University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

PART 8

IDENTIFYING WOOD—*A Primer for Everyone*

Hardwood Growth Rings

Terry Conners, Forestry

As in softwoods, hardwood species identification is accomplished by looking at species-specific combinations of features. Almost all hardwood species (including all of those from North America) contain vessels which appear as holes (pores) on wood cross-sections; hardwood species without vessels are unlikely to be encountered in North America. Those species are more commonly found in the southern hemisphere and are rarely sold as commercial species.

The first step in identifying an unknown wood sample, then, comes down to this: does the piece contain vessels (pores), in which case it's a hardwood, or does it lack vessels, in which case it's a softwood. When you first look at a cross-section, be careful to make sure you've identified the cells that you are looking at correctly; when you are first learning how to identify wood it's fairly common to wonder whether you are seeing vessels and resin canals. Confusion arises because vessels are larger than the surrounding hardwood fibers, and resin canals are larger than the softwood tracheids. There are far fewer resin canals on softwood cross-sections than there are vessels on a hardwood cross-section, however. Additionally, softwood tracheids are always arranged in straight rows of small-diameter cells perpendicular to the growth rings, whereas hardwood fibers (if you can see them at all) are arranged irregularly. I described this in more detail in another article in this series.[1]

Once you have established that you are looking at a hardwood, the size and arrangement of the pores on the cross-section can be immensely helpful. Odor, texture, parenchyma, etc., can be as important in hardwoods as they are in softwoods, but these points will be considered in another section.

Hardwood Pore Distributions

Three Categories of Pore Distribution Patterns

There are three different pore distribution patterns on the cross-sections of temperate-zone hardwoods.[2] These patterns are defined by the constancy of the pore size across the growth ring. For example, in some cases the pores are large in the earlywood and small in the latewood, while in other species the pore sizes are about the same throughout the growing season.

The change (or lack of change) in the pore size across the growth rings is the characteristic used to separate species into one of three classifications: 1) diffuse porous; 2) ring porous; or 3) semi-ring porous (also known as semi-diffuse

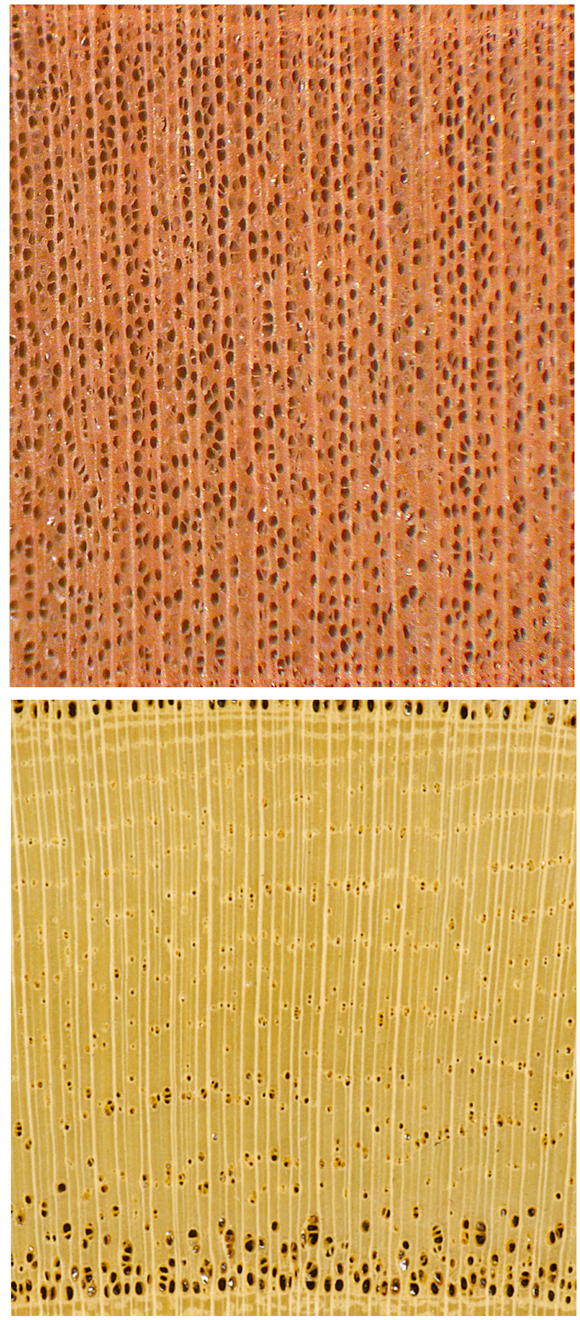

Figure 8-1. Sweetgum (*Liquidambar styraciflua*) (top) and white ash (*Fraxinus americana*) (bottom) have very different pore distribution patterns. Sweetgum pores are all about the same size and the distribution is essentially uniform across the growth ring, but the white ash pores decrease in size and frequency rather abruptly between the earlywood and the latewood.

1 Conners, Terry. 2015. Distinguishing Softwoods from Hardwoods. Agriculture and Natural Resources Publications. Cooperative Extension Service, University of Kentucky College of Agriculture, Food and Environment, Lexington, KY 40546. FOR-125. https://uknowledge.uky.edu/anr_reports/105.

2 In tropical species there can be many more types of pore distribution patterns. Some authors define as many as a dozen or more!

porous). Recognizing the pore pattern present in the specimen is a major step toward systematically determining the species identification.

Look at the photographs of sweetgum and white ash in Figure 8-1 to see how the pore patterns can differ. Sweetgum is a good example of a species whose pores are all about the same size, and white ash is an example of a species whose earlywood and latewood pores have very different diameters.

Diffuse Porous Type

When a piece of hardwood has pores that are essentially uniform in size (like the sweetgum shown in Figure 8-1), the wood is called a diffuse porous species. Sometimes the pores at the end of the growth ring (in the last 5 to 10% or so) look distinctly smaller than those in the rest of the growth ring. These small pores are disregarded when deciding if you are looking at a diffuse porous sample or something else. See the micrographs of maple, a diffuse porous species, in Figure 8-2. The micrographs are displayed at different levels of magnification. It's easy to see the pores in the micrograph on the left, but the fibers aren't visible because their diameter is so small. To see how the fiber diameter compares to the vessels, look at the more highly magnified micrograph on the right side of that figure.

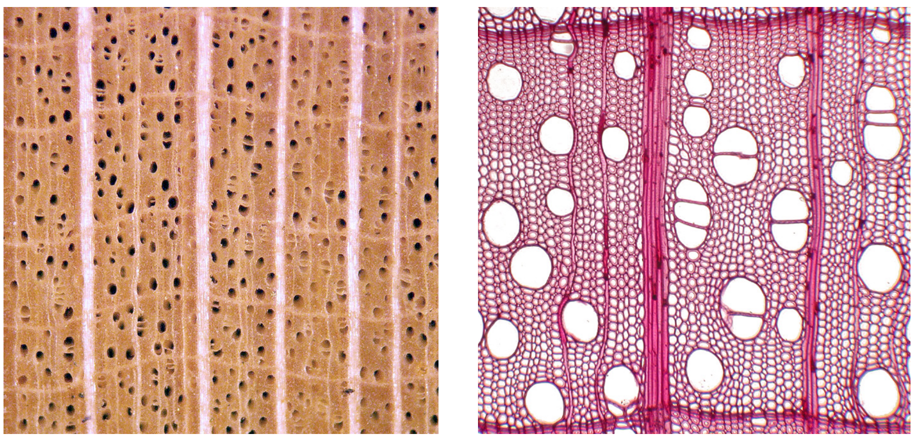

Figure 8-2. Maple is a good example of a diffuse porous species.These micrographs of sugar maple (*Acer saccharum*) illustrate how similar the pore size is and how uniformly distributed the pores are across the growth ring. (The magnifications are different in these two micrographs.) Fibers comprise the bulk of the growth ring surrounding the vessels, as can be seen on the illustration on the right. The ray width varies from uniseriate to multiseriate in this species.

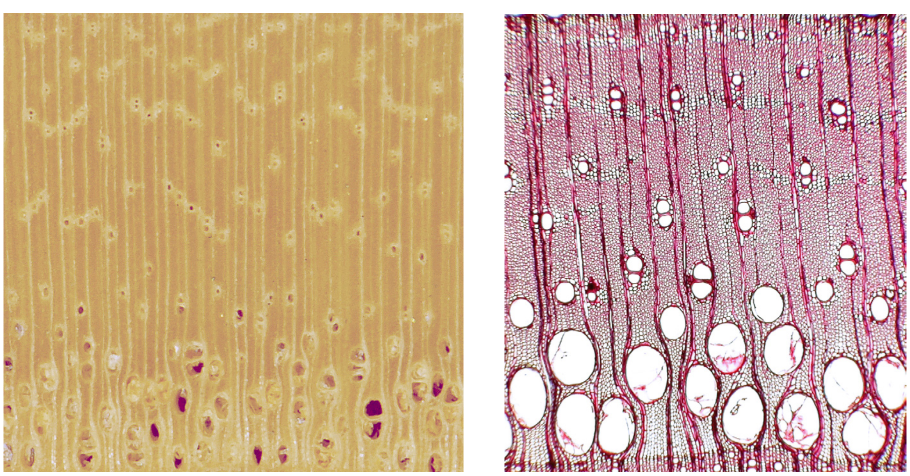

Figure 8-3. Micrographs of white ash (Fraxinus americana), a ring porous species. Notice how the earlywood pores are much larger than the latewood pores, and the proportion of the growth ring occupied by pores changes abruptly as well. In this species the rays are thin and lack contrast with the fibers, hence they are inconspicuous without magnification.

Maple is just one of the many species with a diffuse porous structure; besides sweetgum and the maples, others include aspen (*Populus tremuloides*), American beech (*Fagus grandifolia*), birch (*Betula spp.*), dogwood (*Cornus florida*), cottonwood (*Populus deltoids*), American sycamore (*Platanus occidentalis*), "true" mahogany (*Swietenia sp.*), yellow-poplar (*Liriodendron tulipifera*), etc.

The proportion of the growth ring occupied by the vessels in a diffuse porous species is usually about the same from earlywood through most of the latewood, and consequently the fibers are equally distributed as well.

Ring Porous Type

Ring porous species have vessels with two essentially distinct diameters (large and small), with an abrupt change in pore size. White ash (*Fraxinus americana*) is a good example of a typical ring porous species; the earlywood and latewood pores are distinctly different in size, and the size changes fairly abruptly (Figure 8-3).

Some other common ring porous species include red and white oak (*Quercus rubra and Q. alba*, respectively), chestnut (*Castanea dentata*), black locust (*Robinia pseudoacacia*), honey locust (*Gleditsia triacanthos*), Kentucky coffeetree (*Gymnocladus dioicus*), Osage-orange (*Maclura pomifera*), and elm (*Ulmus spp.*).

The large earlywood pores are readily visible by eye and tend to stand out on the cross-sections of ring porous species. See the photograph of a red oak (*Quercus rubra*) railroad tie below (Figure 8-4).

Semi-Ring Porous (equivalently, semi-diffuse porous) Type

Some species aren't strictly either ring porous or diffuse porous in structure. In some species the pore sizes change slowly across the growth ring; in others the earlywood pores form a more or less continuous ring, and the remaining pores are all about the same size but more uniformly scattered. Black walnut (*Juglans nigra*) is an example of a species in which the pore size gets smaller across the growth ring, and black cherry (*Prunus serotina*) is often given as a good example of a species with a continuous ring of small pores in the earlywood and

Figure 8-4. This cross-section demonstrates how easy it is to see the large earlywood pores in the end grain of a ring porous species (red oak (*Quercus rubra*) shown here). The earlywood pores look like rings of holes; these are accentuated by some pulled fibers at the pore boundaries as a result of the saw cut. This illustration is approximately full-size.

similar-sized pores scattered throughout the rest of the growth ring. (Because the pores in black cherry are mostly about the same size, some authors describe this as a diffuse porous species.)

Figure 8-5 shows a combination micrograph/sketch for black walnut; I traced the pores digitally and made a second image so you could see the pore size changing without distractions. It's impossible to draw a boundary line between the earlywood and the latewood.

Figure 8-6 is a micrograph of black cherry. Notice how the pores are all about the same size throughout the growth ring, though there is a much higher density of pores in the beginning of the earlywood that appear to constitute a continuous ring of pores. Like many species, the pores grow smaller at the very end of the growth ring, and this is generally viewed as anomalous, and the small pores here are disregarded when the pore pattern is determined

In addition to black walnut and black cherry, some other fairly common North American semi-ring porous/semi-diffuse porous species are butternut (*Juglans cinerea*) (sometimes known as "white

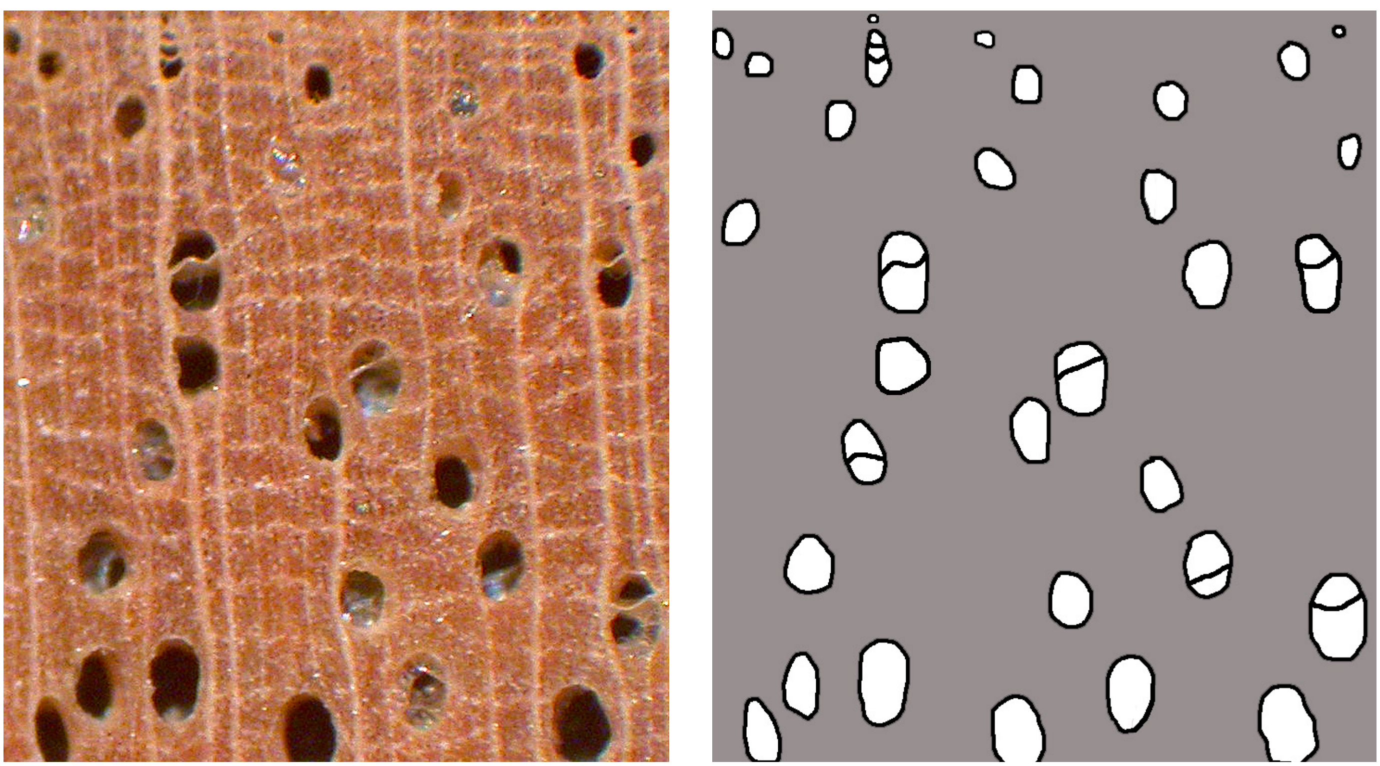

Figure 8-5. The micrograph of a black walnut (*Juglans nigra*) growth ring on the left is sketched on the right to better show how the pore size changes across the growth ring. Black walnut is a semi-ring porous wood, but it can also be correctly called a semi-diffuse porous wood.

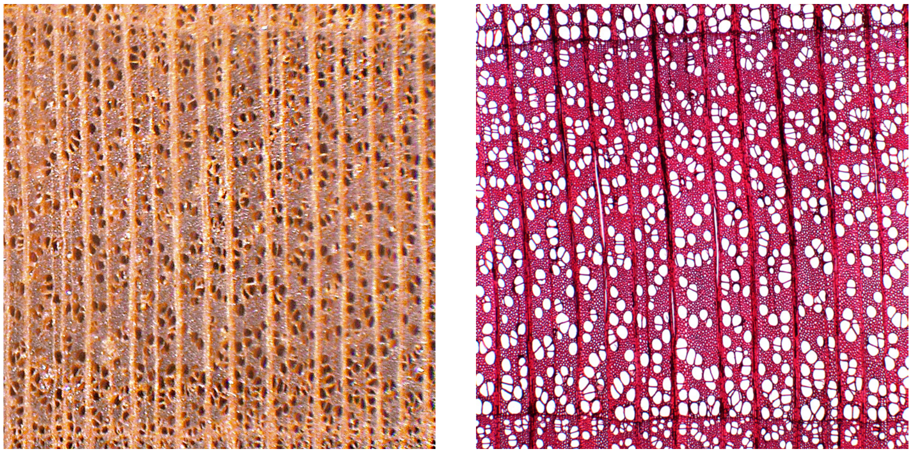

Figure 8-6. Micrographs of black cherry (*Prunus serotina*). The pores appear to be similar in size until the very end of the growth ring, though it's evident that there is a higher concentration of pores at the very beginning of the growth ring.

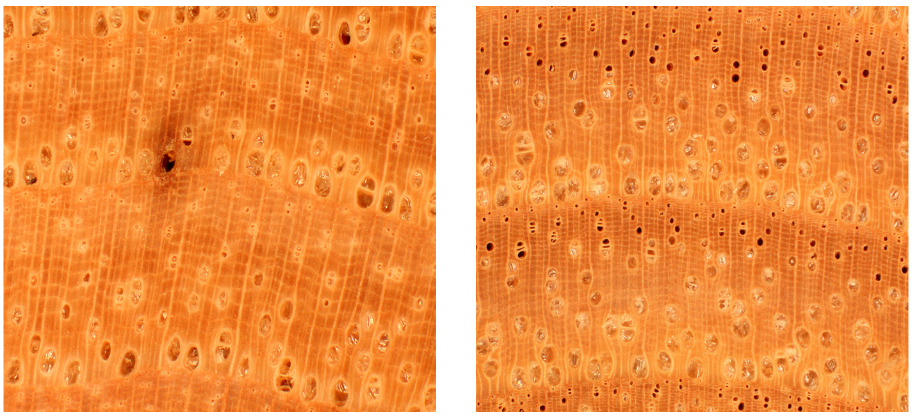

Figure 8-7. As seen in the photograph on the left, the growth rings of hickory (*Carya sp.*) sometimes exhibit different pore patterns, even in adjacent growth rings. Notice that the lower growth ring is semi-ring porous, while the upper growth ring is plainly ring porous. In pecan (*C. illinoensis*), as seen in the sample on the right, growth rings seem to typically be exclusively semi-ring porous.

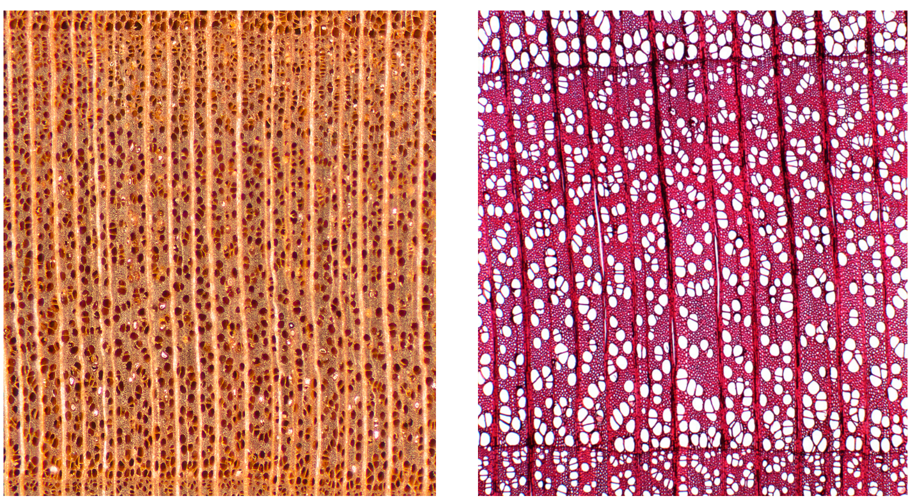

Figure 8-8. Micrographs of black cherry (Prunus serotina). In the sample on the left the pores seem to gradually get smaller across the growth ring. The micrograph on the right shows a similar sample of black cherry through an ordinary light microscope. The transmitted light might make it easier to see that the pore size appear to decrease slowly from the earlywood through to the final 10 percent of the growth ring, where the vessels get smaller quite suddenly. The higher concentration of pores at the beginning of the growth ring is typical for black cherry.

walnut") and American persimmon (*Diospyros virginiana*). Yellowwood (*Cladrastis kentukea*) doesn't grow over a wide area (it's native to eastern Kentucky and parts of the adjoining Appalachian states) but it's also a semi-ring porous wood. Sometimes planted as an ornamental, it's a species that is aptly named for the color of its heartwood.

Varying Pore Distribution Patterns

Many commercially important species exhibit "typical" pore distribution patterns, but sometimes wood can't be placed neatly into one of the three pore pattern categories. Most temperate species *are* typically ring porous, diffuse porous, or semi-ring porous, but even North American species can have pore patterns that vary from sample to sample or even from one growth ring to another in the same piece! This might be due to differing amounts of rainfall, differing latitudes, etc.[3]

When pore patterns vary they are most noticeable in species with larger, more obvious pores. The hickories (*Carya sp.*) are a good example of this; you can sometimes find both semi-ring porous and ring porous patterns in adjacent growth rings in hickory, and identification keys in different textbooks sometimes put hickory into different categories for that reason. Pecan hickory (*Carya illinoensis*) is an exception, as it always seems to be semi-ring porous. Take a look at the photographs of hickory and pecan in Figure 8-7.

Black cherry (*Prunus serotina*) doesn't have large pores, but it's another example of a species where you might find both semi-ring porous and diffuse porous specimens. Many times the pores look similar in size across most of the growth ring, but sometimes the pores seem to gradually get smaller. In either case, black cherry would be classified as semi-ring porous (Figure 8-8).

The hickories and black cherry aren't

3 For example, see Roque, R., M. Filho, and C. Dias. (2007). Wood anatomical variation of Gmelina arborea Roxb. (Verbenaceae) trees from dry and wet tropical climatic in Costa Rica. Scientia Forestalis/Forest Sciences. 35(75): 65–75.

the only species with variable pore patterns on the cross-section. Cottonwood and aspen (both Populus sp.) and black willow (Salix nigra) are also documented to be semi-ring porous to diffuse porous. You might need a hand lens, and not every sample has noticeable gradations in pore size from the beginning to the end of the growth ring. You might also need magnification to see differences in the frequency of pores across the growth ring (see Figures 8-9 and 8-10).

Remember: It's important to keep in mind that wood is a variable material! Consider this when you're trying to key out an unknown sample.

Comparison of Hardwood Growth Ring Types

Sometimes the best way to learn is to make direct comparisons so you can see how they are different. With that in mind, take a look at how the different pore distribution patterns look next to each other. Figure 8-11 has side-by-side photographs of some representative diffuse porous, semi-ring porous and ring porous species, respectively. It's easy to see that the pores are all about the same size in the diffuse porous sugar maple, and that the pores gradually decrease in size from earlywood to latewood for the black walnut. Ash should be instantly recognizable as a ring porous species because the pore size changes from large to small so quickly.

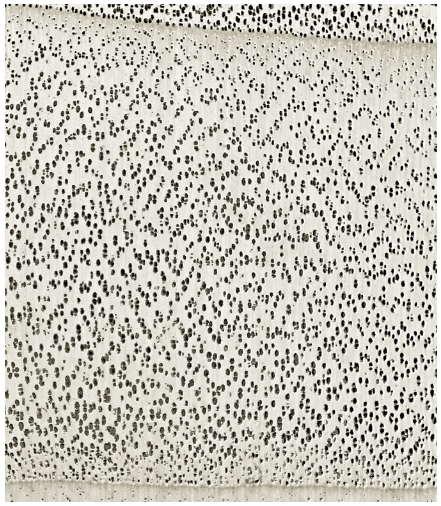

Figure 8-9. A micrograph of a piece of cottonwood (*Populus deltoides*) reproduced at a size that approximates the view you would see with a 10X hand lens. In this sample the pores all look about the same size for a large part of the growth ring, so this might be classified as diffuse porous even though the pores become noticeably smaller and sparser.

Growth Ring Boundaries

When pore sizes change across the growth ring, as in ring porous species, it's fairly easy to see the growth ring boundaries. In diffuse porous species the pore sizes are more consistent, so it's often somewhat difficult to see where one growth ring stops and another begins. There are a couple of features that you can look for: depending on the species, there might be fine lines of denser fibers or lines of parenchyma cells between

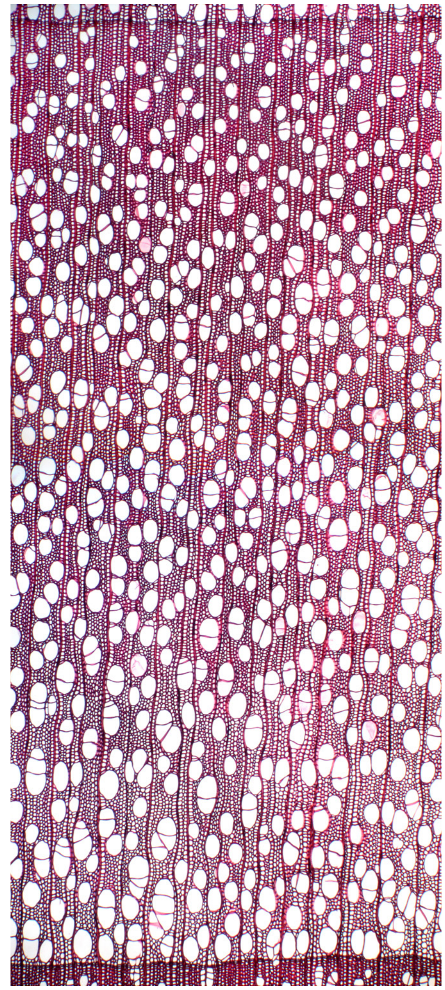

Figure 8-10. Another piece of cottonwood (*Populus deltoides*). The pore sizes get somewhat smaller across the growth ring, although this happens very gradually; as in the preceding example, the pores gradually occupy smaller fractions of the growth ring from beginning to end.

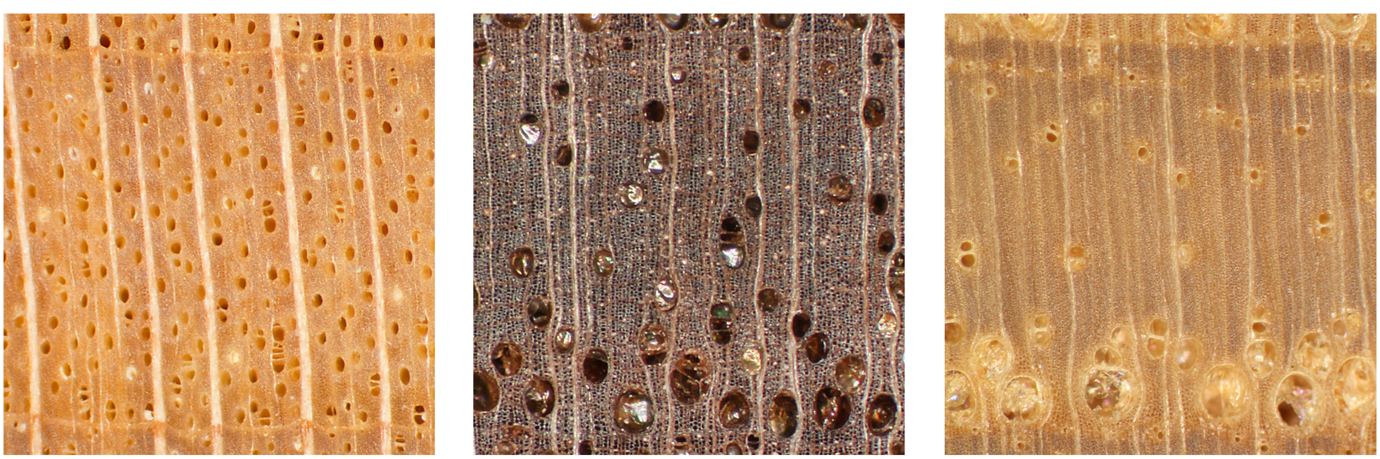

Figure 8-11. Sugar maple (*Acer saccharum*), a diffuse porous species, is on the far left. Black walnut (*Juglans nigra*), a semi-ring porous species, is in the middle photograph. White ash (*Fraxinus americana*), a ring porous species, is on the far right. Each of these photographs shows a single growth ring, and the photos were taken at similar but not necessarily identical magnifications.

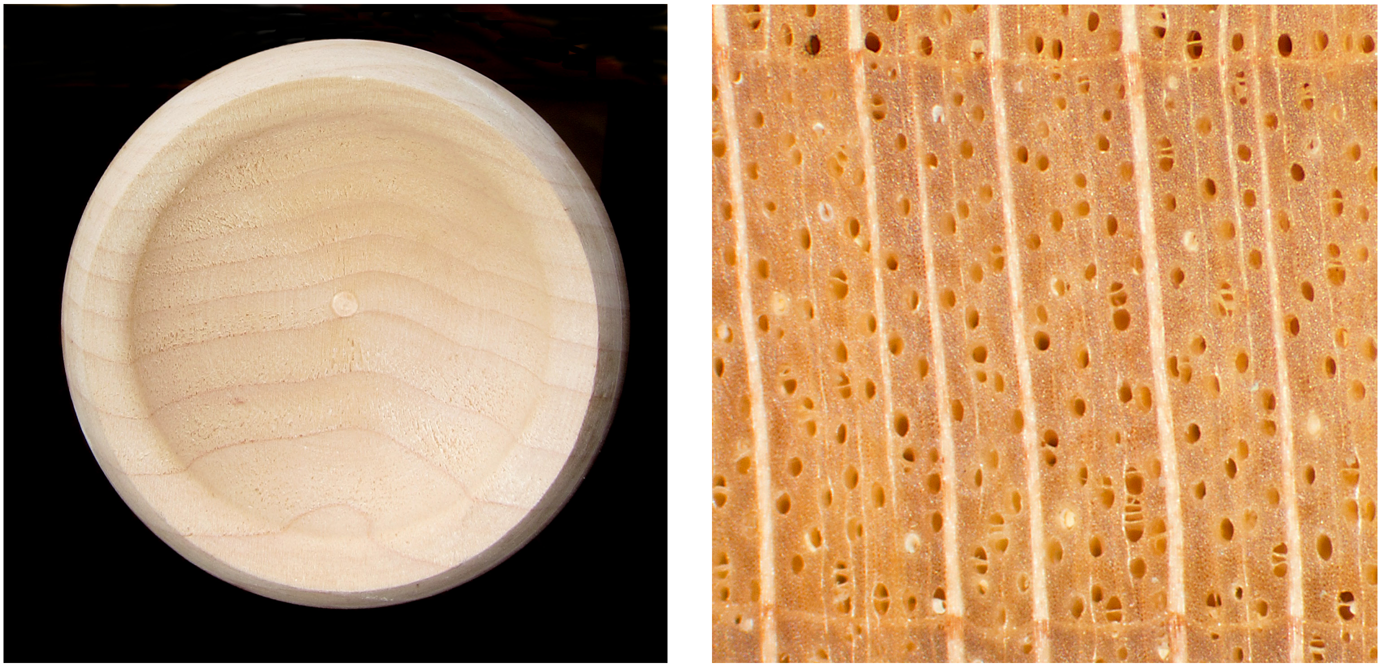

Figure 8-12. The photograph on the left shows the cup end of a sugar maple baseball bat (*A. saccharum)*. The dark lines indicating the boundaries between growth rings are caused by thin lines of denser fibers. The micrograph on the right is an enlarged version of the sugar maple photograph shown in Figure 8-11. The fine lines of denser fibers are less distinct than they appear to the naked eye, though they are easy to see once you know what to look for. The magnification is somewhat higher than you would normally see with a 10X hand lens.

growth rings. Some tropical species have no features to distinguish growth ring boundaries.

Lines of Dense Fibers

Sugar maple is an example of a species with dense fibers at the ends of the growth ring. Figure 8-12 shows two photographs of sugar maple (*A. saccharum*) that show how growth rings might appear differently at different levels of magnification.

Color differences at the growth ring boundaries appear more significant when viewed with the naked eye than they do under magnification.

Figure 8-13 illustrates another view of the transmitted light micrograph of sugar maple previously shown in Figure 8-2. It's easy to see how the fibers get thicker at the very ends of the growth rings.

Parenchyma at Growth Ring Boundaries

In hardwoods, parenchyma often appear as a lighter-colored band between growth rings. Typical examples include yellow-poplar (*Liriodendron tulipifera*) and basswood (*Tilia americana*). Observing parenchyma between growth rings is often used as one of the identifying features of these species (and others).

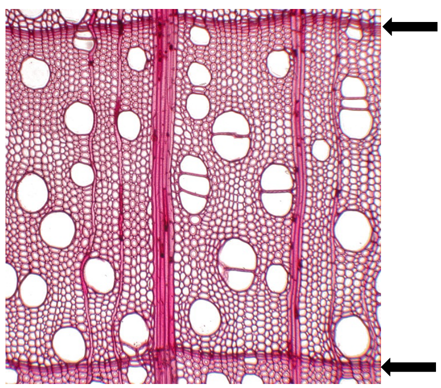

Figure 8-13. This thin section from a piece of sugar maple (*A. saccharum*) clearly shows the denser fibers at the ends of the growth rings (see arrows).

Parenchyma cells can form either at the end or the beginning of growth rings, depending on the species. When they are found at the beginning of the growth ring they are called *initial parenchyma* and when they are found at the end of the growth ring they are called *terminal parenchyma*; they look very similar in either case. To simplify things, the term *marginal parenchyma* is often used to cover both situations. Figure 8-14 shows an example of a piece of yellow-poplar (*Liriodendron tulipifera*) with marginal parenchyma.

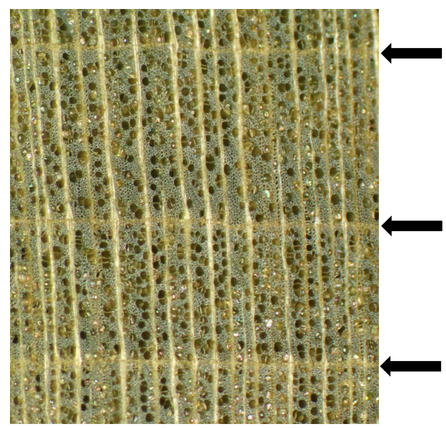

Figure 8-14. This photograph of yellow-poplar (*Liriodendron tulipifera*) was made with a stereozoom microscope and shows light-colored bands of marginal parenchyma at the boundaries of two complete growth rings. (The marginal parenchyma are indicated by arrows.)

Growth Ring Boundaries in Tropical Species

Marginal parenchyma are fairly common in hardwoods, particularly in tropical species. If you're a woodworker, you may be familiar with these tropical species that contain marginal parenchyma: true mahogany (*Swietenia macrophylla*), jatobá (*Hymenaea courbaril*), and cocobolo (*Dalbergia retusa*). (There

Figure 8-15. Photographs showing the differences between a ring porous hardwood (red oak, on the left) and a diffuse porous hardwood (hard maple, on the right). Note how the growth rings differ between the two species. In red oak, the earlywood pores are large and appear darker because they result in a greater effect of depth on the surface. In hard maple, the pores are not visible, and the growth rings are distinguished by the darker latewood fibers at the ends of the growth rings.

are many other species in this category, far too many to list.)

Some diffuse porous species have neither marginal parenchyma nor thickened fibers at the growth ring boundaries, so identifying growth ring boundaries is difficult. Balsa (*Ochroma pyramidale*) is one species you may be familiar with that has these characteristics. Sometimes a growth ring boundary is visible in one location but not in another.

Looking at Growth Rings on Wood Side Grain

Sometimes it's desirable to identify a piece of wood even though you can't inspect the end grain. This happens more often than you might imagine; perhaps you're looking at the wood on a desk front, flooring, or a door, for example. Because trees are shaped more like overlapping cones than rolls of paper, every flat board exposes growth rings on the side grain surfaces. One of the easiest things to determine from side grain is whether the wood is ring porous or diffuse porous. In smooth pieces of wood, the earlywood pores are visible as dark streaks on the side grain of ring porous species because the ambient light reflects differently from the rough surface. With rough-cut pieces

Figure 8-16. Another real-world example of growth ring differences between diffuse porous and ring porous species. In this photograph, a ring porous tie (red oak) is at the top and the central tie is diffuse porous (yellow-poplar). Notice the pulled fibers from the saw cut at the earlywood boundaries in the oak tie, and compare that to the smooth surface of the yellow-poplar tie. Notice the pulled fibers at the earlywood boundaries in the ring-porous tie, and compare that to the smooth surface of the diffuse porous tie. The regularly spaced marks are indentations (called *incisions*) that are mechanically pressed into the ties to minimize long checks arising during shrinkage. Without incisions, some species tend to develop severe cracks, sometimes extending almost the entire length of the tie. Long checks are undesirable because they will degrade the mechanical performance of the ties.

of ring porous wood, the earlywood pores will often be slightly pulled away from the surface, making them easy to see. Diffuse porous woods are smooth-textured; growth ring boundaries may be indicated by either terminal parenchyma or compressed fibers at the ends of the growth rings. See the photographs of red oak (*Q. rubra*) and hard maple (*A. saccharum*) panels in Figure 8-15, and notice the differences in the side grain of the ring porous and diffuse railroad ties in Figure 8-16.

Summary

There are three categories of pore distributions for temperate hardwood species: 1) in diffuse porous species, the vessel diameters are very similar across almost the entire growth ring (with the possible exception of the very end of the growing season); 2) ring porous species have earlywood pores that are significantly larger than the latewood pores; 3) semi-ring porous species can also correctly be called semi-diffuse porous species (the terms are synonymous), and these species have pore sizes which gradually change across the growth ring. Some species can be found with more than a single pore distribution pattern, probably because of where they grow. Variation like this is easiest to spot in species with large pores, and especially in ring porous species.

Marginal parenchyma are light-colored bands of tissue located either at the ends or the beginnings of growth rings; they help make individual growth rings much more distinguishable, especially for diffuse porous species where the lack of pore size variation makes the wood look pretty uniform otherwise. The appearance of large pores on the side grain of ring porous species distinguishes them from diffuse porous species.

VOCABULARY

If you don't remember any of the following words, please review this section. Vocabulary is very important!

1. Diffuse porous
2. Ring porous
3. Semi-ring porous
4. Semi-diffuse porous
5. *Liquidambar styraciflua (s*weetgum)
6. *Fraxinus americana* (white ash)
7. *Acer saccharum* (sugar maple)
8. *Fagus grandifolia* (American beech)
9. *Betula papyrifera* (white birch)
10. *Cornus florida* (American dogwood)
11. *Populus deltoides* (cottonwood)
12. *Platanus occidentalis* (American sycamore)
13. *Liriodendron tulipifera* (yellow-poplar)
14. *Quercus rubra* (red oak)
15. *Juglans nigra* (black walnut)
16. *Prunus serotina* (black cherry)
17. *Juglans cinerea* (butternut, also known as "white walnut")
18. *Diospyros virginiana* (American persimmon)
19. *Cladrastis kentukea* (yellowwood)
20. *Carya sp.* (shorthand for one of the hickory species)
21. *Carya illinoensis* (pecan hickory)
22. *Salix nigra* (black willow)
23. *Tilia americana* (American basswood)
24. *Swietenia macrophylla* (true mahogany)
25. *Hymenaea courbaril* (jatobá)
26. *Dalbergia retusa* (cocobolo)
27. *Ochroma pyramidale* (balsa)

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