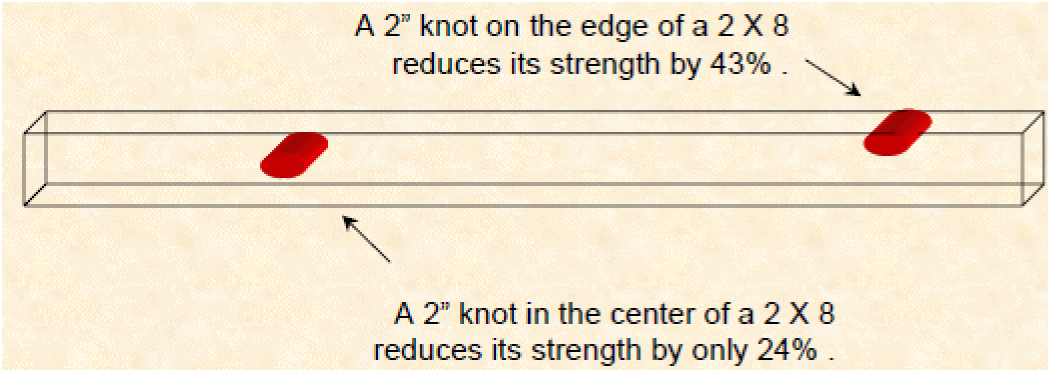
Plane-sawed Quarter-sawed

Quarter-sawed boards are from a trunk cut into quarters, then each quarter is rotated 90 degrees back and forth sawing off one board at a time. This process is more labor-intensive but results in stronger boards for use as beams (when load is applied to the narrow side); thus, such boards are generally more expensive than plane-sawn boards. On the broad, flat surface, the grain consists of long, parallel lines. The finest (strongest) quarter-sawed boards are those in which the annual rings are oriented between 80-90 degrees relative to the wide plane of the board.

6. You do not want knots in your lumber.

Knots are areas in your wood where there are abrupt, localized changes in the pattern of growth ring deposition (i.e., abrupt changes in the grain). Knots can compromise the mechanical strength substantially b/c the knot disturbs the direction and continuity of the grain, both of which are important for strength.

Examine the specimens of knots in the side of the room and tell me "What are knots, botanically speaking?" Hint: Knots are more abundant and are larger in trees grown in full sun than in forests.



Picture © Terry Brown

B. Bamboozled by Bamboo.

Is bamboo made of wood? If you said yes, you have been tricked by its impressive strength. In the tropics, the many species of bamboo compete with and even surpasses wood in importance as a construction material: it is remarkably strong and flexible for its weight. Yet despite its strength and apparent woodiness, bamboo is not wood and it is more closely related to lawn grass and corn than to oaks, for example.

1. Examine the large stems of bamboo in the room and answer the following:

    a) Is the stem completely hollow? Explain.

    b) What are the prominent rings around the stem? Hint: try to find a young shoot just beginning to grow upward – this has structures on it that make those rings you see on the older stem. If there are no young bamboo shoots in the room, go online and try to find pictures.

2. Examine a short specimen of bamboo stem under a dissecting microscope.

    a) A*side from the hollow pith, how is bamboo anatomy apparently different from the woody dicot and gymnosperm stem? Bamboo stem anatomy seems to consist of…*

    a. Growth rings of secondary xylem b. densely packed primary vascular bundles

3. We don't have any microscope slides of bamboo, but there is a plant of the closely related arborescent monocot, *Dracaena fragrans* (dracaena, dragon-tree) in the room. Examine this. Then, with compound microscope examine a x-section of its stem (prepared slide): although dracaena does not have a hollow pith like bamboo, the arrangement of vasculature and the lignified bundle sheath cells (~fibers) are very similar since dracaena is relatively closely related to bamboo and has had to adapt to its arboreal "woody" habit similarly.

    a) What does the anatomy of dracaena stems look like (circle all that apply)?

    a. Growth rings of secondary xylem and phloem b. closely spaced primary vascular bundles
    c. a clear vascular cambium is present

    b) If there are vascular bundles visible, how are they reinforced (what type of cells immediately surround them)?

    a. Parenchyma b. tracheids c. vessel elements d. lignified cells, probably fibers e. sieve tube members *c) What type of evidence indicates that these surrounding cells are lignified and have secondary walls?*

d) Do any cells further from the bundles, possibly in the cortex/ground tissue look to be reinforced with lignin?

4. As you know, bamboo stems are cylindrical and never get as wide as the trunks of conifers and oaks that boards and lumber come from, yet bamboo is now widely used in flooring and in the manufacture of cutting boards.

a) How can flooring and cutting boards made from bamboo be so broad and flat when the bamboo stems they come from are not? Examine samples of bamboo flooring and, if available, cutting boards in the room and learn how these are made.

b)How is a piece of bamboo flooring differently constructed than a piece of wood flooring (e.g., oak)?

5. *Is bamboo flooring softer or harder than white oak flooring (see Appendix 1)? Explain*. Whether softer or harder, calculate by how much bamboo is softer/harder than white oak. Show your work.

C. Cork.

Like wood, cork is a secondary plant tissue and produced by a lateral meristem. Cork, however, is produced by the cork cambium whereas wood is produced by the vascular cambium. How is cork produced and what biological purpose does it serve? What are its properties that make it so useful to humans? Through the following exercises, you will answer these questions.

1. Cork Cambium. The cork cambium produces most of its cells towards the outside and these mature as cork . Relatively minute amounts of cells are produced towards the inside and these mature as unspecialized parenchyma cells. At maturity, cork cells are dead and the walls are heavily suberized (impregnated with the waxy substance suberin), making the tissue elastic, water proof, and relatively gas proof. The cork cambium plus the tissues it produces are collectively referred to as periderm, which functionally replaces the epidermis as the latter is destroyed by secondary growth.

a) Why is the epidermis destroyed by secondary growth? Choose the more likely answer.

a. *It is torn and ruptured by the expansion of the secondary vascular tissues* b. *the epidermis is inferior to the periderm as a "dermal" tissue.*

b) **Prepared slide** of ***Pelargonium* (geranium) stem x-section.**

- *Notice the vascular cambium that is well formed.*
- *Look for newly formed cork cambium to the outside of the vascular cambium (as evidenced by a zone of many newly formed periclinal walls and radial files of small cells.*
- *Did the cork cambium form in the epidermal layer or in the cortex just beneath the epidermis?*

c) As secondary growth continues, old cork that was produced will be torn and sloughed off of the outer bark. Why is this?

d) Inspect the pieces of tree trunks and their outer bark in the room. Do you see evidence of this tearing & sloughing?

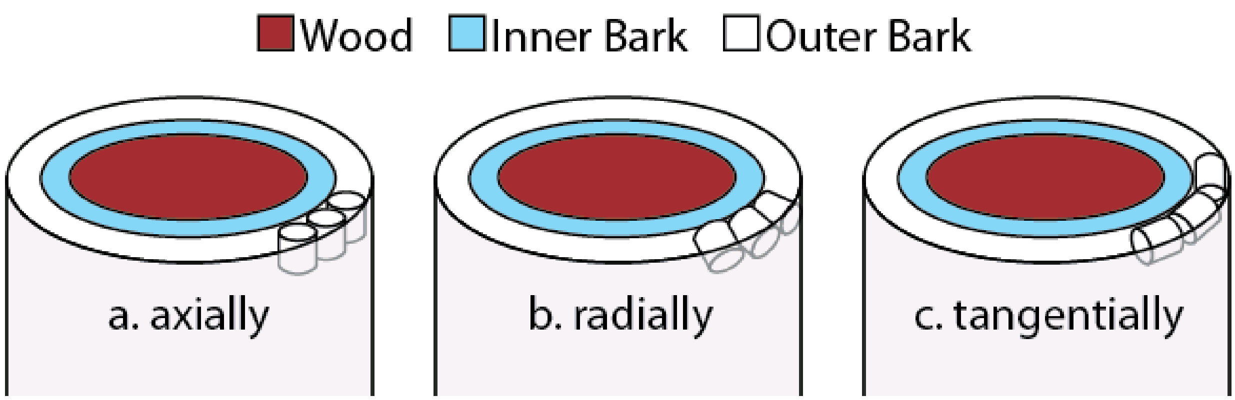
e) Parts of the cork cambium will be placed under tension and rupture, bringing the need to form new cork cambia beneath the older defunct one(s). Thus, multiple periderms form and this results in a complex appearance and layering to outer bark. Inspect cross sections of tree trunks in the room to find evidence of this. Identify the multiple periderms in these specimens.

2. The cork of commerce. While all trees and shrubs produce cork, only the cork oak (*Quercus suber*) of the Mediterranean is used for commerce.

a) Inspect the samples of wine bottle corks, cork flooring, cork stoppers, etc. for the properties of cork. Which samples are made from whole, intact pieces of cork and which are aggregates of many small pieces glued together?

b) Look for layering in a wine cork or cork stopper that conists of a single, intact piece of cork (similar to the layering seen in other barks due to multiple years of cork deposition and multiple periderm formation).

Was the cork bored from the outer bark a) axially, b) radially, or c) tangentially? (See below.) Use the layering visible in the cork as well as your sense of which bore direction would maximize the strength (think about the stress on the cork when you remove and reinsert corks into a bottle) as well as maximizing the number of long corks cut from a piece of Quercus suber outer bark.



c) Inspect pieces of tree trunks (with their corky outerbarks) from other species in the room (e.g., the corky bark of the hackberry, Celtis occidentalis, the Amur cork tree, Phellodendron, or of the winged euonymus, Euonymus alatus). Would these species be a good supply of cork in commerce? Why or why not?

3. Lenticels [DO AT END OF LAB, ONLY IF YOU'VE TIME]. Do you see the soft, raised bumps on a woody twig at your table? These are lenticels, which functionally replace stomata once the epidermis is destroyed and the periderm forms. Lenticels are patches of unsuberized tissue amongst the suberized cork and are conduits for gas exchange between the living cells beneath the cork and the atmosphere.

- *What metabolic process occurs in living, non-photosynthetic cells and what gas(s) must be exchanged?*

- *Why can't gas diffuse through the normal cork cells (that is, why are lenticels even necessary)?*

<u>Prepared slide</u> of a ***<u>Sambucus</u>*** **<u>(elderberry) lenticel</u>** x-section. Here a single lenticel has been sectioned (as in the figure below).

- As orientation, try to find vascular cambium, the outer bit of secondary xylem, the secondary phloem and, if possible, any remaining cortex and primary phloem bundle tissue.
- Next, find the young cork cambium and the lenticels which looks like a rupture in the cork.
- *How is gas exchange facilitated by the lenticels? (circle all that apply)*
  a. *suberin* *b. no suberin* *c. lenticel tissue is loose (w/ many intercellular spaces).*

<u>D. Commercial Fibers for Textiles, Cordage, and Paper</u>

Anatomically, botanists define fibers as cells with a long, tapering shape and an extremely thick, secondary wall that is typically lignified. The term "fiber" of commerce, however, does not refer to an individual fiber cell per se but to stringy, elongate masses of plant material that are actually collections of fiber cells or vascular bundles.

1. Paper "fibers." Most paper today is made from wood. In order to do this, the cells of the wood have to be separated from one another through grinding or chemical digestion to remove the middle lamella that holds the cells together. These cells are then suspended in water to make paper "pulp." We have already made paper pulp for you.

a. Working as a group of 4, follow the directions below to make paper.

- Slide a screen mounted to a frame into a bath of wood pulp and lift with a gentle motion to help drain and level the layer of paper "fibers."
- Let excess water drain back into bath without making a mess.
- Set screen with layer of pulp aside over paper towels and let dry overnight.

b. A beaker on your desk has pulp made by soaking office paper from the biology department in water over night (generally, hydrogen bonds hold paper "fibers" together and so water can easily break those bonds). Take a small pipette and add a drop of paper pulp to a clean, empty glass slide. Add to that a drop of toluidine blue and cover with a coverslip.

1) Look for xylem cells with your compound light microscope. Look for vessel elements, fibers, and/or tracheids. Draw the different cell types you see in your notebook.

2) Was this paper made from hardwoods or only softwoods? Hint: review the cell types found in hardwoods vs. softwoods.

2. Jute. Jute "fiber" is obtained from the stem fibers (aka <u>bast</u> fibers) of herbaceous, annual plants of various Asian species of the genus *Corchorus* of the mallow family, Malvaceae. Leading producers are India and Bangladesh and their jute is exported all over the world for making burlap, ropes/twine, carpet backing, upholstery lining, rugs and inexpensive clothing. The stems are harvested and fibers crude-extracted by <u>retting</u> (soaked in stagnant water to allow bacteria to digest away the non-fibrous materials).

Working in groups of 2 or 4,

a) Take a 10 cm length of jute twine and use your fingers and the palms of your hands to unwind the cords to release the fibers.
b) Measure ten fibers and determine the average length of the jute fibers in centimeters.
c) Examine individual fibers under the dissecting scope or, by making a wet mount, the compound scope. Draw a fiber and note whether or not they are smooth, rough, or having any surface features that might help them bind to one another to make rope.
d) Take your loose fibers and attempt to reconstruct the jute twine by rolling/twisting them together with your hands. Study an intact piece of the twine in order to see how it was done by the manufacturer.

3. Sisal. Sisal "fiber" is obtained from the leaf fibers (actually the fiber-sheathed leaf vascular bundles) of the leaves of perennial, monocotyledonous plants of Mexican species *Agave sisilana* of the agave family, Agavaceae. The fibers are most commonly employed in the manufacture of twine and rope.

Study a leaf of a related species of Agave (*Agave Americana*) that has been partially decorticated (the process whereby the leaf is gently beaten or rolled to separate the fibers from the surrounding soft tissues).

Then, working in groups of 2 or 4,

a) Take a 10 cm length of sisal twine or rope and use your fingers and the palms of your hands to unwind the cords to release the fibers.
b) Measure ten fibers and determine the average length of them in centimeters.
c) Examine individual fibers under the dissecting scope or, by making a wet mount, the compound scope, Draw a fiber and note whether or not they are smooth, rough, or having any surface features that might help them bind to one another to make rope.

   How are sisal fibers similar and different than jute fibers in texture and under the microscope?

d) Take your loose fibers and attempt to reconstruct the sisal twine or rope by rolling/twisting them together with your hands. Study an intact piece of the twine/rope in order to see how it was done by the manufacturer.

4. Pineapple "fiber." Pineapple or *Piña* fiber is obtained from the leaf fibers (actually the fiber-sheathed leaf vascular bundles) of the leaves of perennial, monocotyledonous plants of the pineapple, *Ananas comosus* of the bromeliad family, Bromeliaceae. The fibers are most commonly employed in the manufacture of fine cloth for ceremonial shirts and dress in the Philippines.

Working in group of 4, cut off a leaf of the pineapple plant in the room. Traditionally, the fibers are obtained through decortication: the leaves are scraped with knives to uncover the fibers (bundles). More scraping and beating cleans and separates the fibers.

a) Were you able to obtain any fibers?
b) What color are they? The ceremonial dress made from them are traditionally white. Thus, would these fibers need to be bleached before the shirts and dresses made from them are sold?
c) Examine individual fibers under the dissecting scope or, by making a wet mount, the compound scope. Draw a fiber and note whether or not they are smooth, rough, or having any surface features that might help them bind to one another in the weaving process.

   How are pineapple fibers similar and different than jute & sisal fibers in texture, color, and under the microscope?

d) *Take any loose fibers roll them together with your hands. Do they stick to one another easily? Could you make a twine or rope from them?*

5. Flax and Cotton "fibers." Flax fiber is obtained from the bast (stem) fibers of the Mediterranean-native flax plant, *Linum usitatissimum* of the flax family, Linaceae. The fibers are most commonly used to make thread which is then woven into linen fabric. Cotton fiber is obtained from the surface fibers of the seed of the American cotton plant, *Gossypium hirsutum* and related species. The fibers are most commonly used to make thread which is then woven into cotton fabric.

Working by yourself, isolate individual fibers from the linen cloth and raw cotton at your desk. Make a wet mount of both separately and compare them microscopically with the compound scope.

a) *How are they different in appearance?*

Working by yourself, obtain a prepared slide of the flax stem and find the stem fibers.

b) *Where are the fibers? In the pith, associated with the phloem of vascular bundles or in the cortex?*

6. Milkweed "fibers." Milkweed fiber is obtained from the surface fibers of the seed of various species of the milkweed genus, *Asclepias* in the milkweed family Asclepiadaceae. The fibers are not yet widely used but they are being investigated and breeding programs are underway to produce more productive varieties for the use of milkweed fibers as hypoallergenic fill for pillows, insulation, etc.

From the milkweed fruit in the room, grab a few seeds and take them back to your desk.

a) *Make sure the fibers at the top of the seed are spread out and toss a seed high into the air. What happens to the seed? Suggest an ecological role for these seed "fibers".*

b) *Rip a few seeds worth of fibers off. Study their texture with your fingers, attempt to twist them into a twine. Is it possible? Would these fibers be useful for making twine or rope?*

c) *Study their surface under the dissecting or compound microscope. Are there any surface features that might help them stick together in rope?*

d) *Use a bowl of water and test their water-proofness relative to jute, sisal, and cotton fibers. What happens to each of the fiber types when placed in water? Which of these fibers would be useful for stuffing life-vests, which would not?*

Appendix 1. Average Janka Hardness Rating* of various woods used for flooring, from highest to lowest and with hardwood/softwood classification indicated (bold are species commonly used for flooring in the United States of America).**

2350 - Brazilian Cherry	Hardwood
2345 - Mesquite	Hardwood
2200 - Santos Mahogany	Hardwood
1820 - Hickory	Hardwood
1820 - Pecan	Hardwood
1450 - Hard Maple	Hardwood
1410 - Natural bamboo (can approach 1700 in some products; varies substantially with manufacturer)	Not a wood
1360 - White Oak	Hardwood
1320 - Ash	Hardwood
1300 - American Beech	Hardwood
1290 - Red Oak(Northern)	Hardwood
1260 - Yellow Birch	Hardwood
1010 - Black Walnut	Hardwood
1000 - Teak	Hardwood
950 - Black Cherry	Hardwood
870 - Southern Yellow Pine (long leaf)	Softwood
690 - Southern Yellow Pine (short leaf)	Softwood
660 - Douglas Fir	Softwood
540 - Chestnut	Hardwood
420 - White Birch	Hardwood
410 - Basswood	Hardwood
380 - White Pine	Softwood

*The relative hardness of wood species is measured using the Janka Hardness test. This test measures the force needed to embed a steel ball (11.28 mm or 0.444 inch diameter) into wood to half the ball's diameter, with the rating measured in pounds of force per square inch in the United States. For example, it takes 1360 psi to do this in white oak, but only 380 psi in white pine; therefore, oak is harder than pine. Wood hardness is an important consideration in the flooring industry and other industries that use wood (baseball bats, axe handles, etc.). It is most commonly discussed in terms of flooring since there are so many woods to choose from here and the customer must weigh the appeal of a given wood's grain or color against his/her desire for hardness and therefore resistance to scratches and dents.

**References: www.ifloor.com and www.hardwoodinstaller.com, retrieved 25 Aug 2010.