

# WOOD!

**IDENTIFYING AND  
USING HUNDREDS OF  
WOODS WORLDWIDE**

**ERIC MEIER**

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# A Brief Introduction: From the Author

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When it comes to those who work with wood, there seems to be generally two classes of people: scientists and craftsmen. This book was written for the latter.

What I have found in my own personal observation of those that work with wood is that the first class of people, the scientists, are almost drowning in knowledge. Yet the craftsmen, through no particular fault of their own, are suffering in a relative dearth of solid facts and scientific understanding.

Books on the subject of wood usage and identification have all come from one of two very opposite poles. Either there have been craft-oriented books filled with pretty pictures, but with very weak or vague and impractical statements, such as “this wood is strong, hard, and moderately stable,” or else there have been thinly-veiled scientific books, burying the uninitiated in grainy, black-and-white microscope images and confusing terminology.

As I began researching and writing this book, many questions began circling in my head. “Can’t a book exist that features both vivid and accurate pictures, and also solid, usable facts and information on wood species? What’s practically applicable to the realm of woodworking and related trades, and what should be left to the fastidious and exacting eyes of scientists?”

In the midst of these myriad questions, I was debating whether or not to get a microscope and delve into the world of microscopic wood identification. Here I was, probably one of the biggest wood “nuts” around, utterly fascinated by the many types and varieties of wood, when I had an epiphany. “If I personally don’t have *any* desire to buy and learn to use a microscope to help identify wood, then why in the world would I ever expect anyone else to either?”

At that point, a line had been drawn in the sand. I determined that as I made an effort to learn (and thereafter teach others) about scientific wood data and identification, I didn’t need to consult with the “other side” to see what would be most helpful to them: I *was* the other side! I realized that I was a woodworker, and not a scientist—and for my purposes, that was not necessarily a bad thing.

A friend of mine who works in Bible translation once told me that in order for a translation to be optimally readable and usable for native peoples, it ultimately must be written by someone whose mother tongue is in the native language, or else it will seem awkward, foreign, and inarticulate.

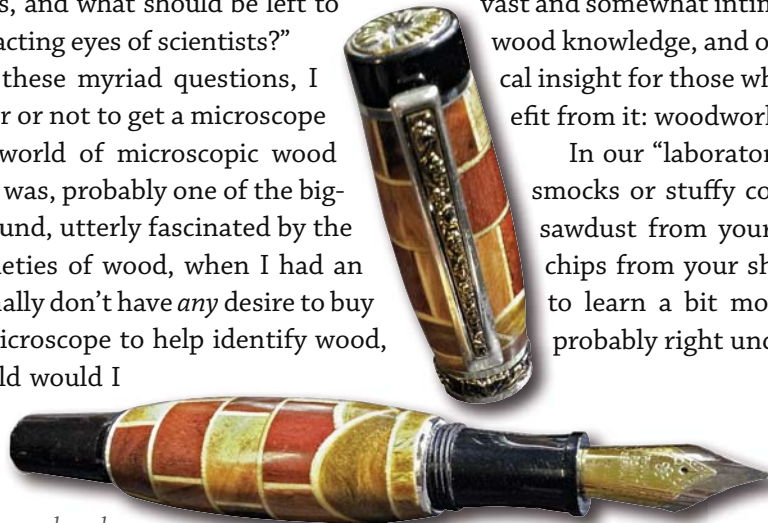
I am of the opinion that a very similar phenomenon happens whenever any attempt is made from the scientific community to condescend and “write down” to craftspeople: the information trying to be relayed is very good and useful, but it’s spoken from an entirely different background and mindset, and is almost completely lost in translation.

It’s therefore my hope and intention with this book to act as an interpreter in a way, and to traverse the vast and somewhat intimidating territory of scientific wood knowledge, and open a fresh pipeline of practical insight for those who stand to most directly benefit from it: woodworkers.

In our “laboratory,” you’ll find no clean white smocks or stuffy collars. Come on in, shake the sawdust from your hair, brush off those wood chips from your shoulders, and take a moment to learn a bit more about the material that’s probably right under your nose: WOOD!

*Eric Min*

Mopane, Olive, Verawood, and  
Yellow Poplar veneer fountain pen



# 1 Foundations: What is Wood?

It's common knowledge that wood comes from trees. What may not be so apparent is the structure of the wood itself, and the individual elements that make up any given piece of lumber. Unlike a mostly homogeneous piece of polystyrene, MDF, or other man-made material, wood is an organic material, and has many distinct characteristics which will be helpful to learn.

## HARDWOODS AND SOFTWOODS

An immediate and broad distinction that can be made between types of trees (and wood) is the label of **hardwood** or **softwood**. This is somewhat of a misnomer, as the label is actually just a separation between **angiosperms** (flowering plants such as maple, oak, or rosewood), and **conifers** (cone-bearing trees such as pine, spruce, or fir).

Hardwoods (angiosperms) have broad-leaved foliage, and tend to be **deciduous**—that is, they lose their leaves in the autumn. (However, many tropical hardwood species exist which are **evergreen**—they maintain their leaves year-round.) Additionally, hardwood trees tend to have a branched or divided trunk, referred to as a **dendritic form**.

Softwoods (conifers) tend to have needle or scale-like foliage, though in some uncommon instances, they can have rather broad, flat leaves, such as Kauri (*Agathis australis*). Most softwood trees are evergreen, however, a few conifers, such as Bald-cypress (*Taxodium distichum*), lose their foliage in the autumn, hence the “bald” prefix in the common name.

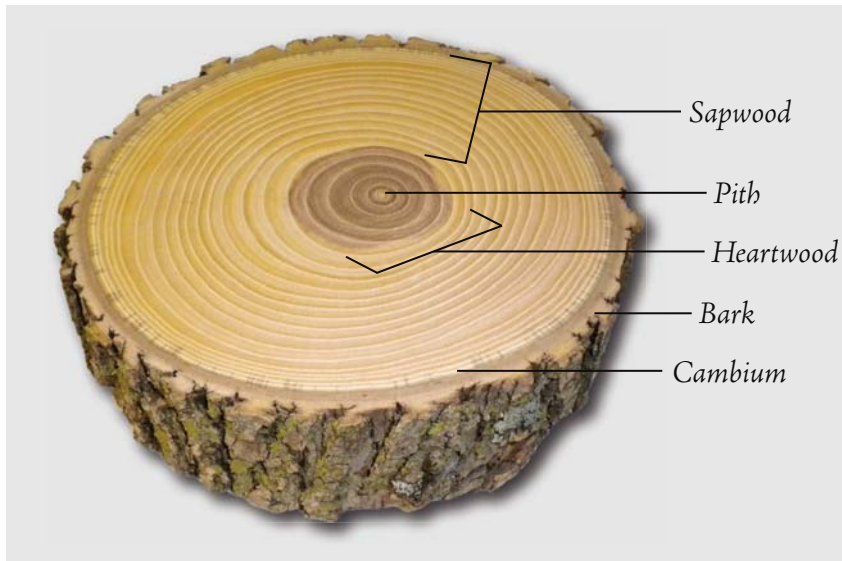
Softwoods tend to have a single, dominant, straight trunk with smaller side branches, referred to as an **ex-current form**—this cone-shaped growth form helps trees in temperate climates shed snow. Again, there are several conifers that are an exception to this growth form, such as Cedar of Lebanon (*Cedrus libani*).

The confusion in labels arises in that the wood of angiosperms is not always hard—a glaring example is Balsa (*Ochroma pyramidale*), which is technically classified as a hardwood. Conversely, the wood of conifers is not necessarily always soft—an example of a relatively hard softwood would be Yew (*Taxus* spp.). However, as a rule of thumb, hardwoods are of course generally harder than softwoods, and the label is still useful to distinguish between two broad groups of trees and certain characteristics of their wood.



The spruce tree pictured to the left is a good representation of a conifer with evergreen, needle-like foliage and a single, dominant trunk. Their long, straight trunks and lightweight timber make softwoods well-suited for structural building purposes. On the right is an oak tree—with a branching form, and leaves that drop seasonally—which is characteristic of most angiosperms. Their higher density and rich heartwood colors make hardwoods well-suited for furniture and decorative woodwork.





In this cross section of Green Ash (*Fraxinus pennsylvanica*), the sapwood section is disproportionately wider than most hardwood species. In some tree species, the sapwood is less than one inch thick, with the remaining trunk being composed of heartwood. Ash (*Fraxinus spp.*), along with maple (*Acer spp.*), birch (*Betula spp.*), and a handful of other woods, are utilized mainly for their wide, light-colored sapwood. Conversely, the darker heartwood is normally the commercially valuable part of the tree, as in domestic species such as Black Walnut (*Juglans nigra*) and Black Cherry (*Prunus serotina*).

## TREE GROWTH

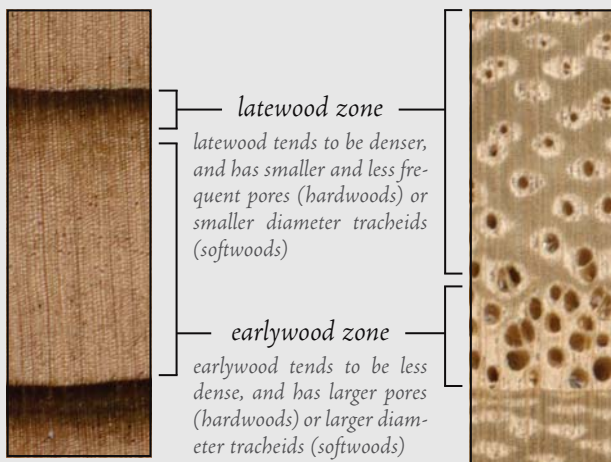
When considering a tree's growth—whether a tiny sapling, or a one-thousand-year-old giant—there are many features that are common to all species. Besides the basics of the roots, the main stem (trunk), and the

leaves and branches, there are growing points at the tips of the stems and roots, called **apical meristems**. These growing points, through cell division, are responsible for the *vertical* growth in trees.

Additionally, sandwiched between the bark and the inner wood is a thin layer or sheath called the **lateral meristem** or **vascular cambium**—usually referred to simply as the *cambium*. This tiny, seemingly magical layer is responsible for practically all of the *horizontal* growth on a tree. The cambium consists of reproductive cells that, by cell division, forms new bark outward, and new wood inward.

It is the seasonal growing activity of the cambium that is responsible for the formation of **growth rings** seen in wood. In temperate zones, the cambium is most active in the spring—this wood is sometimes referred to as **springwood** or **earlywood**, with growth slowing in the summer (called **summerwood** or **latewood**), and completely ceasing in the winter. These differences in growing cycles from year to year form **annual rings**, which are a reasonably accurate indicator of a tree's age.

In tropical zones, where temperature and seasonal variations are minimal, wood can completely lack



Note the much wider earlywood zone in softwoods such as the Redwood (*Sequoia sempervirens*), pictured on the left (10×), as compared to hardwoods like Paulownia (*Paulownia tomentosa*), on the right. When a tree grows slower than average (perhaps due to an unfavorable growing site), both the earlywood and latewood zones become proportionately condensed. This difference explains why slower growing softwoods tend to be stronger (the weaker earlywood zones are narrower), while slower growing ring-porous woods like oak or ash tend to be weaker (the stronger latewood zones are narrower).



At left is a 10× endgrain view of Avodire (*Turraeanthus africanus*), a tropical African hardwood species. Note the overall lack of discernible growth rings or earlywood and latewood zones.

discernible rings, or they may correspond with various rainy seasons, and thus are more safely referred to as *growth* rings, and not strictly as *annual* rings.

## SAPWOOD AND HEARTWOOD

As the cambium forms new wood cells, they develop into different sizes, shapes, and orientations to perform a variety of tasks, including food storage, sap conduction, trunk strength, etc. When a tree is young, certain cells within the wood are alive and capable of conducting sap or storing nutrients—this wood is referred to as **sapwood**.

After a period of years (the number can greatly vary between species of trees), the tree no longer needs the entire trunk to conduct sap, and the cells in the central part of the stem, beginning at the core (called the **pith**), begin to die. This dead wood which forms at the center of the trunk is thus called **heartwood**.

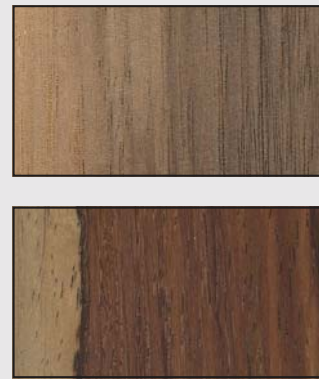
The transition from sapwood to heartwood is accompanied by the accumulation of various deposits and substances, commonly referred to as **extractives**.

Most notably, these extractives are responsible for giving the heartwood its characteristic color: the jet-black color of ebonies (*Diospyros* spp.), the ruby-red of Bloodwood (*Brosimum rubescens*), and the chocolate-brown of Black Walnut (*Juglans nigra*)—each owe their vivid hues to their respective heartwood extractives. Without extractives, the sapwood of nearly all species of wood is a pale color, usually ranging from white to a straw-yellow or gray color.

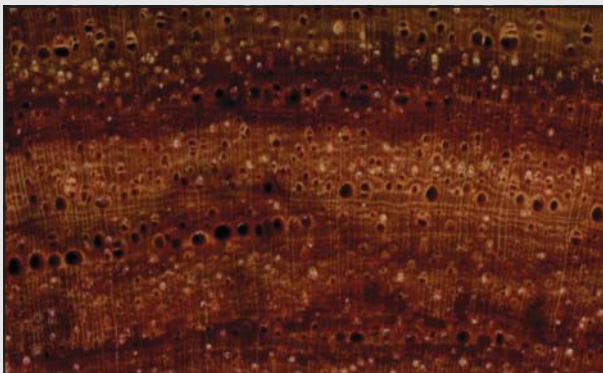
But heartwood extractives are responsible for more than just color: extractives increase (to varying degrees)

the heartwood's resistance to rot and decay, and give it added stability and hardness. (Sapwood has virtually no resistance to decay.) From a biological standpoint, it's easy to see the benefits that heartwood brings to the tree as it grows taller and broader. Incidentally, many of these same benefits translate into advantages for woodworkers as well.

However, it should be noted that the transition area from sapwood to heartwood, commonly referred to as **sapwood demarcation**, can vary from gradual to very abrupt: this can be important in wood projects where decay resistance is needed. A clear line of demarcation helps prevent the inadvertent inclusion of sapwood, and minimizes the risk of subsequent rotting or structural damage.



Notice the very subtle transition from sapwood to heartwood on the upper sample of Black Walnut (*Juglans nigra*) as compared with the very sharp line of demarcation on Amazon Rosewood (*Dalbergia spruceana*) on the bottom.

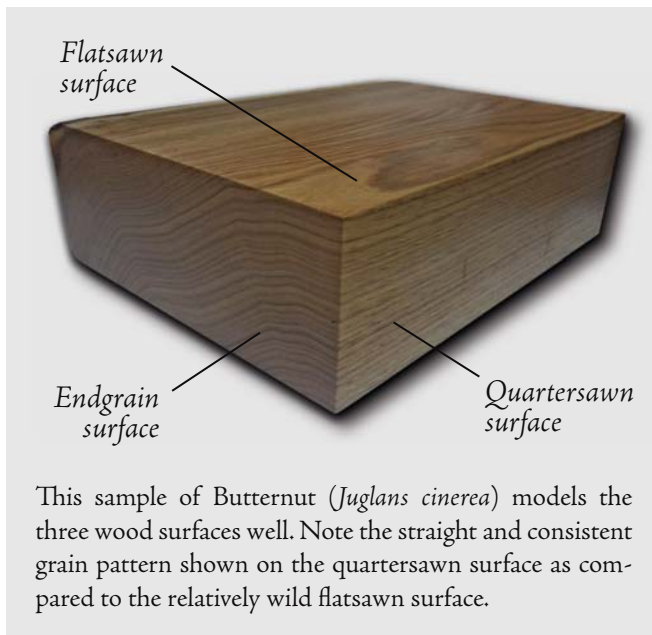


Heartwood extractives, like those found in this sample of Tulipwood (*Dalbergia decipularis*), provide a cornucopia of colors and unique wood properties. (10×)

## PLANES OR SURFACES OF WOOD

When discussing processed wood and lumber, it's necessary to understand which surface of the wood is being referred to. Working within the scope of the growth rings and their orientation within the tree's trunk, there are three primary planes, or surfaces, that are encountered in processed wood.

The first wood surface is the **endgrain** (which is by far the most useful plane for wood identification purposes). This surface is sometimes referred to as the **transverse surface**, or the **cross section**. This plane is mostly self-explanatory: in processed lumber, it's the section where a board is typically viewed on its end, and circular growth rings may be clearly observed. For the sake of simplicity and clarity, all references in this book will refer to this wood plane as simply the *endgrain*.



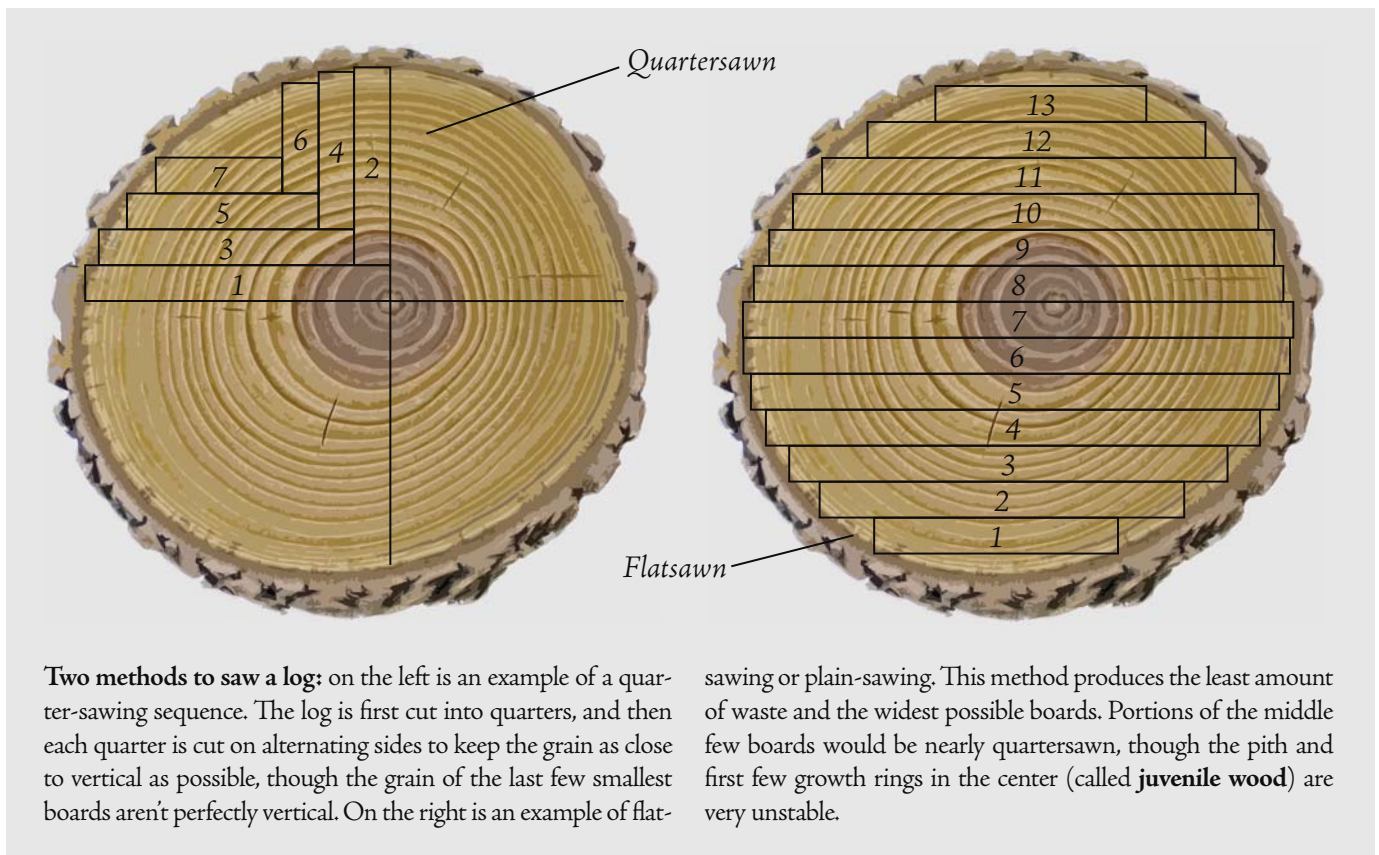
The second primary wood plane is the **radial surface**. (Think of the word *radiate*: this wood surface radiates out from the center of the log like spokes on a wheel, and crosses the growth rings at a more-or-less 90° angle.) This surface goes by a number of names, and is sometimes called **vertical grain**, or the **quartersawn section**.

The reason for such naming is that when sawing a log, it may be sawn into quarters along the length of the log, forming four long, triangular, wedge-shaped pieces. Next, boards are sawn from each wedge on alternating sides, resulting in boards which (when viewed from the endgrain) have growth rings that are perpendicular to the face and run vertically.

Again, for simplicity and clarity, most references in this book will refer to this wood plane as the *quarter-sawn surface*. This is perhaps not the standard scientific terminology used, but it's the most common description used among sawyers and woodworkers.

The third and final surface is the **tangential surface**. (Think of the word *tangent*: the wood surface is more or less on a tangent with the growth rings.) This plane is sometimes called the **flatsawn** or **plainsawn surface**.

The reason for such naming comes again from the process of sawing the log. The normal or “plain” method of sawing a log is to cut straight through in a repetitious sequence, leaving the log flat throughout the entire process. (This is also sometimes called through-and-through sawing.) Most subsequent references in this book will refer to this wood plane as the *flatsawn surface*.



## GRAIN APPEARANCE

Although quartersawn and flatsawn surfaces are named after their original method of sawing, in practice, the terms typically just refer to the angle of the growth rings on a piece of processed lumber, with anything approaching 90° being referred to as quartersawn, and anything near 0° generally considered as flatsawn, regardless of how the log was actually milled.

There's sometimes an intermediate angle commonly called **riftsawn** or **bastard grain**, which corresponds with growth rings angled between approximately 30° to 60°. Although it's called riftsawn, sawyers today will rarely, if ever, specifically saw up a log in order to get such an angle—usually the name merely serves as a convenient term to describe wood that is not perfectly quartersawn.

Additionally, the term **face grain** usually denotes the most predominant/widest plane on any given piece of lumber (excluding the endgrain), and does not refer to any specific cut. By observing the angle of the growth rings—as when looking at a stack of boards where only

the endgrain is visible—a reasonably accurate prediction of the appearance of the face of the board can be made. Likewise, in many instances where only the face grain of a board is visible, the endgrain may be extrapolated by “reading” the grain pattern. Each grain cut has varying strengths and weakness, and is used in different applications.

Quartersawn boards are very uniform in appearance and are good for long runs of flooring where the boards need to be butted end-to-end with minimal disruption in appearance. Quartersawing also produces the stablest boards with the least tendency to cup or warp with changes in humidity, which is very useful in many applications, such as for the rails and stiles of raised panel doors. However, because of the extra handling involved with processing the log, and the higher waste factor, quartersawn lumber tends to be more expensive than flatsawn lumber.

Most would agree that flatsawn boards—with their characteristic dome-shaped **cathedral grain**—tend to yield the most visually striking patterns (and it



**Reading the grain:** note the appearance of the face grain of these three boards, as well as their corresponding endgrain surfaces beneath. On the left, Beli (*Julbernardia pellegriniana*) is almost perfectly quartersawn, resulting in a straight, narrowly spaced, and uniform grain pattern. In the middle, Ponderosa Pine (*Pinus ponderosa*) is flatsawn, resulting in a

characteristic “cathedral” grain pattern. On the right, Western Hemlock (*Tsuga heterophylla*) has a section on the left that is flatsawn, grading down to riftsawn, as reflected on the face of the board, which appears flatsawn on the wild portion on the left, and closer to quartersawn on the straighter and more uniform portion on the right.

should come as no surprise that many veneers are also rotary-sliced from logs to reproduce this appearance). Flatsawn boards are also available in wider dimensions than quartersawn stock, and are well-suited to applications such as raised or floating panels, or other areas where width or appearance are important.

Riftsawn wood lies somewhere between these two aforementioned types. It has a uniform appearance that is very similar to quartersawn wood—and it's nearly as stable too. On large square posts, such as those used for table legs, riftsawn wood has the added benefit of appearing roughly the same on all four sides (since the growth rings on each of the surfaces are all at approximately 45° angles to the face), whereas quartersawn squares would have two sides that display flatsawn grain, and two with quartersawn grain.

## RAYS

A discussion on quartersawn and riftsawn lumber would not be complete without mentioning the most significant visual distinction between the two: presence (or absence) of **rays**—or perhaps more accurately, the *conspicuous presence* of rays on the face of the board, known commonly as **ray fleck**, or **ray flakes**.



Note the lighter colored rays radiating out from the pith in this sample of Holm Oak (*Quercus ilex*). Ray fleck is only apparent in areas on the face of the board that are nearly perfectly quartersawn, with the flat and rift sawn areas on the left two thirds obscuring the rays under a lower profile.

In the same way that quartersawn surfaces radiate out from the center of the log (hence the term *radial* surface), rays are also oriented in the same direction; for this reason, although rays are always technically present in the wood, they become most visible and pronounced on quartersawn surfaces. (Additionally, end-grain drying checks also tend to occur along the rays.)



The rays seen in this 1× endgrain view of Lacewood (*Panopsis* spp.) are so large and prevalent, they could easily be mistaken for growth rings.

But even though virtually all woods have rays, only species with wide, conspicuous rays will produce dramatic ray fleck on the quartersawn surface. Perhaps the largest rays are found on woods like Leopardwood (*Roupala montana*) and Lacewood (*Panopsis* spp.), so named for the superb ray fleck seen on their quartersawn surfaces.

Domestic woods like oak (*Quercus* spp.) and sycamore (*Platanus* spp.) also have easily observable rays. Other woods have more modest ray fleck, such as cherry (*Prunus* spp.) or elm (*Ulmus* spp.). Many other species, such as ash (*Fraxinus* spp.), walnut (*Juglans* spp.), and chestnut (*Castanea* spp.), as well as most softwoods, lack visible ray fleck patterns.

It should be noted that ray fleck is not always greeted with enthusiasm: the very same feature that may entice a person to purchase quartersawn oak may also repel another away. In some instances—such as for hardwood floors where a subdued or consistent grain pattern may be desired—ray fleck may be viewed as objectionable or distracting. For this reason, riftsawn woods, most commonly White Oak (*Quercus alba*), are occasionally offered as a means to reap the benefits of uniformity and stability of quartersawn lumber without the sometimes distracting rays.

# 2 Building on Basics: Wood and Moisture

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Perhaps the most important aspect of woodworking deals with the relationship between wood and moisture. The most skilled builder may plane, chisel, or otherwise finesse a wood project into a flawless work, but if wood moisture is ignored, all will be for naught. Joints will pop loose, wide glued-up panels will warp or split, and flooring planks will retract and reveal unsightly gaps (or expand and buckle).

A fundamental fact is that wood is **hygroscopic**. This means that wood, almost like a sponge, will gain or lose moisture from the air based upon the conditions of the surrounding environment. But not only does wood gain or lose moisture, but it will also *expand or contract* according to its moisture level. It's this swelling and shrinking in finished wood products, often referred to

as the wood's **movement in service**, that's responsible for so much mischief and so many malfunctions in woodworking.

When a tree is first felled, it's considered to be in the **green** state, denoting its maximum moisture level. This moisture exists in two different forms: as **free water** that's contained as liquid in the pores or vessels of the wood itself, and as **bound water** that's trapped within the cell walls.

Once a fresh log or piece of lumber is cut and exposed to the air, it will immediately begin losing free water. At this point, the wood does not yet contract or otherwise change in dimension since the fibers are still completely saturated with bound water. Once all the free water has been lost, the wood will reach what is called the **fiber saturation point**, or simply **FSP**.

Below the FSP, the wood will then begin to lose moisture in the form of bound water, and an accompanying reduction in the wood's physical volume will occur. In a practical sense, the wood at this point is now considered to be in a state of *drying*.

During drying, not all of the bound moisture will be lost: just how much water is lost will ultimately depend upon the temperature and relative humidity (RH) of the surrounding air. At 100% RH, no bound water will be lost. At 0% RH, all the bound water in the wood will be lost, a condition known as **ovendry** (so-called because a kiln or oven is typically required to completely drive out all moisture).

The amount of water in a given piece of wood is expressed as a percentage of the weight of the water as compared to its ovendry weight. Some species of trees, when they are initially felled, may contain more water by weight than actual wood fiber, resulting in a **moisture content** (MC) over 100%.



The panel of this old church door has a split. The door is located next to a radiator, exposing the wood to extremely low humidity levels, which more than likely caused the panel to contract and eventually split.

# Yellow Birch

## *Betula alleghaniensis*

**DISTRIBUTION:** Northeastern North America

**TREE SIZE:** 65–100 ft (20–30 m) tall,  
2–3 ft (.6–1 m) trunk diameter

**AVERAGE DRIED WEIGHT:** 43 lbs/ft<sup>3</sup> (690 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .55, .69

**JANKA HARDNESS:** 1,260 lb<sub>f</sub> (5,610 N)

**MODULUS OF RUPTURE:** 16,600 lb<sub>f</sub>/in<sup>2</sup> (114.5 MPa)

**ELASTIC MODULUS:** 2,010,000 lb<sub>f</sub>/in<sup>2</sup> (13.86 GPa)

**CRUSHING STRENGTH:** 8,170 lb<sub>f</sub>/in<sup>2</sup> (56.3 MPa)

**SHRINKAGE:** Radial: 7.3%, Tangential: 9.5%,  
Volumetric: 16.8%, T/R Ratio: 1.3

**COLOR/APPEARANCE:** Heartwood is light reddish brown, with nearly white sapwood. Occasionally figured pieces are seen with a wide, shallow curl similar to the curl found in Black Cherry (*Prunus serotina*). There is very little color distinction between annual growth rings, giving birch a somewhat dull, uniform appearance.

**GRAIN/TEXTURE:** Grain is generally straight or slightly wavy; fine, even texture with low natural luster.

**ROT RESISTANCE:** Rated as PERISHABLE; poor insect/borer resistance.

### ENDGRAIN (10×

**Porosity:**

diffuse-porous

**Arrangement:**

mostly radial multiples

**Vessels:** small to

medium, numerous

**Parenchyma:**

marginal, and  
sometimes diffuse-  
in-aggregates

**Rays:** narrow, fairly  
close spacing

**Odor:** none

**Notes:** individual  
*Betula* species cannot  
be reliably separated



**WORKABILITY:** Generally easy to work with hand and machine tools, though boards with wild grain can cause tearout during planing. Turns, glues, and finishes well.

**ALLERGIES/TOXICITY:** Birch in the *Betula* genus has been reported as a sensitizer; can cause skin and respiratory irritation.

**PRICING/AVAILABILITY:** Very common as plywood; also available in board form. Prices are moderate for a domestic hardwood.

**SUSTAINABILITY:** Not listed in the CITES Appendices, or on the IUCN Red List of Threatened Species.

**COMMON USES:** Plywood, boxes, crates, turned objects, interior trim, and other small specialty wood items.

**COMMENTS:** Frequently used worldwide for veneer and plywood. One of the highest grades of plywood—with no inner softwood plies as fillers—is referred to as Baltic Birch.

It's technically not a particular species, but is a general designation of plywood from Russia and nearby Baltic states such as Finland. The plies in these higher grades are thinner and more numerous, imparting greater stiffness and stability.



Masur Birch vase  
by Steve Earis



# Masur Birch

## *Betula pendula* var. *carelica*

*pendula*). It's also sometimes known as Karelian Birch—with Karelia being a region between Finland and Russia where the figured wood is sometimes found.

Once surmised to have been caused by the boring larvae of a certain beetle, Masur Birch has been shown to be hereditary,\* classifying the name of the variant as *Betula pendula* var. *carelica*. Regardless of the exact cause, the resulting figure and appearance is very similar to burl wood or birdseye maple, though of a different origin.

**LOOKALIKES:** Maple (*Acer* spp.) and birch may be distinguished by comparing the size of their pores in relation to the rays (when observed from the endgrain). In maple, the widest rays are about the same width as the pores, while in birch the rays are noticeably narrower than the pores.

Masur Birch is not a particular species of birch, but is rather a grain figure that is most commonly seen in Downy Birch (*Betula pubescens*) and Silver Birch (*Betula*

\*Risto Haggqvist, *Curly Birch (Betula pendula* var. *carelica*) and its Management in Finland, (Karkkilantie: Finnish Forest Research Institute, 2007).

RELATED SPECIES	AVERAGE DRIED WEIGHT	JANKA HARDNESS	MODULUS OF RUPTURE	ELASTIC MODULUS	CRUSHING STRENGTH	SHRINKAGE
<b>Alder-Leaf Birch</b> <i>Betula alnoides</i>	33 lbs/ft <sup>3</sup> (530 kg/m <sup>3</sup> )	830 lb <sub>f</sub> (3,690 N)	8,980 lb <sub>f</sub> /in <sup>2</sup> (61.9 MPa)	1,235,000 lb <sub>f</sub> /in <sup>2</sup> (8.52 GPa)	6,400 lb <sub>f</sub> /in <sup>2</sup> (44.1 MPa)	Radial–5% Tangential–7% Volumetric–13% T/R Ratio–1.4
<b>Sweet Birch</b> <i>Betula lenta</i>	46 lbs/ft <sup>3</sup> (735 kg/m <sup>3</sup> )	1,470 lb <sub>f</sub> (6,540 N)	16,900 lb <sub>f</sub> /in <sup>2</sup> (116.6 MPa)	2,170,000 lb <sub>f</sub> /in <sup>2</sup> (11.59 GPa)	8,540 lb <sub>f</sub> /in <sup>2</sup> (58.9 MPa)	Radial–6.5% Tangential–9.0% Volumetric–15.6% T/R Ratio–1.4
<b>Alaska Paper Birch</b> <i>Betula neoalaskana</i>	38 lbs/ft <sup>3</sup> (610 kg/m <sup>3</sup> )	830 lb <sub>f</sub> (3,690 N)	13,600 lb <sub>f</sub> /in <sup>2</sup> (93.8 MPa)	1,900,000 lb <sub>f</sub> /in <sup>2</sup> (13.10 GPa)	7,450 lb <sub>f</sub> /in <sup>2</sup> (51.4 MPa)	Radial–6.5% Tangential–9.9% Volumetric–16.7% T/R Ratio–1.5
<b>River Birch</b> <i>Betula nigra</i>	37 lbs/ft <sup>3</sup> (590 kg/m <sup>3</sup> )	970 lb <sub>f</sub> (4,320 N)* <i>*estimated</i>	13,100 lb <sub>f</sub> /in <sup>2</sup> (90.3 MPa)	1,580,000 lb <sub>f</sub> /in <sup>2</sup> (10.90 GPa)	No data available	Radial–4.7% Tangential–9.2% Volumetric–13.5% T/R Ratio–2.0
<b>Paper Birch</b> <i>Betula papyrifera</i>	38 lbs/ft <sup>3</sup> (610 kg/m <sup>3</sup> )	910 lb <sub>f</sub> (4,050 N)	12,300 lb <sub>f</sub> /in <sup>2</sup> (84.8 MPa)	1,590,000 lb <sub>f</sub> /in <sup>2</sup> (10.97 GPa)	5,690 lb <sub>f</sub> /in <sup>2</sup> (39.2 MPa)	Radial–6.3% Tangential–8.6% Volumetric–16.2% T/R Ratio–1.4
<b>Silver Birch</b> <i>Betula pendula</i>	40 lbs/ft <sup>3</sup> (640 kg/m <sup>3</sup> )	1,210 lb <sub>f</sub> (5,360 N)	16,570 lb <sub>f</sub> /in <sup>2</sup> (114.3 MPa)	2,024,000 lb <sub>f</sub> /in <sup>2</sup> (13.96 GPa)	No data available	No data available
<b>Gray Birch</b> <i>Betula populifolia</i>	35 lbs/ft <sup>3</sup> (560 kg/m <sup>3</sup> )	760 lb <sub>f</sub> (3,380 N)	9,800 lb <sub>f</sub> /in <sup>2</sup> (67.6 MPa)	1,150,000 lb <sub>f</sub> /in <sup>2</sup> (7.93 GPa)	4,870 lb <sub>f</sub> /in <sup>2</sup> (33.6 MPa)	Radial–5.2% Tangential–9.5% Volumetric–14.7% T/R Ratio–1.8

# African Padauk

*Pterocarpus soyauxii*

**DISTRIBUTION:** Central and tropical west Africa

**TREE SIZE:** 100–130 ft (30–40 m) tall,  
2–4 ft (.6–1.2 m) trunk diameter

**AVERAGE DRIED WEIGHT:** 47 lbs/ft<sup>3</sup> (745 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .61, .75

**JANKA HARDNESS:** 1,970 lb<sub>f</sub> (8,760 N)

**MODULUS OF RUPTURE:** 16,830 lb<sub>f</sub>/in<sup>2</sup> (116.0 MPa)

**ELASTIC MODULUS:** 1,700,000 lb<sub>f</sub>/in<sup>2</sup> (11.72 GPa)

**CRUSHING STRENGTH:** 8,130 lb<sub>f</sub>/in<sup>2</sup> (56.0 MPa)

**SHRINKAGE:** Radial: 3.3%, Tangential: 5.2%,  
Volumetric: 7.6%, T/R Ratio: 1.6

**COLOR/APPEARANCE:** Heartwood ranges from pinkish orange to deep brownish red. Most pieces tend to start reddish orange when freshly cut, darkening substantially over time to a reddish brown (some lighter-colored pieces age to a grayish brown).

**GRAIN/TEXTURE:** Grain is usually straight, but can sometimes be interlocked; coarse, open texture with good natural luster.

## ENDGRAIN (10×)

### Porosity:

diffuse-porous

**Arrangement:** solitary  
and radial multiples

**Vessels:** very large,  
very few, orange/  
brown deposits present

**Parenchyma:** diffuse-  
in-aggregates, winged,  
confluent, and banded

**Rays:** narrow,  
close spacing

**Odor:** pleasing scent  
when being worked

**Notes:** fluoresces  
under blacklight;  
ripple marks present



**ROT RESISTANCE:** Rated as DURABLE to VERY DURABLE; excellent resistance to termites and other insects.

**WORKABILITY:** Generally easy to work, though tearout can occur during planing on quartersawn or interlocked grain. Turns, glues, and finishes well.

**ALLERGIES/TOXICITY:** Reported as a sensitizer; can cause eye, skin, and respiratory irritation.

**PRICING/AVAILABILITY:** Widely imported as lumber in a variety of sizes, as well as turning and craft blanks. Prices are in the mid range for an imported hardwood.

**SUSTAINABILITY:** Not listed in the CITES Appendices, or on the IUCN Red List of Threatened Species.

**COMMON USES:** Veneer, flooring, turned objects, musical instruments, furniture, tool handles, and other small specialty wood objects.

**COMMENTS:** With a very unique reddish orange coloration, the wood is also called Vermillion. Unfortunately, this dramatic color is inevitably darkened to a deep reddish brown color. UV-inhibiting finishes may prolong (but not prevent) the gradual color-shift of this brightly colored wood.



*Padauk bowl  
by Steve Earis*



# Amendoim

*Pterogyne nitens*

**DISTRIBUTION:** Scattered throughout southern South America

**TREE SIZE:** 50–75 ft (15–23 m) tall,  
2–3 ft (.6–1 m) trunk diameter

**AVERAGE DRIED WEIGHT:** 50 lbs/ft<sup>3</sup> (800 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .66, .80

**JANKA HARDNESS:** 1,780 lb<sub>f</sub> (7,940 N)

**MODULUS OF RUPTURE:** 15,780 lb<sub>f</sub>/in<sup>2</sup> (108.8 MPa)

**ELASTIC MODULUS:** 1,771,000 lb<sub>f</sub>/in<sup>2</sup> (12.21 GPa)

**CRUSHING STRENGTH:** 7,500 lb<sub>f</sub>/in<sup>2</sup> (51.7 MPa)

**SHRINKAGE:** Radial: 3.4%, Tangential: 6.0%,  
Volumetric: 10.0%, T/R Ratio: 1.8

This wood is called by a myriad of local and regional names, but it's simply marketed as Amendoim in the United States. The wood's overall appearance is very similar to mahogany (*Swietenia* spp.), and it's primarily sold as flooring planks. Prices are in the mid range for an imported South American species.

Amendoim has a blunting effect on cutters due to its naturally high silica content. It turns, glues, and finishes well, and also responds well to steam bending.



# Pear

*Pyrus communis*

**DISTRIBUTION:** Central and eastern Europe; also widely planted in temperate regions worldwide

**TREE SIZE:** 20–30 ft (6–9 m) tall,  
6–12 in (15–30 cm) trunk diameter

**AVERAGE DRIED WEIGHT:** 43 lbs/ft<sup>3</sup> (690 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .52, .69

**JANKA HARDNESS:** 1,660 lb<sub>f</sub> (7,380 N)

**MODULUS OF RUPTURE:** 12,080 lb<sub>f</sub>/in<sup>2</sup> (83.3 MPa)

**ELASTIC MODULUS:** 1,131,000 lb<sub>f</sub>/in<sup>2</sup> (7.80 GPa)

**CRUSHING STRENGTH:** 6,400 lb<sub>f</sub>/in<sup>2</sup> (44.1 MPa)

**SHRINKAGE:** Radial: 3.9%, Tangential: 11.3%,  
Volumetric: 13.8%, T/R Ratio: 2.9

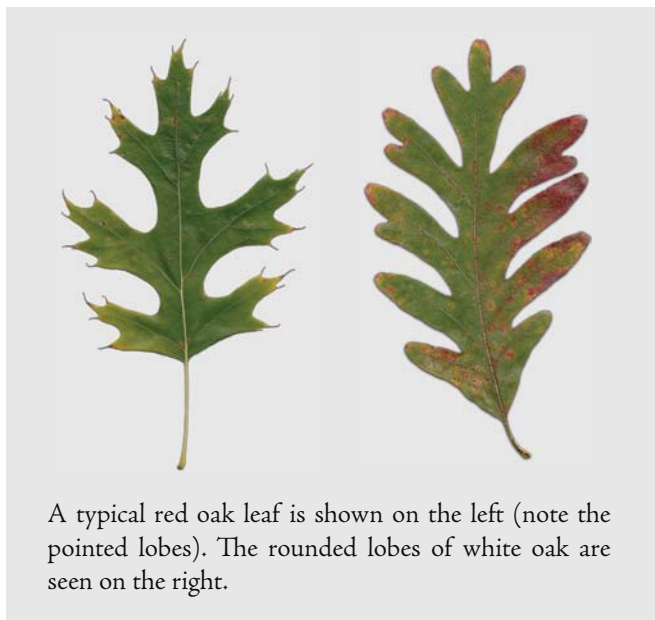
Used in Europe much in the same way that Black Cherry (*Prunus serotina*) is utilized in North America: as a high-quality cabinet hardwood. Both woods are in the *Rosaceae* or Rose family and belong to a broader category simply labeled as *fruitwood*. Both Pear and Cherry are similar visually and anatomically (though Pear tends to have narrower rays), and the two can't be reliably separated.

Pear is sometimes steamed to deepen the pink coloration, or it's dyed black and used as a substitute for ebony. Larger logs are commonly turned into veneer for architectural purposes.

*Pear bowl by Steve Earis*

# Distinguishing Red Oak from White Oak

Within the massive *Quercus* genus, oak species are subdivided into a number of sections, though all commercially harvested New World oaks can be placed into one of two categories: red oak, or white oak. This division is based on the morphology of the trees themselves—for instance, red oaks have pointed lobes on the leaves, while white oaks have rounded lobes. But the wood also has a few important distinctions, most notably, white oak is rot resistant, while red oak is not—an important detail for boatbuilding and exterior construction projects.



A typical red oak leaf is shown on the left (note the pointed lobes). The rounded lobes of white oak are seen on the right.

At a casual glance, unfinished oak lumber will generally be light brown, either with a slight reddish cast (usually red oak), or a subtle olive-colored cast (white oak). However, there are abnormally light or dark outliers and pieces that are ambiguously colored, making separation based on color alone unreliable—this is especially true if the wood is finished and/or stained.

While there is one particular species that's commonly considered the White Oak (*Quercus alba*), and one particular species that's considered the Red Oak (*Quercus rubra*), in reality, oak lumber is not sold on a species level. Instead, it's sold under a broader species grouping: either red or white.

Besides the leaves, there are a few other ways to distinguish between the two groupings of oak wood.

**TYLOSES:** When viewing the endgrain, the large early-wood pores found on red oaks are open and empty. The pores of white oaks, however, are all plugged with tyloses (bubble-like structures: discussed on page 32). Corresponding endgrain images of red and white oak are shown on their respective profiles over the next few pages.

**RAY HEIGHT:** When looking at the face grain, particularly in the flatsawn areas, the thin dark brown streaks running with the grain direction are rays. Red oaks will almost always have very short rays, usually between  $\frac{1}{8}$ " to  $\frac{1}{2}$ " high, rarely ever more than  $\frac{3}{4}$ " to 1" in height. White oaks, on the other hand, will have much taller rays, frequently exceeding  $\frac{3}{4}$ " on most boards.



Black Oak (*Quercus velutina*) is pictured on the left, and exhibits very short rays, indicative of red oak species. The image on the right shows the longer rays that are characteristic of flatsawn sections of the white oak species—in this case, Swamp Chestnut Oak (*Quercus michauxii*).

**CHEMICAL TESTING:** The process for differentiating between red and white oaks using a chemical reagent (along with a recipe for mixing a solution of sodium nitrite) is described on page 22.



# White Oak

## *Quercus alba*

**DISTRIBUTION:** Eastern United States

**TREE SIZE:** 65–85 ft (20–25 m) tall,  
3–4 ft (1–1.2 m) trunk diameter

**AVERAGE DRIED WEIGHT:** 47 lbs/ft<sup>3</sup> (755 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .60, .75

**JANKA HARDNESS:** 1,360 lb<sub>f</sub> (6,000 N)

**MODULUS OF RUPTURE:** 15,200 lb<sub>f</sub>/in<sup>2</sup> (104.8 MPa)

**ELASTIC MODULUS:** 1,780,000 lb<sub>f</sub>/in<sup>2</sup> (12.30 GPa)

**CRUSHING STRENGTH:** 7,440 lb<sub>f</sub>/in<sup>2</sup> (51.3 MPa)

**SHRINKAGE:** Radial: 5.6%, Tangential: 10.5%,  
Volumetric: 16.3%, T/R Ratio: 1.9

**COLOR/APPEARANCE:** Heartwood is light to medium brown, commonly with an olive cast. White to light brown sapwood isn't always sharply demarcated from the heartwood. Quartersawn sections display prominent ray fleck patterns.

**GRAIN/TEXTURE:** Grain is straight; coarse, uneven texture.

**ROT RESISTANCE:** Rated as VERY DURABLE; frequently used in boatbuilding and tight cooperage applications.

**WORKABILITY:** Produces good results with hand and machine tools. Moderately high shrinkage values, resulting in mediocre dimensional stability, especially in flat-sawn boards. Can react with iron (particularly when wet) and cause staining and discoloration. Responds well to steam bending. Glues, stains, and finishes well.

**ALLERGIES/TOXICITY:** Reported as a sensitizer; can cause eye and skin irritation, runny nose, asthma-like respiratory effects, and nasopharyngeal cancer (with occupational exposure).

**PRICING/AVAILABILITY:** Abundant availability in a range of widths and thicknesses, both as flatsawn and quartersawn lumber. Slightly more expensive than Red Oak (*Q. rubra*), prices are moderate for a domestic hardwood.

**SUSTAINABILITY:** Not listed in the CITES Appendices, or on the IUCN Red List of Threatened Species.

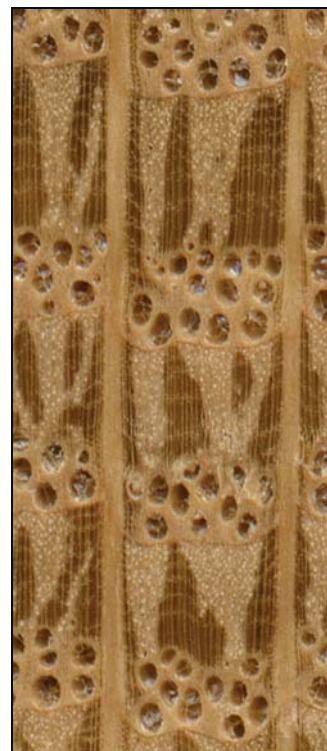


Quartersawn White Oak box

**COMMON USES:** Cabinetry, furniture, interior trim, flooring, boatbuilding, barrels, and veneer.

**COMMENTS:** Strong, beautiful, rot-resistant, easy to work, and economical, White Oak represents an exceptional value to woodworkers. It's no wonder that the wood is so widely used in cabinet and furniture making.

Connecticut's state quarter was minted with a picture and inscription of a famous White Oak, the Charter Oak. In 1687, a cavity within the tree was used as a hiding place for the Connecticut Charter of 1662 to prevent its confiscation by the British.



### ENDGRAIN (10×)

**Porosity:** ring-porous

#### Arrangement:

earlywood exclusively solitary in two to four rows, latewood in radial/dendritic arrangement

**Vessels:** very large in earlywood, small in latewood; tyloses abundant

**Parenchyma:** diffuse-in-aggregates

**Rays:** narrow and very wide, normal spacing

**Odor:** distinct scent when being worked

# White Oak Grouping

In addition to *Quercus alba*, there are several other species of oak that are categorized and sold interchangeably as white oak. These species are all found in the eastern United States.

- Swamp White Oak (*Quercus bicolor*)
- Overcup Oak (*Quercus lyrata*)
- Bur Oak (*Quercus macrocarpa*)
- Swamp Chestnut Oak (*Quercus michauxii*)

Chestnut Oak (*Q. prinus*) and Post Oak (*Q. stellata*) are found in the same geographic region, but don't typically yield quality lumber. However, when these trees are found in better growing conditions, they produce good timber and are marketed within the white oak group as well.

Oregon White Oak (*Q. garryana*), sometimes referred to as Garry Oak, is one of the only species of oak found in the Pacific Northwest region of North America. It's roughly the western equivalent to the eastern white oaks, though not nearly as widespread, nor as commercially important.

**INTERNATIONAL:** In Europe, Sessile Oak (*Q. petraea*) bears much similarity to the white oak species found in North America. However, being native to Europe, the wood is much more frequently seen with English Oak (*Q. robur*), a tremendously popular species listed separately on page 214. Both European species are commercially important, and are harvested and sold for the same purposes as American white oaks.

RELATED SPECIES	AVERAGE DRIED WEIGHT	JANKA HARDNESS	MODULUS OF RUPTURE	ELASTIC MODULUS	CRUSHING STRENGTH	SHRINKAGE
<b>Swamp White Oak</b> <i>Quercus bicolor</i>	48 lbs/ft <sup>3</sup> (765 kg/m <sup>3</sup> )	1,600 lb <sub>f</sub> (7,140 N)	17,400 lb <sub>f</sub> /in <sup>2</sup> (120.0 MPa)	2,029,000 lb <sub>f</sub> /in <sup>2</sup> (13.99 GPa)	8,400 lb <sub>f</sub> /in <sup>2</sup> (57.9 MPa)	Radial-5.5% Tangential-10.6% Volumetric-17.7% T/R Ratio-1.9
<b>Oregon White Oak</b> <i>Quercus garryana</i>	51 lbs/ft <sup>3</sup> (815 kg/m <sup>3</sup> )	1,640 lb <sub>f</sub> (7,310 N)	10,200 lb <sub>f</sub> /in <sup>2</sup> (70.3 MPa)	1,089,000 lb <sub>f</sub> /in <sup>2</sup> (7.51 GPa)	7,320 lb <sub>f</sub> /in <sup>2</sup> (50.5 MPa)	Radial-4.2% Tangential-9.0% Volumetric-13.2% T/R Ratio-2.1
<b>Overcup Oak</b> <i>Quercus lyrata</i>	47 lbs/ft <sup>3</sup> (760 kg/m <sup>3</sup> )	1,190 lb <sub>f</sub> (5,290 N)	12,600 lb <sub>f</sub> /in <sup>2</sup> (86.9 MPa)	1,420,000 lb <sub>f</sub> /in <sup>2</sup> (9.79 GPa)	6,200 lb <sub>f</sub> /in <sup>2</sup> (42.8 MPa)	Radial-5.3% Tangential-12.7% Volumetric-16.0% T/R Ratio-2.4
<b>Bur Oak</b> <i>Quercus macrocarpa</i>	45 lbs/ft <sup>3</sup> (720 kg/m <sup>3</sup> )	1,360 lb <sub>f</sub> (6,030 N)	10,920 lb <sub>f</sub> /in <sup>2</sup> (75.3 MPa)	1,040,000 lb <sub>f</sub> /in <sup>2</sup> (7.17 GPa)	5,890 lb <sub>f</sub> /in <sup>2</sup> (40.6 MPa)	Radial-4.4% Tangential-8.8% Volumetric-12.7% T/R Ratio-2.0
<b>Swamp Chestnut Oak</b> <i>Quercus michauxii</i>	49 lbs/ft <sup>3</sup> (780 kg/m <sup>3</sup> )	1,230 lb <sub>f</sub> (5,460 N)	13,760 lb <sub>f</sub> /in <sup>2</sup> (94.9 MPa)	1,753,000 lb <sub>f</sub> /in <sup>2</sup> (12.09 GPa)	7,200 lb <sub>f</sub> /in <sup>2</sup> (49.6 MPa)	Radial-5.2% Tangential-10.8% Volumetric-16.4% T/R Ratio-2.1
<b>Sessile Oak</b> <i>Quercus petraea</i>	44 lbs/ft <sup>3</sup> (710 kg/m <sup>3</sup> )	1,120 lb <sub>f</sub> (4,990 N)	14,080 lb <sub>f</sub> /in <sup>2</sup> (97.1 MPa)	1,518,000 lb <sub>f</sub> /in <sup>2</sup> (10.47 GPa)	6,860 lb <sub>f</sub> /in <sup>2</sup> (47.3 MPa)	Radial-4.5% Tangential-9.7% Volumetric-14.2% T/R Ratio-2.2
<b>Chestnut Oak</b> <i>Quercus prinus</i>	47 lbs/ft <sup>3</sup> (750 kg/m <sup>3</sup> )	1,130 lb <sub>f</sub> (5,030 N)	13,300 lb <sub>f</sub> /in <sup>2</sup> (91.7 MPa)	1,590,000 lb <sub>f</sub> /in <sup>2</sup> (10.97 GPa)	6,830 lb <sub>f</sub> /in <sup>2</sup> (47.1 MPa)	Radial-5.3% Tangential-10.8% Volumetric-16.4% T/R Ratio-2.0
<b>Post Oak</b> <i>Quercus stellata</i>	47 lbs/ft <sup>3</sup> (750 kg/m <sup>3</sup> )	1,350 lb <sub>f</sub> (5,990 N)	13,070 lb <sub>f</sub> /in <sup>2</sup> (90.1 MPa)	1,495,000 lb <sub>f</sub> /in <sup>2</sup> (10.31 GPa)	6,530 lb <sub>f</sub> /in <sup>2</sup> (45.1 MPa)	Radial-5.4% Tangential-9.8% Volumetric-16.2% T/R Ratio-1.8



# Red Oak

## *Quercus rubra*

**DISTRIBUTION:** Northeastern United States and Southeastern Canada

**TREE SIZE:** 80–115 ft (25–35 m) tall, 3–6 ft (1–2 m) trunk diameter

**AVERAGE DRIED WEIGHT:** 44 lbs/ft<sup>3</sup> (700 kg/m<sup>3</sup>)

**SPECIFIC GRAVITY (BASIC, 12% MC):** .56, .70

**JANKA HARDNESS:** 1,290 lb<sub>f</sub> (5,700 N)

**MODULUS OF RUPTURE:** 14,300 lb<sub>f</sub>/in<sup>2</sup> (98.6 MPa)

**ELASTIC MODULUS:** 1,820,000 lb<sub>f</sub>/in<sup>2</sup> (12.50 GPa)

**CRUSHING STRENGTH:** 6,760 lb<sub>f</sub>/in<sup>2</sup> (46.6 MPa)

**SHRINKAGE:** Radial: 4.0%, Tangential: 8.6%, Volumetric: 13.7%, T/R Ratio: 2.2

**COLOR/APPEARANCE:** Heartwood is light to medium brown, commonly with a reddish cast. White to light brown sapwood isn't always sharply demarcated from the heartwood. Quartersawn sections display prominent ray fleck patterns.

**GRAIN/TEXTURE:** Grain is straight; coarse, uneven texture.

**ROT RESISTANCE:** Rated as NON-DURABLE to PERISHABLE; poor insect/borer resistance. Stains when in contact with water (particularly along the porous growth ring areas).

**WORKABILITY:** Produces good results with hand and machine tools. Moderately high shrinkage values, resulting in mediocre dimensional stability, especially in flatsawn boards. Responds well to steam bending. Glues, stains, and finishes well.

**ALLERGIES/TOXICITY:** Reported as a sensitizer; can cause eye and skin irritation, runny nose, asthma-like respiratory effects, and nasopharyngeal cancer (with occupational exposure).

**PRICING/AVAILABILITY:** Abundant availability in a good range of widths and thicknesses, both as flatsawn and quartersawn lumber. Usually slightly less expensive than

White Oak (*Q. alba*), prices are moderate for a domestic hardwood.

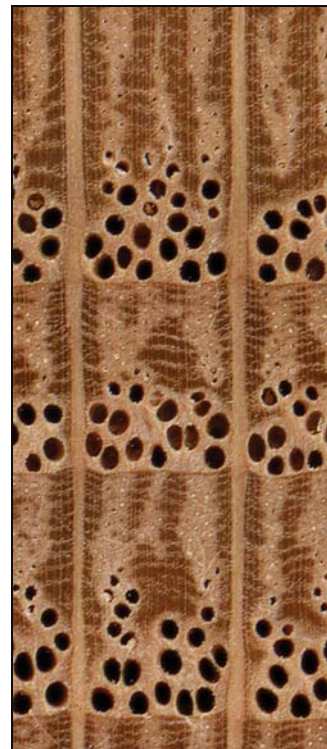
**SUSTAINABILITY:** Not listed in the CITES Appendices, or on the IUCN Red List of Threatened Species.

**COMMON USES:** Cabinetry, furniture, interior trim, flooring, and veneer.

**COMMENTS:** Arguably the most popular hardwood in the United States, Red Oak is a ubiquitous sight in many homes. Even many vinyl/imitation wood surfaces are printed to look like Red Oak.



Red Oak and Sapele veneer segmented bowl



### ENDGRAIN (10×)

**Porosity:** ring-porous

#### Arrangement:

earlywood exclusively solitary in two to four rows, latewood in radial/dendritic arrangement

**Vessels:** very large in earlywood, small in latewood; tyloses absent or scarce

**Parenchyma:** diffuse-in-aggregates

**Rays:** narrow and very wide, normal spacing

**Odor:** distinct scent when being worked

# Red Oak Grouping

*Quercus rubra* (seen on facing page) is sometimes referred to more specifically as Northern Red Oak to help distinguish it from Southern Red Oak (*Q. falcata*), a species that's sold interchangeably in the red oak grouping, though the wood of the southern species is typically of inferior quality (as seen by the mechanical data below).

There are also a number of other species of oak native to the eastern United States (listed below) which are harvested and sold within the red oak group. Cherrybark Oak

(*Q. pagoda*) and Shumard Oak (*Q. shumardii*) rank among the strongest and highest-quality timbers in the red oak group. At the opposite end of the spectrum is Laurel Oak (*Q. laurifolia*), which is typically only used for firewood or as pulpwood in papermaking.

One geographic outlier is California Black Oak (*Q. kelloggii*), found on the west coast of the United States. Historically, it's been regarded very lowly, but more recently efforts have been made to utilize this tree for lumber.

RELATED SPECIES	AVERAGE DRIED WEIGHT	JANKA HARDNESS	MODULUS OF RUPTURE	ELASTIC MODULUS	CRUSHING STRENGTH	SHRINKAGE
<b>Scarlet Oak</b> <i>Quercus coccinea</i>	46 lbs/ft <sup>3</sup> (735 kg/m <sup>3</sup> )	1,400 lb <sub>f</sub> (6,230 N)	16,080 lb <sub>f</sub> /in <sup>2</sup> (110.9 MPa)	1,766,000 lb <sub>f</sub> /in <sup>2</sup> (12.18 GPa)	8,250 lb <sub>f</sub> /in <sup>2</sup> (56.9 MPa)	Radial-4.4% Tangential-10.8% Volumetric-14.7% T/R Ratio-2.5
<b>Southern Red Oak</b> <i>Quercus falcata</i>	42 lbs/ft <sup>3</sup> (675 kg/m <sup>3</sup> )	1,060 lb <sub>f</sub> (4,720 N)	12,040 lb <sub>f</sub> /in <sup>2</sup> (83.0 MPa)	1,480,000 lb <sub>f</sub> /in <sup>2</sup> (10.20 GPa)	6,090 lb <sub>f</sub> /in <sup>2</sup> (42.0 MPa)	Radial-4.7% Tangential-11.3% Volumetric-16.1% T/R Ratio-2.4
<b>California Black Oak</b> <i>Quercus kelloggii</i>	39 lbs/ft <sup>3</sup> (620 kg/m <sup>3</sup> )	1,090 lb <sub>f</sub> (4,840 N)	8,610 lb <sub>f</sub> /in <sup>2</sup> (59.4 MPa)	980,000 lb <sub>f</sub> /in <sup>2</sup> (6.76 GPa)	5,640 lb <sub>f</sub> /in <sup>2</sup> (38.9 MPa)	Radial-3.6% Tangential-6.6% Volumetric-10.2% T/R Ratio-1.8
<b>Laurel Oak</b> <i>Quercus laurifolia</i>	46 lbs/ft <sup>3</sup> (740 kg/m <sup>3</sup> )	1,210 lb <sub>f</sub> (5,380 N)	14,330 lb <sub>f</sub> /in <sup>2</sup> (98.8 MPa)	1,793,000 lb <sub>f</sub> /in <sup>2</sup> (12.37 GPa)	6,980 lb <sub>f</sub> /in <sup>2</sup> (48.1 MPa)	Radial-4.0% Tangential-9.9% Volumetric-19.0% T/R Ratio-2.5
<b>Water Oak</b> <i>Quercus nigra</i>	45 lbs/ft <sup>3</sup> (725 kg/m <sup>3</sup> )	1,190 lb <sub>f</sub> (5,290 N)	16,620 lb <sub>f</sub> /in <sup>2</sup> (114.6 MPa)	2,034,000 lb <sub>f</sub> /in <sup>2</sup> (14.02 GPa)	6,770 lb <sub>f</sub> /in <sup>2</sup> (46.7 MPa)	Radial-4.4% Tangential-9.8% Volumetric-16.1% T/R Ratio-2.2
<b>Cherrybark Oak</b> <i>Quercus pagoda</i>	49 lbs/ft <sup>3</sup> (785 kg/m <sup>3</sup> )	1,480 lb <sub>f</sub> (6,580 N)	18,100 lb <sub>f</sub> /in <sup>2</sup> (124.8 MPa)	2,280,000 lb <sub>f</sub> /in <sup>2</sup> (15.72 GPa)	8,740 lb <sub>f</sub> /in <sup>2</sup> (60.3 MPa)	Radial-5.5% Tangential-10.6% Volumetric-16.1% T/R Ratio-1.9
<b>Pin Oak</b> <i>Quercus palustris</i>	44 lbs/ft <sup>3</sup> (705 kg/m <sup>3</sup> )	1,500 lb <sub>f</sub> (6,650 N)	13,860 lb <sub>f</sub> /in <sup>2</sup> (95.6 MPa)	1,713,000 lb <sub>f</sub> /in <sup>2</sup> (11.81 GPa)	6,750 lb <sub>f</sub> /in <sup>2</sup> (46.6 MPa)	Radial-4.3% Tangential-9.5% Volumetric-14.5% T/R Ratio-2.2
<b>Willow Oak</b> <i>Quercus phellos</i>	48 lbs/ft <sup>3</sup> (770 kg/m <sup>3</sup> )	1,460 lb <sub>f</sub> (6,490 N)	14,860 lb <sub>f</sub> /in <sup>2</sup> (102.4 MPa)	1,804,000 lb <sub>f</sub> /in <sup>2</sup> (12.44 GPa)	7,040 lb <sub>f</sub> /in <sup>2</sup> (48.6 MPa)	Radial-5.0% Tangential-9.6% Volumetric-18.9% T/R Ratio-1.9
<b>Shumard Oak</b> <i>Quercus shumardii</i>	46 lbs/ft <sup>3</sup> (730 kg/m <sup>3</sup> )	1,290 lb <sub>f</sub> (5,750 N)* <i>*estimated</i>	17,830 lb <sub>f</sub> /in <sup>2</sup> (123.0 MPa)	2,154,000 lb <sub>f</sub> /in <sup>2</sup> (14.86 GPa)	No data available	No data available
<b>Black Oak</b> <i>Quercus velutina</i>	45 lbs/ft <sup>3</sup> (715 kg/m <sup>3</sup> )	1,210 lb <sub>f</sub> (5,380 N)	14,430 lb <sub>f</sub> /in <sup>2</sup> (99.5 MPa)	1,736,000 lb <sub>f</sub> /in <sup>2</sup> (11.97 GPa)	6,450 lb <sub>f</sub> /in <sup>2</sup> (44.5 MPa)	Radial-4.4% Tangential-11.1% Volumetric-15.1% T/R Ratio-2.5

# Modulus of Elasticity

Botanical name	×1,000 lb <sub>f</sub> /in <sup>2</sup>	GPa	Botanical name	×1,000 lb <sub>f</sub> /in <sup>2</sup>	GPa	Botanical name	×1,000 lb <sub>f</sub> /in <sup>2</sup>	GPa	Botanical name	×1,000 lb <sub>f</sub> /in <sup>2</sup>	GPa
Swartzia cubensis	3,715	25.62	Diospyros virginiana	2,010	13.86	Cordia dodecandra	1,585	10.93	Castanea sativa	1,248	8.61
Chlorocardium rodiei	3,573	24.64	Betula alleghaniensis	2,010	13.86	Guarea cedrata	1,582	10.91	Pinus jeffreyi	1,240	8.55
Swartzia benthamiana	3,535	24.38	Aspidosperma polyneuron	2,002	13.81	Senna siamea	1,581	10.90	Pinus strobus	1,240	8.55
Brosimum guianense	3,364	23.20	Pinus elliottii	1,980	13.66	Albizia ferruginea	1,581	10.91	Pinus pinaster	1,238	8.54
Manilkara bidentata	3,344	23.06	Pinus palustris	1,980	13.66	Betula nigra	1,580	10.90	Betula alnoides	1,235	8.52
Dipteryx odorata	3,237	22.33	Carapa spp.	1,965	13.55	Liriodendron tulipifera	1,580	10.90	Baikiaea plurijuga	1,230	8.48
Handroanthus spp.	3,200	22.07	Quercus virginiana	1,960	13.52	Machaerium spp.	1,574	10.86	Arbutus menziesii	1,230	8.48
Dalbergia steversonii	3,190	22.00	Palaquium spp.	1,939	13.37	Mansonina altissima	1,570	10.83	Castanea dentata	1,230	8.48
Acacia omalophylla*	3,118	21.50	Cornus florida	1,922	13.26	Juglans regia	1,568	10.81	Aucoumea klaineana	1,228	8.47
Brosimum rubescens	3,013	20.78	Tamarindus indica	1,918	13.22	Weinmannia trichosperma	1,568	10.81	Enterolobium cyclocarpum	1,226	8.46
Krugiodendron ferreum	2,966	20.46	Colophospermum mopane	1,917	13.22	Pinus nigra	1,568	10.81	Umbellularia californica	1,225	8.45
Eucalyptus diversicolor	2,965	20.44	Gluta spp.	1,915	13.21	Lagerstroemia spp.	1,566	10.80	Dyera costulata	1,224	8.44
Manilkara zapota	2,960	20.41	Betula neoalaskana	1,900	13.10	Eucalyptus deglupta	1,565	10.79	Sequoia sempervirens	1,220	8.41
Peltogyne spp.	2,937	20.26	Carya laciniosa	1,890	13.03	Picea rubens	1,560	10.76	Catalpa speciosa	1,210	8.34
Koompassia malaccensis	2,913	20.09	Larix occidentalis	1,870	12.90	Tieghemella heckelii	1,552	10.71	Abies alba	1,200	8.28
Roupala montana	2,887	19.91	Parashorea spp. (Wht. Seraya)	1,841	12.70	Pinus pungens	1,550	10.69	Tsuga canadensis	1,200	8.28
Platymiscium spp.	2,837	19.56	Albizia lebbeck	1,836	12.66	Shorea spp. (Yellow Meranti)	1,548	10.68	Fraxinus mandshurica	1,195	8.24
Zygia racemosa	2,818	19.43	Acer saccharum	1,830	12.62	Quercus robur	1,544	10.65	Celtis occidentalis	1,190	8.21
Bambusa spp.	2,755	19.00	Nothofagus cunninghamii	1,830	12.62	Ulmus thomasii	1,540	10.62	Rhus spp.	1,190	8.21
Lophira alata	2,754	18.99	Magnolia acuminata	1,820	12.55	Khaya spp.	1,537	10.60	Pinus lambertiana	1,190	8.21
Lonchocarpus spp.	2,745	18.93	Quercus phellos	1,804	12.44	Abies grandis	1,530	10.55	Nyssa sylvatica	1,188	8.19
Hymenaea courbaril	2,745	18.93	Quercus laurifolia	1,793	12.37	Picea mariana	1,523	10.50	Populus tremuloides	1,180	8.14
Metopium brownei	2,733	18.85	Carya cordiformis	1,790	12.34	Pinus virginiana	1,520	10.48	Juglans cinerea	1,180	8.14
Eucalyptus globulus	2,721	18.76	Pinus taeda	1,790	12.34	Terminalia superba	1,520	10.49	Pinus flexilis	1,170	8.07
Caesalpinia paraguayensis*	2,712	18.70	Fraxinus excelsior	1,785	12.31	Quercus petraea	1,518	10.47	Aesculus spp. (Buckeye)	1,170	8.07
Dalbergia retusa*	2,712	18.70	Tectona grandis	1,781	12.28	Dalbergia sissoo	1,508	10.40	Ulmus pumila	1,154	7.96
Guibourtia ehie	2,701	18.63	Pinus kesiya	1,776	12.25	Acacia koa	1,503	10.37	Grevillea robusta	1,151	7.93
Anadenanthera colubrina	2,672	18.43	Distemonanthus benthamianus	1,773	12.23	Simira salvadorensis*	1,497	10.32	Betula populifolia	1,150	7.93
Guibourtia spp. (Bubinga)	2,670	18.41	Pterogyne nitens	1,771	12.21	Quercus stellata	1,495	10.31	Samanea saman	1,149	7.92
Acacia cambagei	2,610	18.00	Cordia spp. (Ziricote)	1,767	12.19	Ulmus rubra	1,490	10.28	Acer saccharinum	1,140	7.86
Dalbergia melanoxylon	2,603	17.95	Quercus coccinea	1,766	12.18	Prunus serotina	1,490	10.28	Pinus edulis	1,140	7.86
Vouacapoua americana	2,586	17.83	Pseudotsuga menziesii	1,765	12.17	Shorea spp. (White Meranti)	1,485	10.24	Cupressus macrocarpa	1,133	7.81
Olea spp.	2,577	17.77	Quercus alba	1,762	12.15	Abies concolor	1,485	10.24	Roseodendron donnell-smithii	1,133	7.81
Caesalpinia platyloba	2,574	17.76	Quercus rubra	1,761	12.14	Abies magnifica	1,483	10.23	Juglans neotropica	1,132	7.81
Millettia laurentii	2,550	17.59	Prosopis juliflora	1,759	12.13	Ulmus crassifolia	1,480	10.21	Pyrus communis	1,131	7.80
Caesalpinia echinata	2,544	17.54	Pterocarpus dalbergioides	1,754	12.10	Quercus falcata	1,480	10.20	Dalbergia tucurensis	1,125	7.76
Prosopis kuntzei	2,520	17.38	Quercus michauxii	1,753	12.09	Spirostachys africana	1,478	10.19	Sassafras albidum	1,120	7.72
Diospyros celebica	2,515	17.35	Pinus echinata	1,750	12.07	Prunus domestica	1,478	10.19	Prosopis nigra	1,117	7.70
Buxus sempervirens	2,494	17.20	Pinus serotina	1,750	12.07	Cedrus libani	1,465	10.10	Ilex opaca	1,110	7.66
Combretum schumannii	2,494	17.20	Casuarina cunninghamiana	1,747	12.05	Pinus patula	1,463	10.09	Thuja plicata	1,110	7.66
Bobgunnia fistuloides	2,480	17.10	Entandrophragma cylindricum	1,746	12.04	Pinus sylvestris	1,461	10.08	Cryptomeria japonica	1,109	7.65
Shorea spp. (Balau)	2,457	16.95	Betula pubescens	1,745	12.03	Pinus monticola	1,460	10.07	Populus balsamifera	1,100	7.59
Diospyros crassiflora	2,449	16.89	Pinus caribaea	1,745	12.03	Tilia americana	1,460	10.07	Quercus garryana	1,089	7.51
Euxylophora paraensis	2,413	16.64	Shorea spp. (Dk. Red Meranti)	1,743	12.02	Swietenia macrophylla	1,458	10.06	Acer negundo*	1,050	7.24
Schinopsis spp.	2,407	16.60	Dalbergia baronii	1,742	12.01	Pinus radiata	1,458	10.06	Quercus macrocarpa	1,040	7.17
Astronium graveolens	2,401	16.56	Eucalyptus leucoxylon	1,740	12.00	Acer macrophyllum	1,450	10.00	Calocedrus decurrens	1,040	7.17
Hemenopsis ebano	2,398	16.54	Fraxinus americana	1,740	12.00	Taxodium distichum	1,440	9.93	Aesculus hippocastanum	1,036	7.14
Myroxylon balsamum	2,380	16.41	Quercus velutina	1,736	11.97	Acer pseudoplatanus	1,438	9.92	Ulmus procera	1,032	7.12
Piptadenia spp.	2,380	16.41	Carya illinoensis	1,730	11.93	Pinus rigida	1,430	9.86	Salix nigra	1,010	6.97
Dalbergia cochinchinensis	2,375	16.38	Pterocarpus indicus	1,724	11.89	Populus grandidentata	1,430	9.86	Cupressus x leylandii	989	6.82
Microberlinia brazzavillensis	2,374	16.37	Araucaria heterophylla	1,723	11.89	Quercus lyrata	1,420	9.79	Quercus kelloggii	980	6.76
Julbernardia pellegriniana	2,334	16.09	Agathis australis	1,721	11.87	Cupressus nootkatensis	1,420	9.79	Triplochiton scleroxylon	970	6.69
Intsia bijuga	2,310	15.93	Pericopsis elata	1,715	11.83	Gymnocladus dioicus	1,420	9.79	Rhamnus spp.	960	6.62
Dipteryx odorata	2,293	15.81	Quercus palustris	1,713	11.81	Platanus occidentalis	1,420	9.79	Chamaecyparis thyoides	930	6.41
Calycophyllum candidissimum	2,284	15.75	Eucalyptus calmdulensis	1,711	11.80	Populus tremula	1,414	9.75	Prosopis alba	882	6.08
Millettia stuhlmannii	2,281	15.73	Araucaria cunninghamii	1,706	11.77	Pinus clausa	1,410	9.72	Juniperus virginiana	880	6.07
Quercus pagoda	2,280	15.72	Pterocarpus soyauxii	1,700	11.72	Picea abies	1,406	9.70	Thuja occidentalis	800	5.52
Bulnesia arborea	2,272	15.67	Carya myristiciformis	1,700	11.72	Pinus glabra	1,405	9.69	Juniperus deppeana	650	4.48
Borassus flabellifer	2,262	15.60	Ostrya virginiana	1,700	11.72	Fraxinus quadrangulata	1,400	9.66	Paulownia spp.	635	4.38
Carya glabra	2,260	15.59	Tilia x europaea	1,698	11.71	Magnolia grandiflora	1,400	9.66	Ochroma pyramidale	538	3.71
Apuleia leiocarpa	2,257	15.57	Carpinus spp.	1,693	11.68	Ocotea porosa	1,394	9.61			
Gonystylus spp.	2,255	15.55	Maclura pomifera	1,689	11.64	Abies balsamea	1,387	9.57			
Carya tomentosa	2,220	15.31	Entandrophragma utile	1,689	11.65	Mitragyna ciliata	1,386	9.56			
Pinus oocarpa	2,209	15.23	Abies amabilis	1,681	11.59	Alnus rubra	1,380	9.52			
Berchemia zeyheri	2,193	15.12	Juglans nigra	1,680	11.59	Populus deltoides	1,370	9.45			
Betula lenta	2,170	14.97	Cinnamomum camphora	1,676	11.56	Picea engelmannii	1,369	9.44			
Centrolobium spp.	2,164	14.93	Mangifera indica	1,672	11.53	Milicia spp.	1,360	9.38			
Pinus merkusii	2,161	14.90	Dalbergia latifolia	1,668	11.50	Fraxinus latifolia	1,360	9.38			
Carya ovata	2,160	14.90	Fraxinus pennsylvanica	1,660	11.45	Terminalia ivorensis	1,355	9.34			
Maclura tinctoria	2,160	14.90	Endiandra palmerstonii	1,656	11.42	Morus spp.	1,352	9.32			
Quercus shumardii	2,154	14.86	Cocos nucifera	1,654	11.41	Callitris columellaris	1,351	9.32			
Acacia melanoxylon	2,148	14.82	Shorea spp. (Lt. Red Meranti)	1,652	11.39	Swietenia mahogany	1,351	9.31			
Eucalyptus marginata	2,132	14.70	Ulmus alata	1,650	11.38	Taxus brevifolia	1,350	9.31			
Acacia mearnsii	2,117	14.60	Araucaria angustifolia	1,648	11.37	Pinus banksiana	1,350	9.31			
Chloroxylon swietenia	2,111	14.56	Chamaecyparis lawsoniana	1,646	11.35	Lovoa trichilioides	1,340	9.24			
Azefelia spp.	2,094	14.44	Acer rubrum	1,640	11.31	Ulmus americana	1,340	9.24			
Fagus sylvatica	2,075	14.31	Liquidambar styraciflua	1,640	11.31	Pinus contorta	1,340	9.24			
Eucalyptus obliqua	2,071	14.29	Larix laricina	1,640	11.31	Lagarostrobos franklinii	1,339	9.23			
Eucalyptus grandis	2,052	14.15	Magnolia virginiana	1,640	11.31	Toona ciliata	1,336	9.22			
Robinia pseudoacacia	2,050	14.14	Gleditsia triacanthos	1,630	11.24	Abies lasiocarpa	1,324	9.13			
Eucalyptus urograndis	2,049	14.13	Tsuga heterophylla	1,630	11.24	Cedrela odorata	1,323	9.12			
Eucalyptus robusta	2,047	14.12	Pinus resinosa	1,630	11.24	Hevea brasiliensis	1,315	9.07			
Gualacum officinale	2,043	14.09	Ailanthus altissima	1,623	11.19	Picea glauca	1,315	9.07			
Diospyros ebenum	2,040	14.07	Acer nigrum	1,620	11.17	Alnus glutinosa	1,303	8.99			
Quercus nigra	2,034	14.02	Abies procera	1,619	11.17	Melia azedarach	1,300	8.97			
Eucalyptus regnans	2,033	14.02	Ulmus glabra	1,615	11.14	Cardwellia sublimis	1,293	8.92			
Eucalyptus melliodora	2,030	14.00	Turraeanthus africanus	1,614	11.13	Platanus x acerifolia	1,291	8.90			
Guibourtia hymenaeifolia	2,030	14.00	Acacia mangium	1,605	11.07	Populus alba	1,290	8.90			
Quercus bicolor	2,029	13.99	Fraxinus nigra	1,600	11.03	Pinus ponderosa	1,290	8.90			
Betula pendula	2,024	13.96	Picea sitchensis	1,600	11.03	Malus sylvestris	1,270	8.76			
Dalbergia nigra	2,020	13.93	Quercus prinus	1,590	10.97	Populus trichocarpa	1,270	8.76			
Carya aquatica	2,020	13.93	Betula papyrifera	1,590	10.97	Pterocarpus angolensis	1,267	8.73			
Prosopis africana	2,019	13.92	Pouteria spp.	1,588	10.95	Nyssa aquatica	1,251	8.62			

\*Estimated/strength group values

All values are for wood at 12% MC

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## Donations:

Amboyna	Oak, Bog
Ash, Olive	Oak, Brown
Balsa	Oak, English
Birch, Masur	Oak, Holm
Blackwood, African	Obeche
Blackwood, Australian	Okoume
Bosse	Olive
Boxwood	Osage Orange
Bubinga	Padauk, African
Bulletwood	Padauk, Andaman
Cebil	Pau Rosa
Cedar of Lebanon	Pear
Cherry, Sweet	Peroba Rosa
Chestnut, Horse	Yellow Poplar
Cocobolo	Primavera
Ebony, Gaboon	Purpleheart
Ekki	Rosewood, Amazon
Elm, English	Rosewood, East Indian
Goncalo Alves	Rosewood, Honduran
Holly, English	Rosewood, Madagascar
Hornbeam, European	Satinwood, East Indian
Imbuia	Sheoak
Idigbo	Silky Oak, Northern
Iroko	Spruce, Sitka
Jarrah	Tambootie
Kingwood	Tulipwood
Laburnum	Verawood
Leadwood	Walnut, African
Lemonwood	Walnut, Black (crotch)
Lime, European	Walnut, English
Madrone (burl)	Wenge
Mahogany, African	Willow, Black (face grain)
Mansonia	Yellowheart
Maple, Quilted	Yew
Mulberry	Ziricote
Myrtle, Tasmanian	

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## Donations:

Myrtle Walnut, Claro

**JUSTIN HOLDEN:** From old standbys to hard-to-find rarities, Justin has donated a number of nice samples from around the world. He sells single pieces upwards to entire pallets worth of exotic and tropical species through his eBay store: <http://stores.ebay.com/exoticwoodsoftheworld>.

## Donations:

Afrormosia	Machiche
Afzelia	Makore
Avodire	Mansonia (endgrain)
Canarywood	Wamara

**MIKE LEIGHER:** Located in South Carolina, Mike and his brother Brad have a portable sawmill and process a number of turning blanks. Mike has donated a number of samples from domestic, ornamental, and/or naturalized trees. His website features great deals on hard-to-find domestic turning blanks: [www.turningblanks.net](http://www.turningblanks.net).

## Donations:

Camphor	Mulberry
Chinaberry	Paulownia
Dogwood	Poplar, Rainbow
Locust, Honey	Sassafras
Magnolia, Southern	Sumac
Maple, Ambrosia	Sweetgum

## DONATION KEY:

- wood or veneer sample donated
- finished wood object photo

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