CHAPTER TWO

THE STRUCTURE OF WOODY PLANTS: GROSS ANATOMICAL FEATURES

In evaluating any unidentified piece of wood, you will routinely find and examine the larger, more obvious anatomical features that are discussed in this chapter. We first look at those elements of tree form and growth that are common to both softwoods and hardwoods. Then we go to the opposite extreme and look at wood cells, since these compose the larger anatomical features.

Although some features can be recognized on any exposed wood surface, many are seen best on a specific plane of cut. Accordingly, the second part of this chapter discusses the three principal planes that we routinely expose on a sample in order to observe many important features.

Tree Form and Growth

Wood comes from higher-order, vascular (fluid-conducting), perennial plants. Woody plants are capable of secondary thickening, that is, of adding new yearly growth layers of cells onto the accumulated growth of previous years. Woody plants include trees, shrubs and vines, which are separated from each other on the basis of size and form.

Species that are taller than 20 ft. when mature and have a dominant single stem are called trees; those species that do not reach 20 ft. are shrubs. The stems of shrubs may be single or multiple, erect or trailing. The stems of woody vines are elongated and usually climb, supported by another plant or by a structure.

The trunk of a tree has limbs that divide into branches and then into twigs. As shown in the drawings on p. 8, if we slice crosswise through a trunk, limb or twig, and look down at the roughly circular surface, we find the **bark** — which is not considered wood — to the outside. To the inside of the bark is the **cambium**, the thin layer of living reproductive tissue separating the bark from the wood. The wood itself is characterized by **growth rings** arranged concentrically around the **pith**.

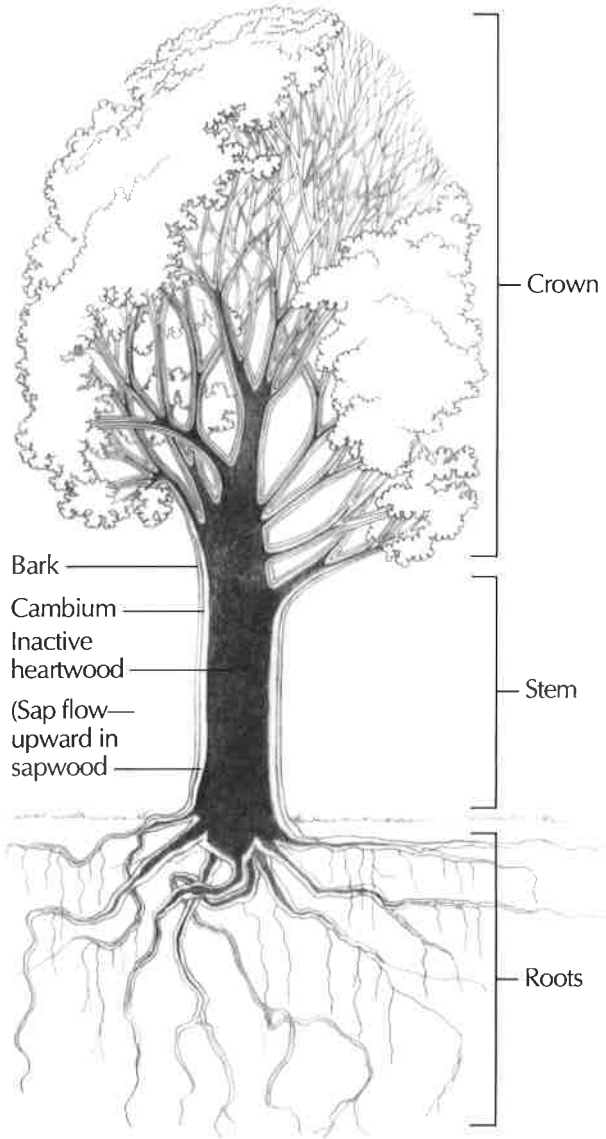
Wood Cells

The basic unit of the structure of plants is the cell. Thus, wood is a collection of various kinds of cells, which are produced by division in the cambium. The cells are typically elongated, consisting of an outer **cell wall** encompassing a **cell cavity**.

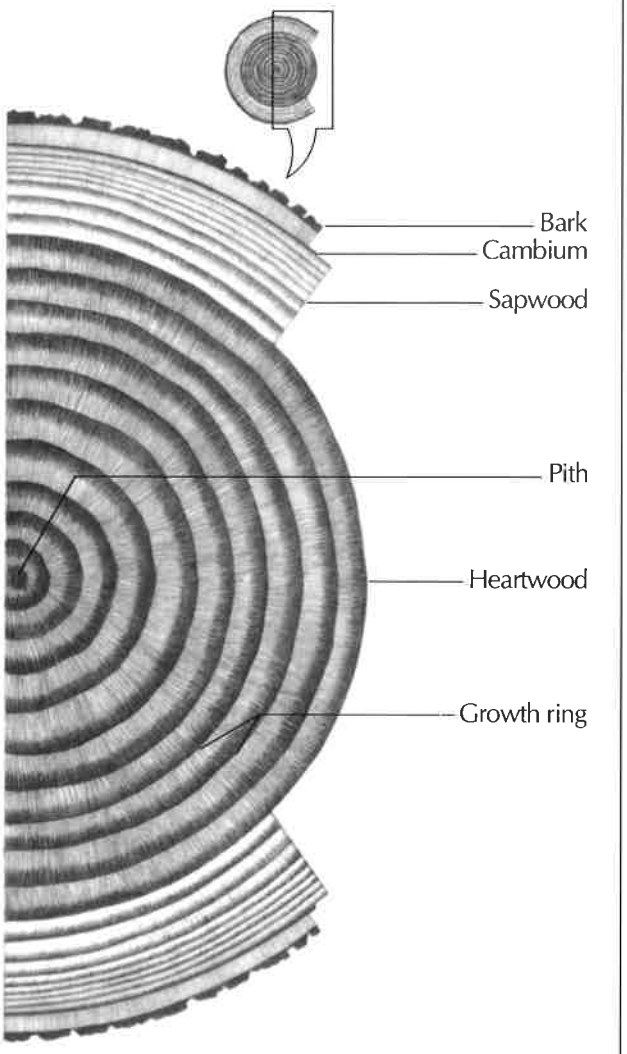
Cells produced by division in the cambium contain living material called **protoplasm** in their cell cavities. As the newly divided cells develop, they assume different sizes and shapes and perform various functions in the tree. Certain cells called **parenchyma** (puh-REN-kih-muh) remain alive for years, performing metabolic functions such as carbohydrate storage in the growing stem. Most wood cells, however, develop into cell types that lose their protoplasm within days after being created. As nonliving cells they function as conductive, or vascular tissue, and/or contribute mechanical support to the tree. These cells include **vessel elements**, **tracheids** and **fibers**; we will study them more closely later.

MAIN PARTS OF A TREE

Wood is the vascular supportive tissue of trees. Sapwood remains active in the conduction of sap and in food storage in living parenchyma cells; heartwood gives the tree mechanical support.



PRINCIPAL FEATURES OF A TREE STEM



The long axis of most wood cells parallels the tree stem — the cells are oriented vertically in the stem. This dominance of longitudinal cells is responsible for **grain direction**, the direction in which the wood most readily splits or cleaves. Where the longitudinal cells are almost perfectly parallel to the stem axis, the grain is described as straight; where cells are significantly nonparallel to the stem, some form of cross grain, such as **spiral grain**, may result.

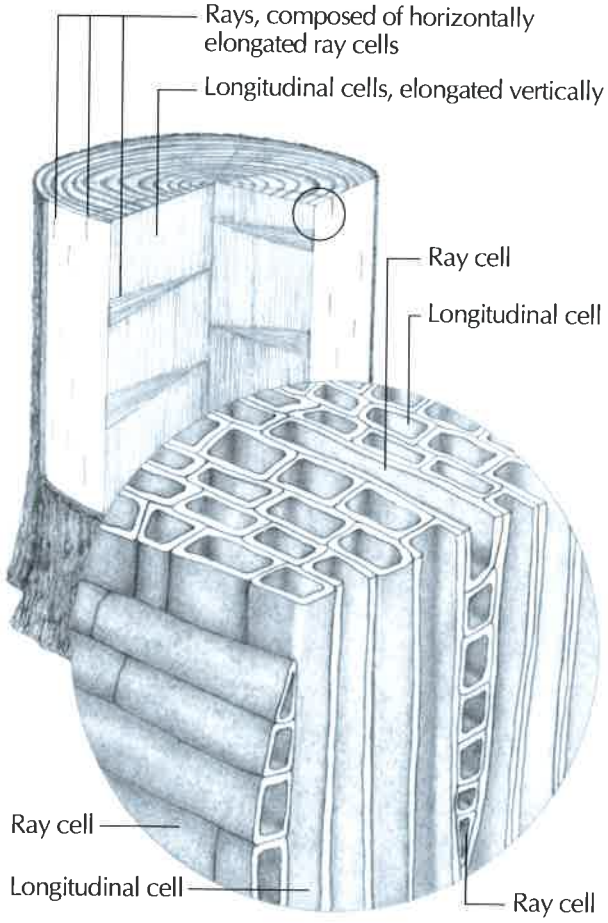
Rays

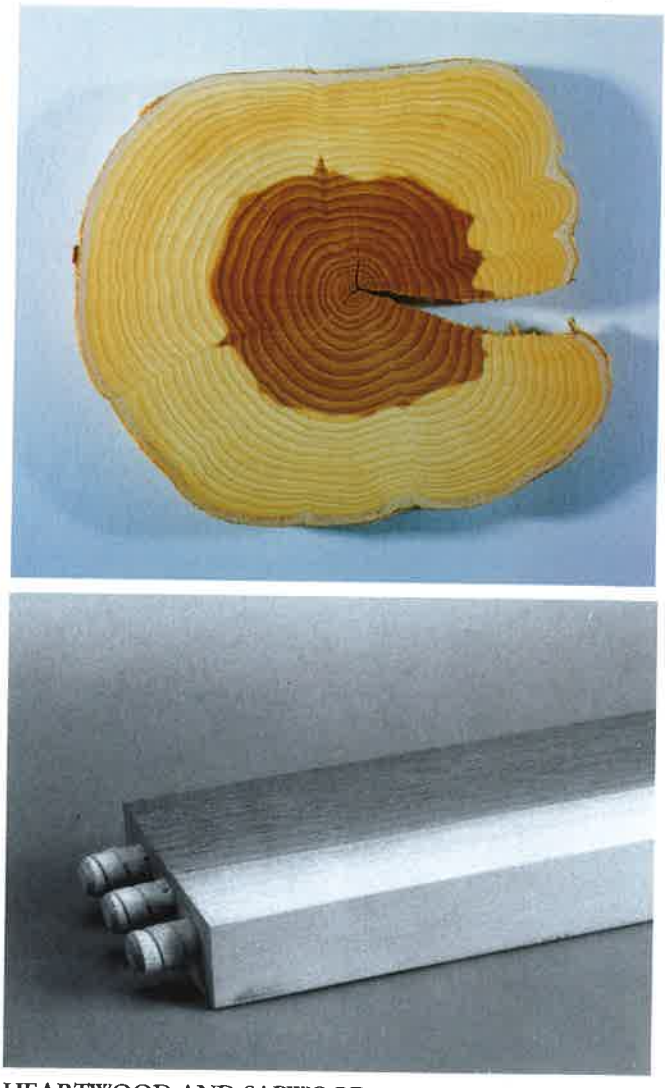
Whereas most cells are elongated in a direction parallel to the stem, a small number of cells — generally accounting for less than 10% of the volume of the wood — are elongated perpendicularly to it. These cells form flattened ribbons of tissue called **rays** (see the drawing on the facing page). The wide side of the rays is oriented vertically, and the rays radiate outward from the pith and connect with the cambium. Consequently they cross the growth rings at right angles.

Rays vary considerably in size among wood species. At one extreme, they are a single cell wide and invisible to the naked eye; at the other, they are 30 to 40 cells wide and over an inch high. These rays are obvious without any magnification. As we shall see in the next chapter, all rays, regardless of size, are very important in wood identification.

LONGITUDINAL AND HORIZONTAL WOOD TISSUE

Wood consists mostly of longitudinal cells, which are elongated vertically along the stem and thereby determine the grain direction of the wood. The ray cells are elongated horizontally in the radial direction and form the rays.





HEARTWOOD AND SAPWOOD
Darker heartwood contrasts with lighter sapwood in tree stem, board and finished product.

Sapwood and Heartwood

In saplings (very young trees), the entire wood portion of the stem is involved in the upward conduction of sap. This wood is called **sapwood**. The conductive cells in sapwood have open cavities to accommodate the moving fluid. Parenchyma cells, which contain living material, are involved in food storage.

As the tree gets older and its trunk increases in girth, the tree no longer needs its entire trunk for the conduction of sap. In the central area of the trunk, that nearest the pith, parenchyma and conductive cells cease to function, save for the structural support they provide. As these cells shut down, the sapwood is transformed into **heartwood** (see the photos above right).

Residue of once-living protoplasts is occasionally found in heartwood parenchyma cells. Bubblelike structures may develop in what were formerly the conducting vessels. The cell walls may accumulate materials, called **extractives.** This gives heartwood its distinctive color. Living sapwood is typically a light, neutral shade of tan, yellow or near-white; any more pronounced color in the heartwood — the dark brown of walnut, the deep red of cedar, the black of ebony — is the result of extractives. However, some species — spruces, for example — do not have pigmented extractives, so the heartwood cannot be distinguished from sapwood on the basis of color.

It is important to remember that wood is always sapwood when it is formed. Once formed, however, no cells are added or lost in the sapwood area, nor does cell size or shape change. Yet, as mentioned, their contents may be modified slightly in the transition to heartwood.

Growth Rings

Tree growth — the result of reproductive activity in the cambium just under the bark — continues as long as the tree is alive to the extent that environmental conditions and tree vigor permit. In the kind of temperate climate that prevails across most of the United States, the characteristic annual life cycle includes a growing season and a dormant season. Cell formation in most trees follows this cycle, resulting in visible **growth layers** or **growth rings**. These increments are called **annual rings** when formed as the result of annual growth.

Ring width varies from species to species. It also varies within a species from year to year in response to more or less favorable conditions during the growing season.

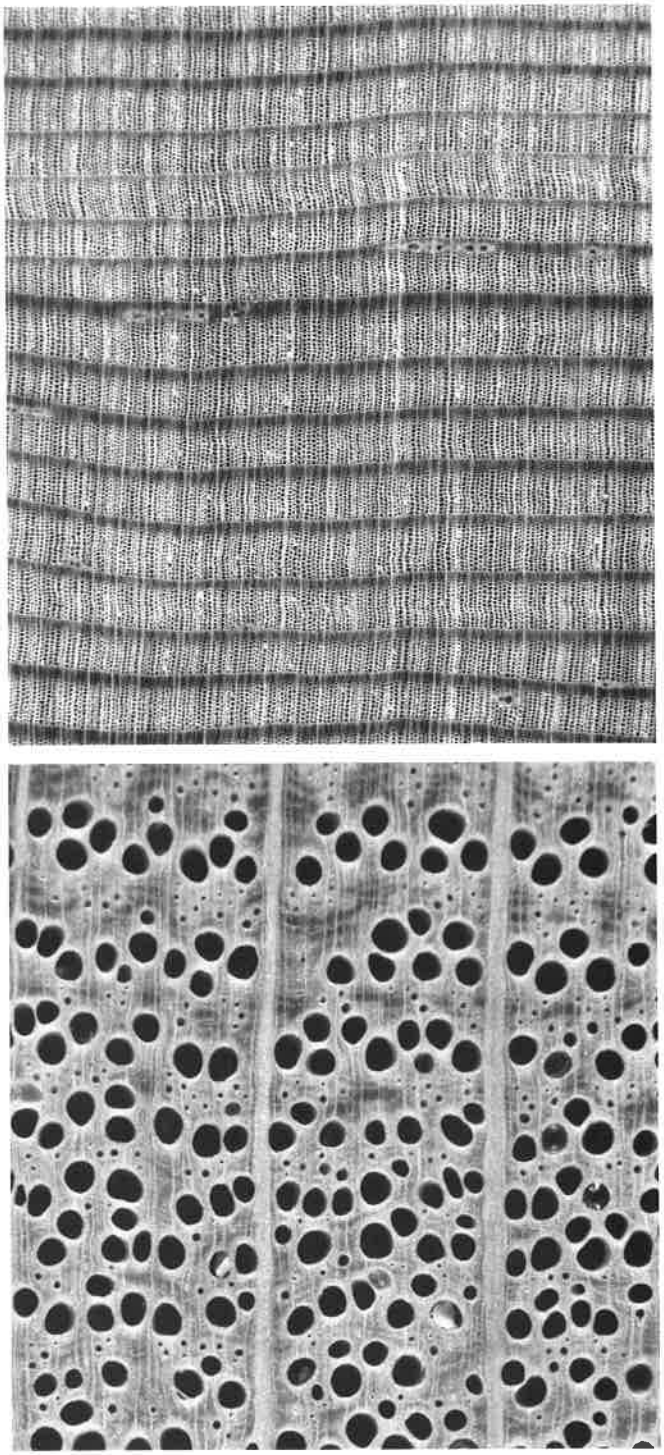
Some growth rings are very obvious, others are nearly invisible. The distinctiveness of a growth ring in a particular species is determined by seasonal variation in cell diameter and cell-wall thickness and by the distribution of different kinds of cells within the wood. Variations in the growing environment of a particular species can have a pronounced effect upon the appearance of growth rings (see the photo on these pages).

Where there is a visible contrast between the first-formed and later-formed portions of a single growth ring, the first-formed portion is called **earlywood** and the remainder **latewood**. The terms **springwood** and **summerwood** are also used, but these terms are misleading because they wrongly suggest a consistent correlation with those seasons.

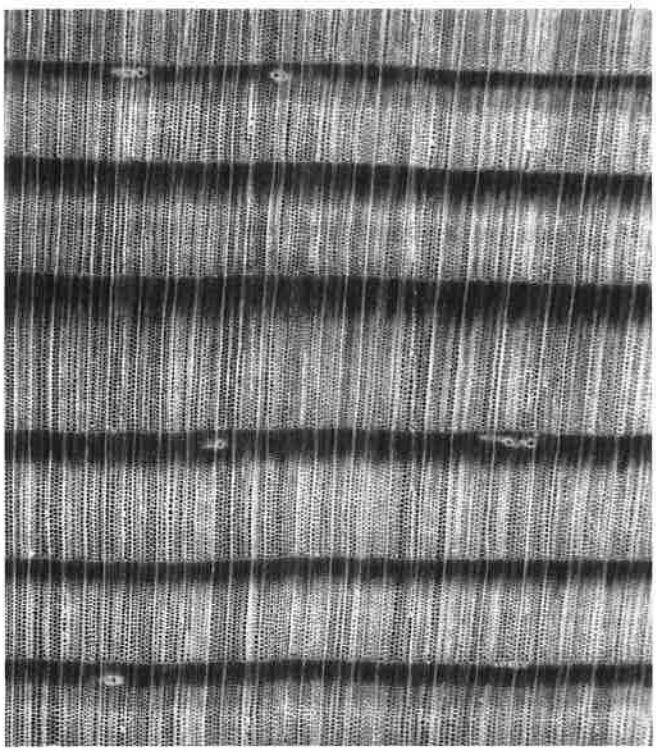
In certain species where earlywood and latewood are visible, the transition from one to the other is abrupt and obvious. But in other cases the transition is so gradual that we cannot point to a single place at which it occurs. In areas with more tropical climates, growth may be consistent year-round. As a result, some tropical species may not exhibit growth layers.

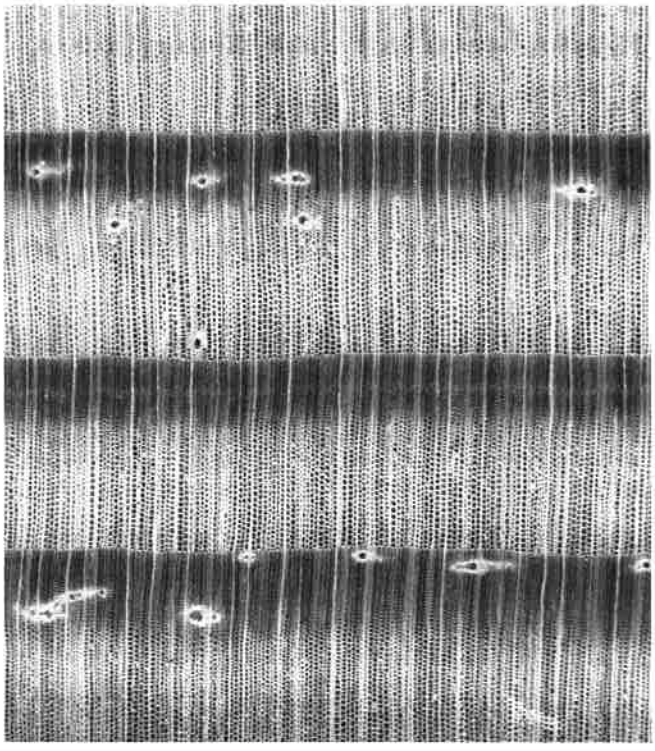
Grain, as we have seen, is used to denote the direction in which a wood splits. But the word "grain" can also be used to describe the visual contrast between earlywood and latewood when coupled with modifiers like "even" or "uneven." If a pronounced contrast exists, the wood is uneven-grained, as in southern yellow pine. If little contrast is evident, the wood is even-grained, as in basswood. Intermediate cases are indicated by adding further modifiers, as in "fairly even-grained" for a wood like eastern white pine or "moderately uneven-grained" for western fir, although the use of this terminology is somewhat subjective.

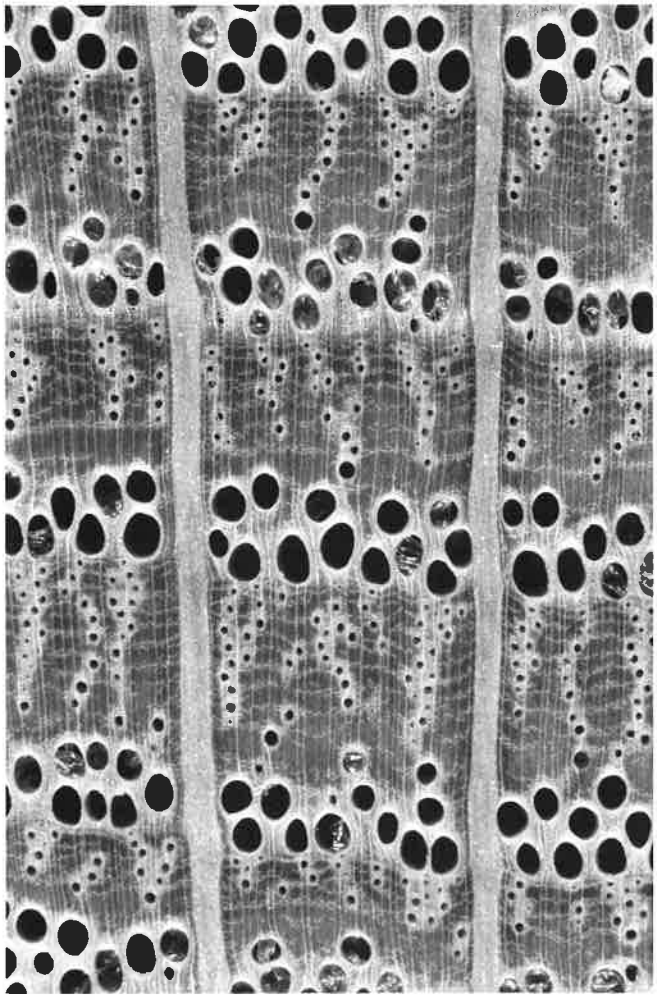
When working with an unidentified sample, it is extremely important to consider the evenness of grain and the transition of earlywood to latewood separately. Although it is common that an uneven-grained species has an abrupt earlywood/latewood transition, as in southern yellow pine, Douglas-fir, tamarack and white ash, an uneven-grained wood can also have a gradual transition, as in western hemlock. And a fairly even-grained wood like ponderosa pine, upon close examination, can show an abrupt earlywood/latewood transition.

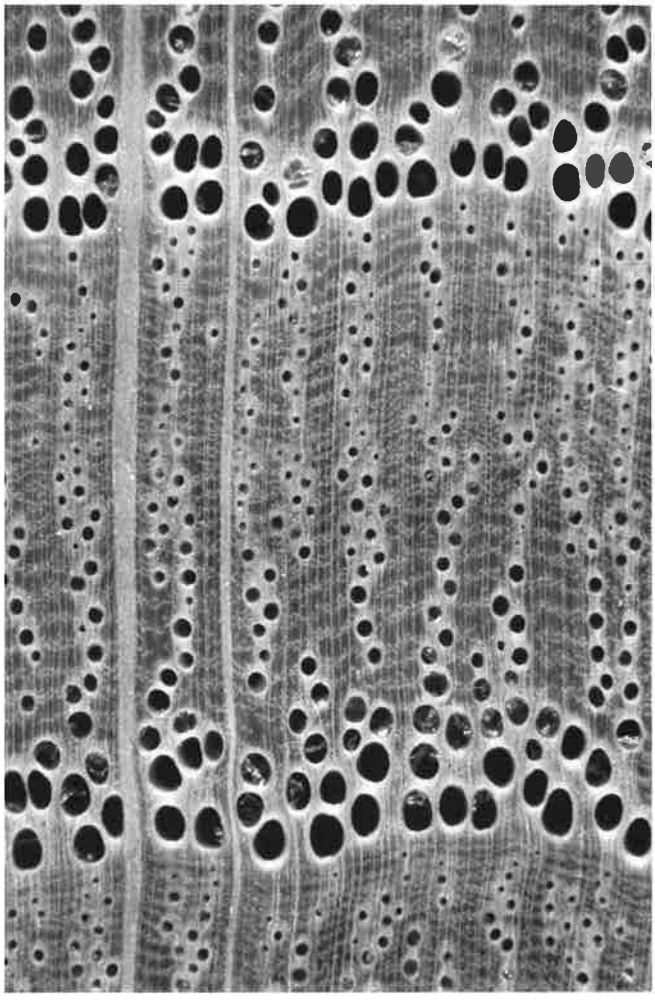


EXTREMES OF GROWTH RATE
AS SEEN IN GROWTH RINGS
The photographs in the top row are all of Douglas-fir (*Pseudotsuga menziesii);* those in the bottom row are of red oak *(Quercus rubra).* The center photograph in each row reflects average growth rate. Note how different extremely slow growth (left) or extremely fast growth (right) can appear in cross section. (15x)



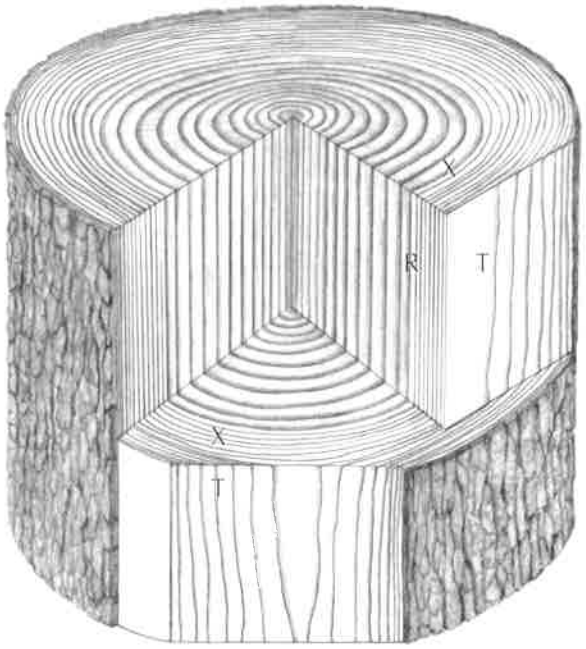






PRINCIPAL STRUCTURAL PLANES IN A STEM: X, R, T

The cross-sectional or transverse plane (X) is perpendicular to the stem axis. The radial plane (R) passes through the pith. The tangential plane (T) forms a tangent to the cylindrical plane of the growth rings; it is therefore a 'compromise', being most truly tangential where the plane forms a right angle with the rays.



Viewing Features in a Sample

So far we have spoken about features as if they were always plainly visible. But that cannot be assumed. The features of a piece of wood can disappear or look dramatically different according to the surfaces exposed by cutting the wood. However, if we remember that cells are layered in a somewhat concentric cylindrical arrangement or that they radiate outward from a central axis, we realize that wood is actually a three-dimensional, triaxial material whose structure and cell orientation bear a close relationship to its grain direction, growth rings and rays (see the drawing above). We can then simplify our complex material somewhat by reducing our study to these three basic planes.

Sometimes we cut horizontally through the stem perpendicular to the grain direction. This is called a **transverse plane**, a **cross-sectional plane** or simply a **cross section**. All three terms are used interchangeably in this book and elsewhere.

Because this view allows us to see the concentric growth rings, we can evaluate growth-ring characteristics such as ring width, percentage of earlywood and latewood, evenness of grain and abruptness of transition from earlywood to latewood. If the rays in the sample are large enough, they appear as lines — usually lighter than the background cell mass — crossing the growth rings at right angles.

Another view, the **radial plane**, is any plane whose surface parallels the stem and passes through the pith. If we take a short section of a log, stand it on end and cut it in half from top to bottom, we expose two radial planes.

Growth rings appear as nearly parallel lines in radial view. The radial plane essentially coincides with the plane of the rays. However, because of slight irregularities in the wood structure, exposure of the rays at the wood surface may be intermittent. The smallest rays are not visible at all or show up only as small patches or streaks that are more reflective than the surrounding area. Medium and larger rays, if present, usually appear as contrasting strips or patches.

In species such as maple and sycamore, rays show up as darker bands or stripes against a lighter background; in other species, such as black cherry or yellow-poplar, they are lighter than the background. The distinctive appearance of the rays on a radial surface is called **ray fleck** (see the photo at left on the facing page), which is an important identification feature, particularly in hardwoods. When cutting a sample in preparation for viewing, the changing appearance of ray fleck can be very helpful in locating the true radial plane.

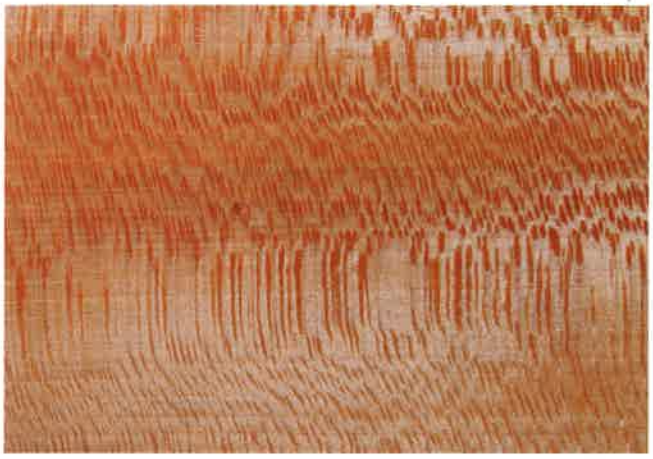
The **tangential plane** or surface (see the photo at right on the facing page), like the radial plane, parallels the stem. The difference is that it does not pass through the pith and it is tangent to the cylindrical growth rings. We may also think of the tangential plane as being perpendicular to the rays — and therefore to the radial plane at that point.

In a small sample, growth-ring curvature is so slight as to be inconsequential. But on a gross scale — board surfaces, for example — the tangential plane cannot be accurately tangential over a large surface due to the growth-ring curvature. So we compromise and accept the surface of any outer slab from the length of a log as tangential.

In reality, growth rings are never perfectly round; their curvature varies from place to place. Therefore, in tangential view they usually appear as irregular U-shaped, V-shaped or oval markings. Rays are visible on tangential surfaces only if they are medium- to large-sized; they usually appear as dark lines along the grain. The length of the line indicates ray height and the breadth indicates width. In a species like sugar maple, rays are barely visible as hairlines up to 1/32 in. long. In red oaks they are clearly visible as in lines up to 1 in., and in white oaks they may be several inches long.

Transverse, Radial and Tangential Sections

Remember that you'll often be working with small samples. If features are to show correctly in a smaller sample, it is critical to cut the wood accurately along the intended planes. The thin, transparent slices of wood tissue removed from these surfaces for microscopic study are termed **transverse**, **radial** and **tangential sections**. For convenience, both planes and sections are often designated by the letters X (for **cross**-sectional), R and T.



RAY FLECK
Striking ray fleck is apparent on the radial surface of this sycamore board.

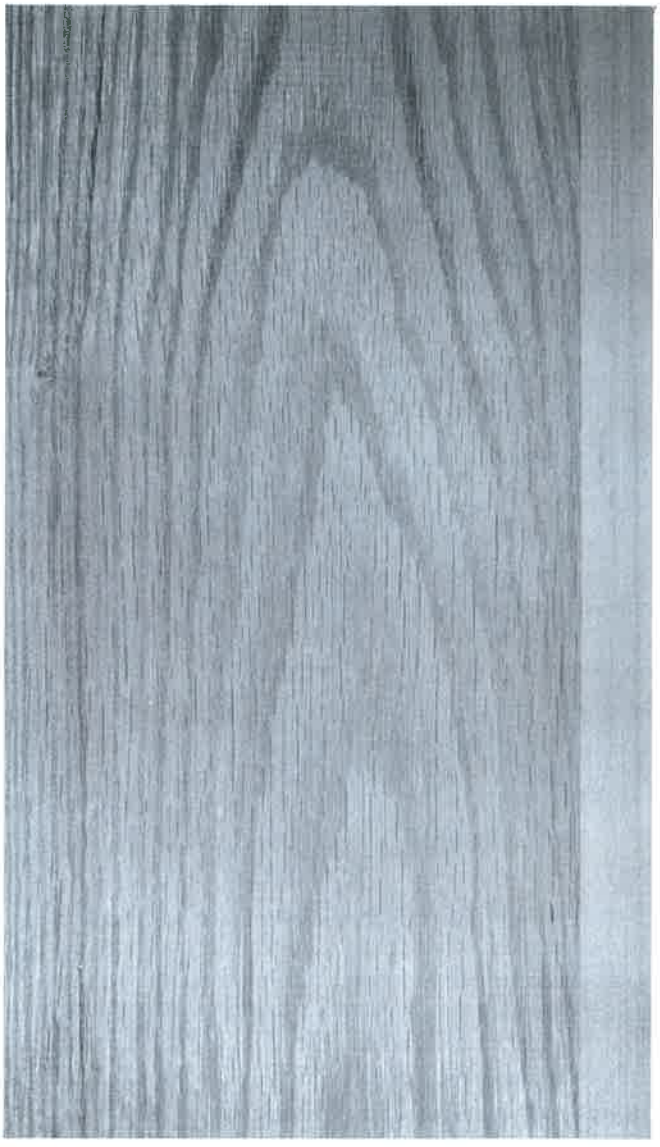
I cannot overemphasize the importance of being able to locate these three planes, since further analysis usually hinges on it. Accurate orientation of planes is especially important in sectioning for microscopic examination; otherwise features will not appear as they should. To prepare a sample with one or more principal planes, first figure out the grain direction. This is sometimes indicated by large visible cells, by rays on an approximate tangential surface or by growth rings on a radial surface. Or you can split the wood. Since wood splits longitudinally, cutting a plane perpendicular to the grain direction and perpendicular to the plane of the split creates a transverse surface.

Once a transverse surface has been produced, the growth rings and rays apparent on it will assist in locating the orientation of radial and tangential planes. I strongly suggest plenty of practice on small pieces of scrap wood, whittling each as necessary to expose the X, R and T surfaces.

Summary

In examining any piece of wood, you should first study it to determine its relationship to the stem from which it came. Decide whether any of the exposed surfaces are true transverse, radial or tangential planes. If not, cut the piece to expose these surfaces (this technique is further described in Chapter 7). Then take note of the following gross anatomical features:

1. Sapwood and heartwood
2. Growth rings
   a. Width
   b. Percentage of earlywood and latewood
   c. Evenness of grain
   d. Transition from earlywood to latewood
3. Rays
   a. Visibility on transverse and tangential surfaces
   b. Ray fleck on radial surface



GROWTH RINGS AND RAYS AS SEEN IN THE TANGENTIAL PLANE
Growth rings and rays are clearly visible without magnification on this tangential surface of red oak.