Topic 09: **Secondary Plant Body: Wood, Periderm, and Bark**

(Photo Atlas Figures 9.35-9.55, 9.57-9.59)

A. Introduction

In many plants, development of the primary plant body and tissues is just the beginning. Easily the most dominating and recognizable type of plant is the tree. Trees are perennial plants that increase in girth as well as height. The increase in girth is due to the activity of two **LATERAL MERISTEMS** that are the source of all **SECONDARY TISSUES**. These lateral meristems include the **VASCULAR CAMBIUM** and the **CORK CAMBIUM (PHELLOGEN).** Through periclinal and anitclinal cell divisions, these lateral meristems give rise to a **RADIAL** pattern in the stem and root of the tree.

Some of the world's most interesting plants undergo this secondary growth. The oldest known species in the world is the Bristlecone Pine (*Pinus longaeva)* that exists in the White Mountains of California. Some of these trees have been documented to be over 4700 years old. One reason for their extensive life is the presence of a woody secondary body that over time becomes nonfunctional in the center but continues to serve as a storage site for resins, tars, gums, tannins and other secondary metabolic products inhibitory to pathogen invasion. Other woody species of interest include the tallest organisms on Earth, the Douglas fir (*Pseudotsuga menziesii*) at 329 ft, the coast redwood (*Sequoia sempervirens*) at 367 ft, and an eucalyptus from Australia (*Eucalyptus regnans*) at 326 ft but with historical evidence suggesting heights of 400-500 ft.

In today's lab, we will be investigating this often overlooked aspect of botany, the secondary plant body.

B. Woody Stem Morphology

C. Types of Wood Sections

D. Vascular Cambium

E. Anatomy of a Vascular Cell

F. Growth Rings

G. Rays & Ray Initials

H. Bark Formation: the Cork Cambium

I. Lenticels

J. Wood Morphology.

Figure 26-18
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Figure 1. A cork harvest.
From the cork-oak *Quercus suber*.

B. Woody Stem Morphology

1. Select a twig from those available on your bench. OBSERVE the twig and Identify all of the structures indicated in figure 2. Pay special attention to the position of the bud scale scars.

How many years of growth are visible on your twig?

Compare your twig to your neighbor's.

Can you tell them apart?

What structures might distinguish one woody stem from another?

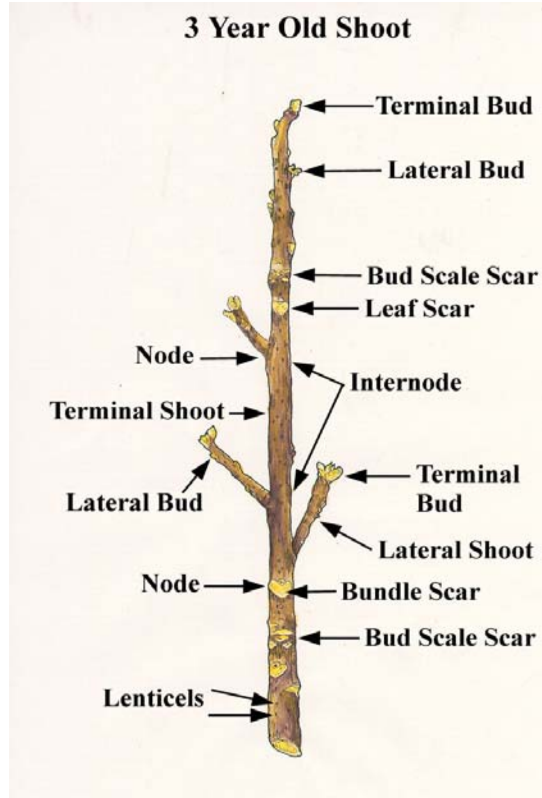


Figure 2. Illustration showing the morphology of a woody stem.

C. Types of Wood Sections

There are three basic types of wood section you need to be familiar with. Each type of section is distinguished by its orientation with the axis of the tree as well as by the structures visible.

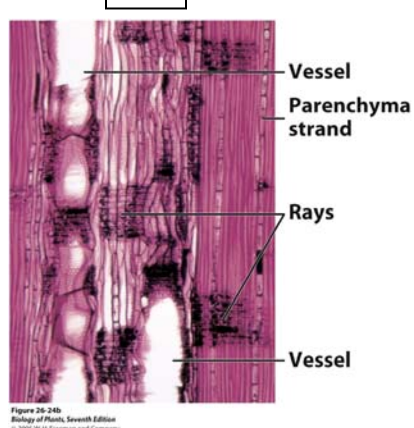
1. <u>cross</u> or "<u>transverse</u>" sections (cut perpendicular to length of stem)

2. <u>radial</u> (a long section cut along one radius of the stem)

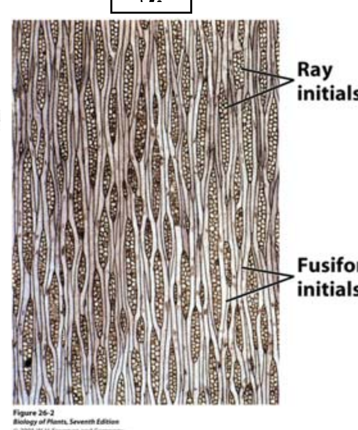
3. <u>tangential</u> (a longitudinal section cut at a tangent to the vascular cylinder, and usually through the vascular cambium itself, such that we can see the two types of initials that make up the cambium.

1.

2.



3.



1. Study the woody stem segment labeled as C1. This section contains the sections described above. Identify each section represented by your piece of woody stem. Keep the orientation in your mind when looking at the rest of the laboratory sections.

2. Observe one of the following prepared slides:

Celtis occidentalis

Abies grandis

Both slides contain all of three types of wood sections described above. In the space below, draw enough of each region in order to be able to distinguish it from the other regions. Focus on using major structural features from each. The rest of the lab will go into further detail regarding what these structures are.

Transverse Section:

Tangential Section:

Radial Section:

Relate your observations of the anatomy back to the wood section C1.

<u>D. Vascular Cambium</u>

Vascular Cambium (VC) = lateral meristem producing secondary xylem and secondary phloem.

<u>The Origin of VC</u> in stems.

VC arises from the procambial (undifferentiated) portion of 1° vascular bundles AND from parenchyma cells between the bundles. Region of VC within bundles is the **FASCICULAR CAMBIUM** and region between is **INTERFASCICULAR CAMBIUM**. Once united, we simply call it the **VASCULAR CAMBIUM**.

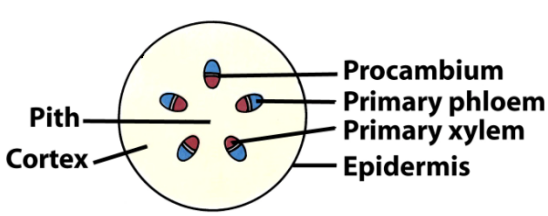


Figure 26-6b
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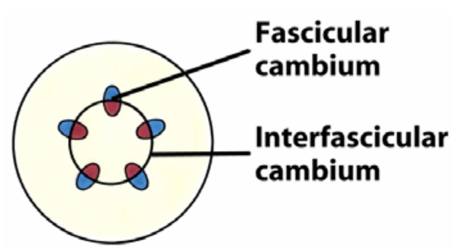

Figure 26-6c
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1. Observe the prepared *Medicago* slide. This slide has three stages of stem growth in transverse sections. Alternatively a *Medicago* slide depicting younger & older stems in cross section may be available.

Carefully observe the sections and DETERMINE which section represents the youngest stem. If you are not certain of which stem is the youngest and which is the oldest, ask your instructor to clarify. Often the youngest stem is the smallest but that is not always a guarantee.

Draw the youngest stem:

Draw the middle aged stem:

Draw the oldest stem:

For each, indicate the presence of the vascular cambium, as well as interfascicular and fascicular regions.

In the appropriately aged section, try to identify the first PERICLINAL divisions in the interfascicular cambium.

What changes are apparent in the primary vascular bundles over time?

Does the ring of vascular bundles ever close?

How can you tell?

How old was the plant when the vascular tissue closed?

E. Anatomy of a Vascular Cell

The following narrative explains in detain the types of vascular cells you will see in plant organs. Be able to recognize these types of cells.

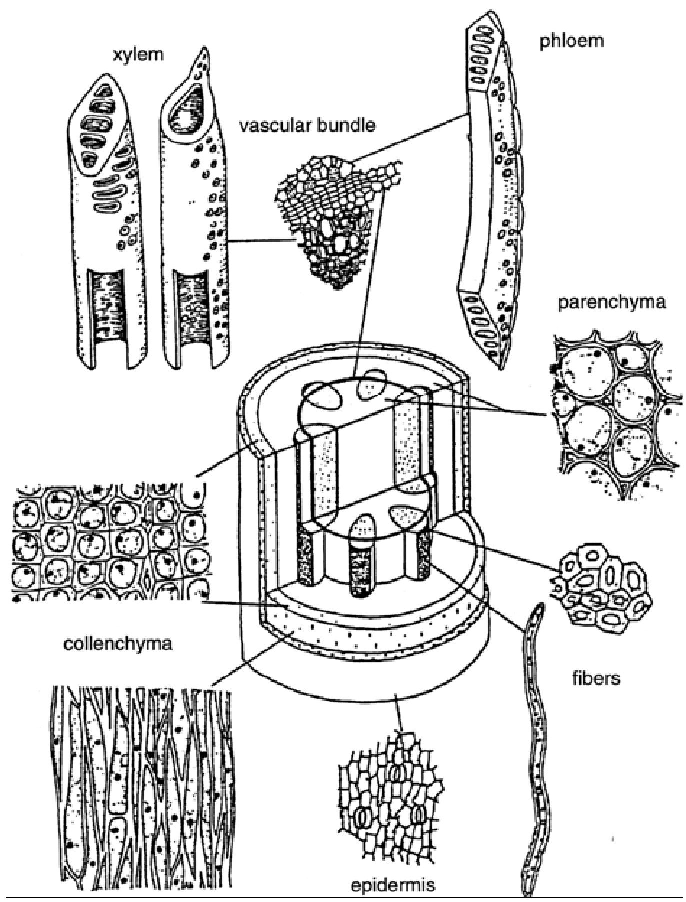
There are two different complex types of vascular tissue, **XYLEM** and **PHLOEM**.

XYLEM. TRACHEIDS--The primary conducting elements in gymnosperms (e.g., pine). Cell with pitted walls and dead at maturity. They also function in support.

VESSEL ELEMENTS--The primary conducting elements of angiosperms. Broad empty, tube-like cells connected end-to-end to form VESSELS.

Xylem FIBERS--Very long cells with very thick walls. Vessels function in transport and fibers provide support; both are dead and empty cells at maturity.

Xylem PARENCHYMA—relatively unspecialized, thin-walled cells rather more abundant in the ground tissue.



Idealized three-dimensional diagram of sections through a typical dicot stem (with no secondary growth), illustrating the locations and general morphologies of various cell and tissue types. (Adapted from Niklas, Plant Biomechanics, p. 267, University of Chicago Press, 1992).

1. Observe the prepared <u>Macerated Oak (*Quercus*) secondary xylem slide</u>. This slide depicts wood that has been digested so that the individual cells separate from one another. Then the suspension of cells is mounted and the result is known as a maceration in which we can determine the types of cells present. Keep in mind that this sample is secondary xylem only so only those cells described above for xylem will apply to your observations.

Initially the cells will not be readily distinguishable and you will need to make careful observations in order to distinguish their characteristics. Use your microscopy skills to bring the cells in and out of focus in order to see detail at the upper and lower surfaces. In addition, systematically move around on the slide in order to maximize your ability to find new cells.

All four cell types will be present!

Label and Draw each type of xylem cell.

Xylem vessel elements will be distinguishable by their large size and the presence of perforation plates at the ends. Label the perforation plates.

Do the vessel elements have pores on the sides?

How can you distinguish the fibers from the tracheids?

Do the tracheids have perforation plates at their ends?

2. Observe the prepared Pine secondary xylem maceration slide. This slide has been prepared in the same manner as the Oak slide observed previously. It too only has xylem cells present.

Label and draw the types of cells found:

How many did you find?

Were any of the angiosperm cell types missing?

What are the structures on the sides of some of the cells in this maceration?

Remember, a fiber does not have these structures on it.

How would a cross-section of pine xylem be distinguishable from an angiosperm cross-section

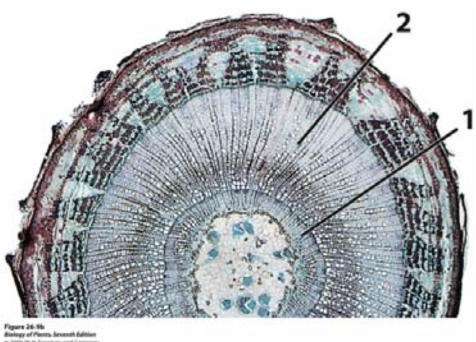
3. Test your observations with the prepared "Wood Cells" maceration. This maceration is from either a conifer (Pine) or an Angiosperm tree secondary xylem.

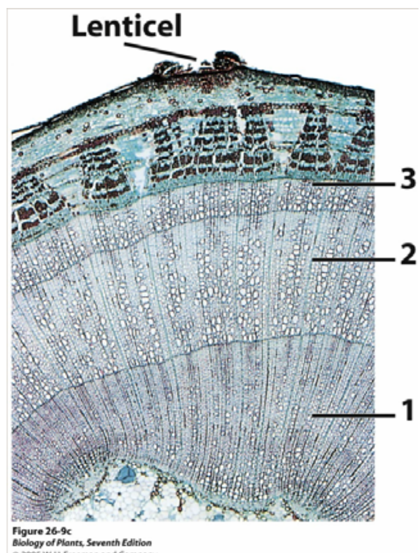
Is this Conifer or Angiosperm tissue?

How do you know?

F. Growth Rings

Growth rings are really just rings of xylem from successive years. Below are two woody stem cross-sections: the one on the left is from a 2 yr-old stem, the right from 3 yr-old.





In this section you will become familiar with the anatomy of the rings and the appearance of the cells in an angiosperm. Keep in mind what type of tissue you are looking at in these slides.

1. Observe the prepared slide of a *Quercus* (oak) wood cross-section. This slide contains all three types of sections (transverse, radial, tangential). For this exercise **IDENTIFY** the transverse or cross-section of *Quercus*.

In the previous section you looked at individual cells using wood macerations. Here the cells are in place as they naturally occur. All of the cells types are present here as well.

Draw a portion of an Oak ring.

Include one entire ring with partial rings at either side. (In essence you will have one ring and two half rings).

On your drawing indicate the following:

Vessels

Tracheids

Fibers

Parenchyma

The ring boundaries

Secondary xylem

The Parenchyma may not be obvious at first but it is there! At higher magnifications, you will notice that spaced somewhat sporadically inbetween all of the vessels, tracheids, and fibers there are regions that seem to be oriented along a different axis. These regions may resemble strings or slivers when you consider the big picture. Some are so large they look like highways moving through the wood tissue. These regions are TOP VIEWS of RAYS. Rays are the conduction pathways from the outside to the inside of the secondary tissue.

Look closely at the rays (If not obvious ask the instructor)

Are they made of one cell or multiple cells?

These cells are the parenchyma that we saw in the macerations.

Indicate a ray on your drawing.

Keep this in mind for section G when we continue our analysis of the wood tissue.

2. The Oak wood you observed is known to be “ring porous”, referring to large vessels formed in the spring (EARLY WOOD) and the not-so-wide-diameter vessels formed in the summer and fall (LATE WOOD).

On your drawing above, indicate the region of one growth ring that represents the EARLY or spring wood and the region of growth that represents the LATE or summer wood.

Other woods may be “diffuse porous”, referring to the more even or “diffuse” distribution of large-diameter vessels throughout the growing season. Nevertheless, definate growth rings are discernible in both types of wood.

3. Observe the transverse section from *Pinus strobus*. This is an example of a conifer wood. As seen previously in the maceration, this secondary xylem does not have a wide variety of vascular cell types. In addition this type of wood is easily distinguished from Angiosperm wood due to the lack of large vessels and the apparent NONPOROUS (no vessels) organization of the rings.

Draw one growth ring and a portion
Of the touching rings on either side.

Label the following:

Tracheids

Early Wood

Late Wood

Resin Canals

The resin canals are not actually cells but air spaces similar in structure to lacuna of monocots.
Considering both the conifer and angiosperm wood transverse sections, Explain why we see rings in woody stems.

4. Determine if growth rings are present in roots also. Observe the prepared *Quercus* (oak) secondary root cross-section slide.

Are growth rings present?

5. Continue your observations of the differences between DIFFUSE POROUS, RING POROUS, and NONPOROUS types of wood. Angiosperms have both diffuse and ring porous since they alone have vessel elements! Conifers have nonporous wood.

Locate the DISSECTING MICROSCOPE stations already set up. Stations 1-6 have examples of the different types of wood growth rings. Study these closely. Use your observations to determine what type of growth rings are present and indicate if you are looking at an Angiosperm or a conifer.

	Ring Type	Angiosperm or Conifer
Station A		
Station B		
Station C		

G. Horizontal Transport through Secondary Tissues: Rays & Ray Initials

The vascular cambium (VC) is made up of "fusiform initials" and "ray initials". These initials in turn give rise, respectively, to the axial-oriented secondary tissue and the radial or horizontally oriented conduction structures called RAYS.

1. Fusiform initials = meristematic cells of the VC, arranged longitudinally, and form the axial (vertical-conducting) system of 2° vascular tissues.

2. Ray initials = horizontally oriented, meristematic cells that form the "vascular rays" or "radial system". This system allows transport of food form 2° phloem to 2° xylem, and transport of water and ions from 2° xylem to 2° phloem. Very important, indeed.

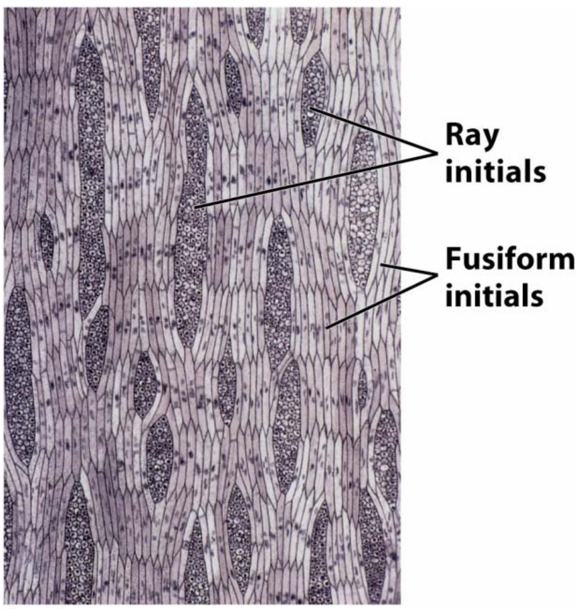


Figure 26-3
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Tangential section through vascular cambium.

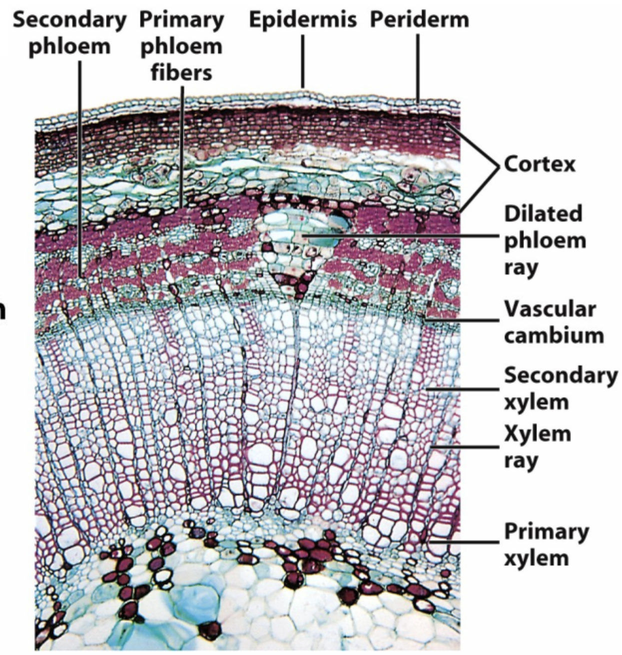

Figure 26-9a
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Cross-section through 1 yr old secondary growth stem.

1. Go back to either the *Celtis occidentalis OR the Abies grandisslide* slide with the three different sections present. Observe the Tangential section and sketch an example of a ray below.

What is the function of rays?

How many cells thick does a typical ray appear?

You should be able to see multiple sizes of rays.

Be able to relate the position of the rays in the tangential section to the rays that are present in the radial and the transverse sections. Rays are visible in all sections.

Sketch what the rays look like in your radial section

H. Bark Formation: the Cork Cambium

The CORK CAMBIUM (abbreviated here as CC) is a lateral meristem producing PHELLODERM (living parenchyma cells) to the inside, and PHELLEM ("cork", dead and suberized at maturity) to the outside. Appears in both secondary growth roots and stems.

Together, these three (cork cambium, phelloderm, and phellem) comprise the PERIDERM, which functionally replaces the epidermis in secondary growth stems and roots.

1. Stems: The CC usually appears during first year of growth, but after VC. Most commonly originating in a layer of cortical cells just below the epidermis (although sometimes in epidermis!). Repeated divisions of the CC result in the formation of radial rows of cells (most of which are cork cells).

PREPARED SLIDE: *Pelargonium* stem x-section (cork).

Notice the vascular cambium in these sections.

Look for the newly formed cork cambium.

Where is it with regard to the vascular cambium?

2. Observe the pieces of BARK on your lab bench. Technically these fragments do not constitute the entire bark since we cannot be for certain that the vascular cambium and the secondary phloem are present. However, they do provide us with an excellent opportunity to see the multiple PERIDERMS that are present. Just like with growth rings in the secondary xylem, we can see alternating layers of periderm in the bark.

How many periderms can you count.

Are the outermost periderms intact?

What is the purpose of the periderm?

I. Bark Breathing: Lenticels

LENTICELS allow gas exchange through the periderm of the stem.

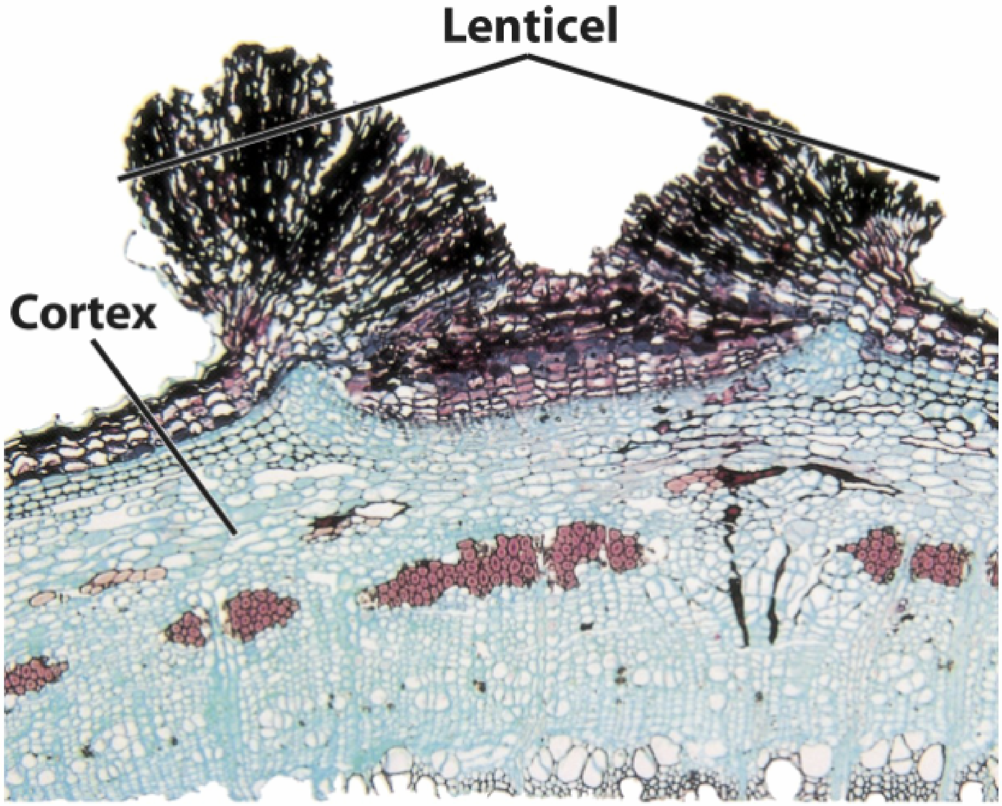

Figure 26-10d
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The suberized cork cells of periderm are fairly impermeable to gases and water (remember the cork in wine bottles). The 2° plant body still must breath. **Lenticels** = portions of the periderm with numerous intercellular spaces, which allow for gas exchange.

1. **PREPARED SLIDE:** *Sambucus* lenticel (cross-section).

A single lenticel has been sectioned (as in the above Figure).

First, a bit of orientation: find the vascular cambium and the outer bit of secondary xylem and the secondary phloem (which is externally bound by the fiber (red-staining) caps of the primary phloem.

Second, find the young cork cambium: the cells it leaves behind are the short-lived and inconsequential phelloderm. The derivative cells yielded in advance of it (to the outside) become phellem (cork).

Relate your understanding of the Periderm to the cell layers present in the section.

J. Wood Morphology

Fact sheet and observations on big chunks of wood:

1. Hardwood vs. Softwood.
Hardwoods are Angiosperm woods, softwoods are Gymnosperm (conifer) woods. Gymnosperm (conifer) woods lack fibers and so they generally tend to be, but are not always, softer than angiosperm wood. See the dissecting scopes for a recap on the difference of these.

2. Heartwood vs. Sapwood.
Heartwood = innermost and nonfunctional (i.e., no conduction) and generally darker wood; often darker due to the accumulation of substances such as oils, gums, and tannins. These accumulated substances may make the heartwood aromatic.

Sapwood = contains living cells and reserve materials. May or may not be entire functional in terms of water conduction.

3. Early wood vs. Late Wood.

a. Early wood = first-formed wood of a growth ring (i.e., a growing season). It's cells are larger and this part of the ring is therefore less dense than that formed towards of the end of the growing season.

b. Late wood = latter-formed wood, of smaller diameter cells.

-this phenomenon is responsible for the growth rings of a tree! See below.

4. Bark.
--technically, all tissues outside the vascular cambium.

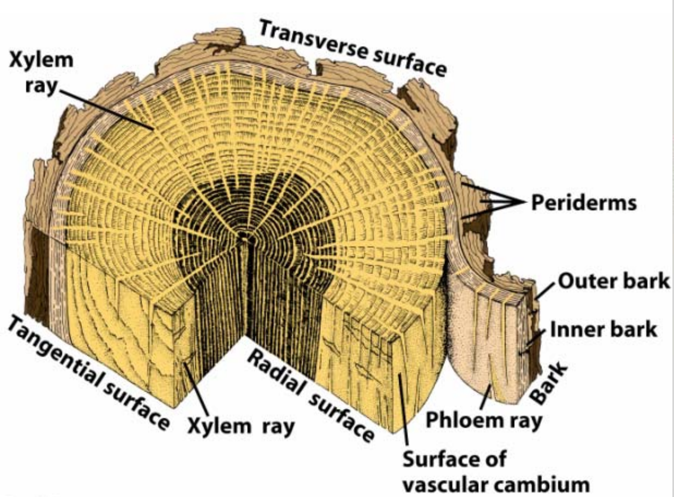

Figure 26-12
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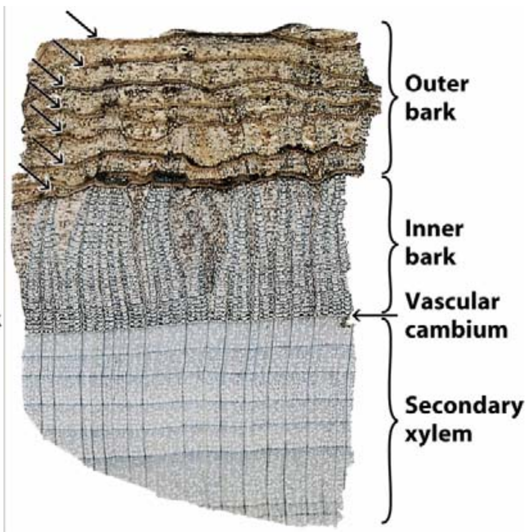

Figure 26-13
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FINAL TASK: Observe the wood cross-sections on the tables and be able to apply as many of the terms above that apply to each. Look closely to see the early and late wood.