WOOD!

IDENTIFYING AND USING HUNDREDS OF WOODS WORLDWIDE

ERIC MEIER

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A Brief Introduction: From the Author

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.

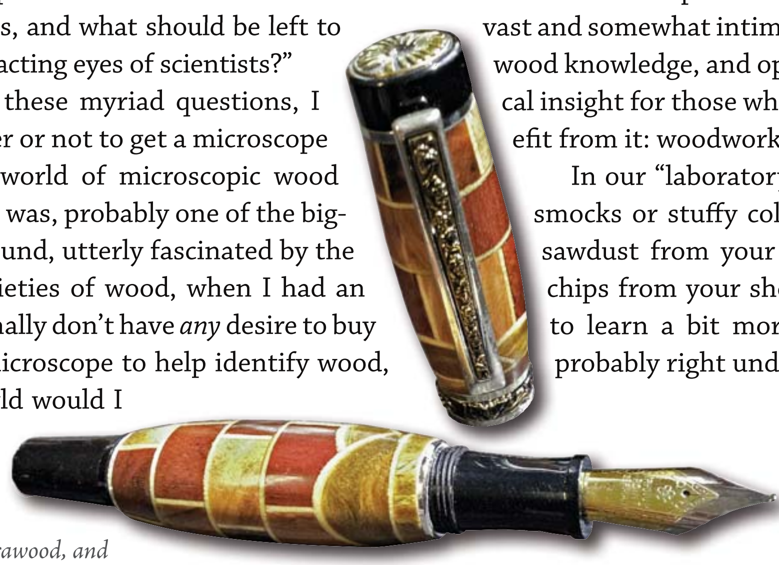
A friend of mine who works in Bible translation once told me that in order for a translation to be optimally readable and usable for native peoples, it ultimately must be written by someone whose mother tongue is in the native language, or else it will seem awkward, foreign, and inarticulate.

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 Meier



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 homogenous 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).

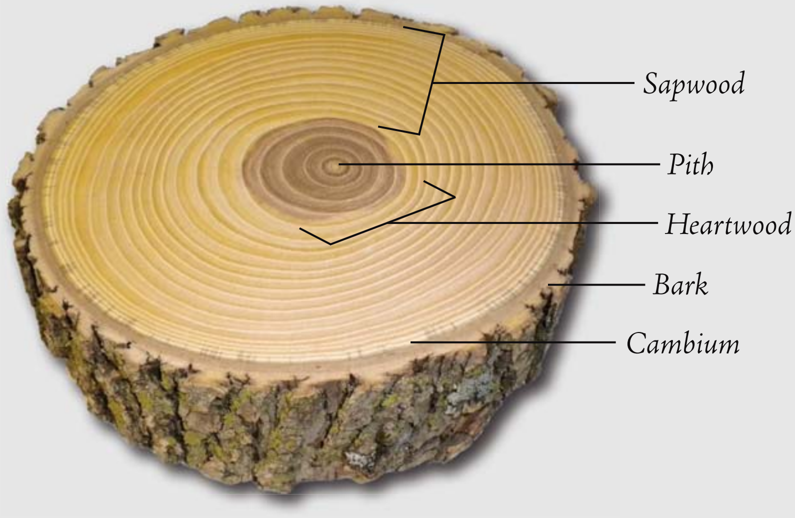
Hardwoods (angiosperms) have broad-leaved foliage, and tend to be **deciduous**—that is, they lose their leaves in the autumn. (However, many tropical hardwood species exist which are **evergreen**—they maintain their leaves year-round.) Additionally, hardwood trees tend to have a branched or divided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

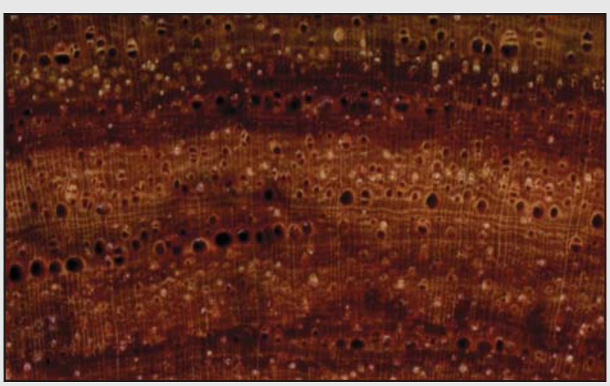
The transition from sapwood to heartwood is accompanied by the accumulation of various deposits and substances, commonly referred to as **extractives**.

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.

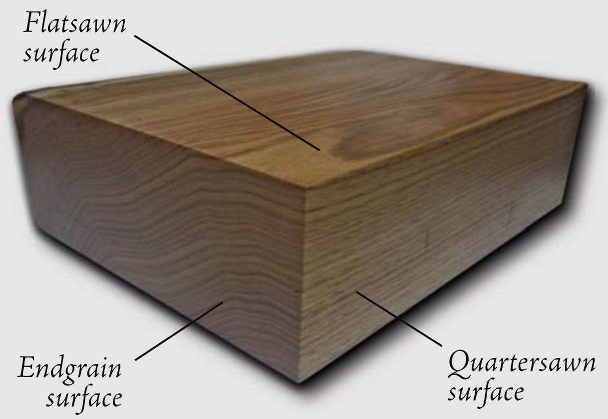


Heartwood extractives, like those found in this sample of Tulipwood *(Dalbergia decipularis)*, provide a cornucopia of colors and unique wood properties. (10×)

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*.



This sample of Butternut (*Juglans cinerea*) models the three wood surfaces well. Note the straight and consistent grain pattern shown on the quartersawn surface as compared to the relatively wild flatsawn surface.

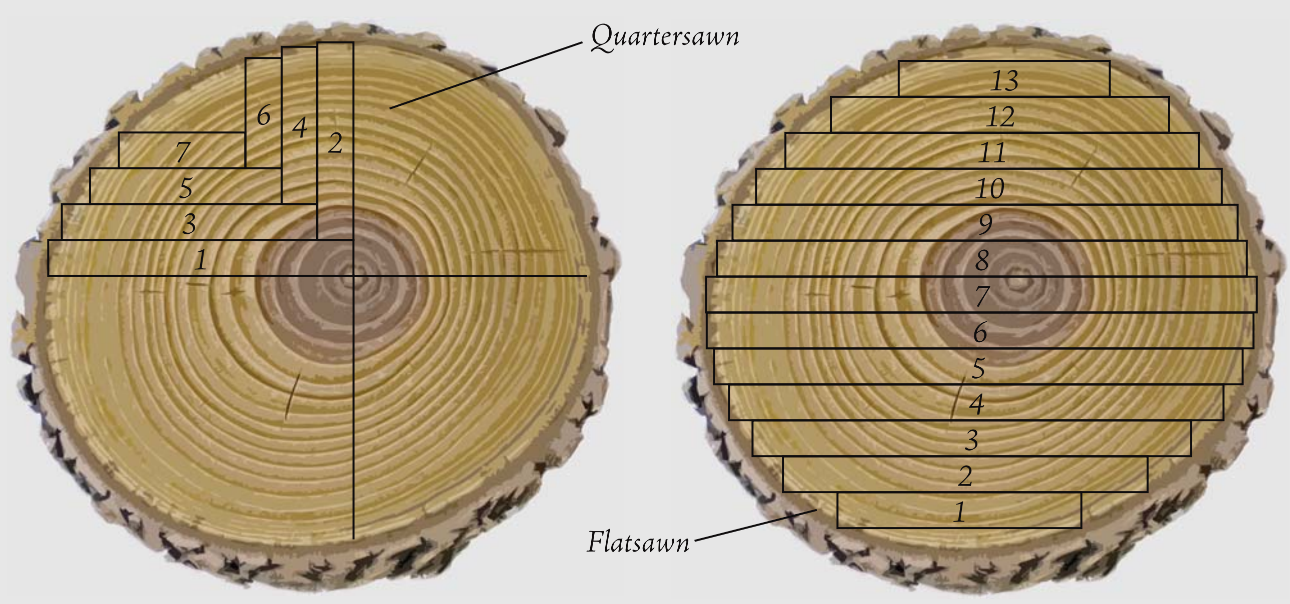
The second primary wood plane is the **radial surface**. (Think of the word *radiate:* this wood surface radiates out from the center of the log like spokes on a wheel, and crosses the growth rings at a more-or-less 90° angle.) This surface goes by a number of names, and is sometimes called **vertical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



Two methods to saw a log: on the left is an example of a quarter-sawing sequence. The log is first cut into quarters, and then each quarter is cut on alternating sides to keep the grain as close to vertical as possible, though the grain of the last few smallest boards aren't perfectly vertical. On the right is an example of flat-sawing or plain-sawing. This method produces the least amount of waste and the widest possible boards. Portions of the middle few boards would be nearly quartersawn, though the pith and first few growth rings in the center (called **juvenile wood**) are very unstable.

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, endgrain 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

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.

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.

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%.

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^3 (690 kg/m^3)

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

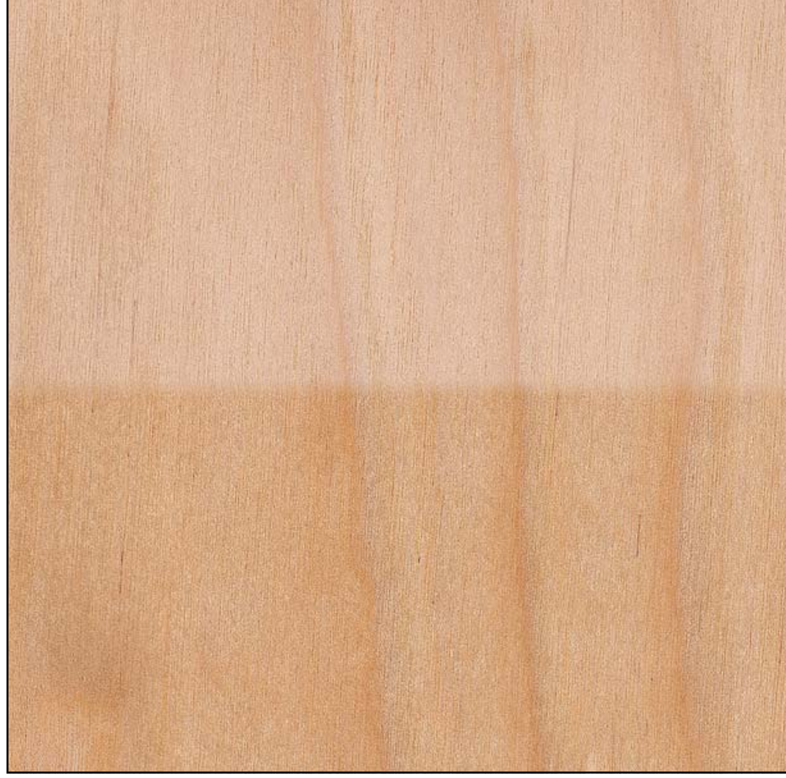
JANKA HARDNESS: 1,260 lb$_f$ (5,610 N)

MODULUS OF RUPTURE: 16,600 lb$_f$/in^2 (114.5 MPa)

ELASTIC MODULUS: 2,010,000 lb$_f$/in^2 (13.86 GPa)

CRUSHING STRENGTH: 8,170 lb$_f$/in^2 (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

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 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.

*Risto Hagqvist, *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
Alder-Leaf Birch *Betula alnoides*	33 lbs/ft^3 (530 kg/m^3)	830 lb$_f$ (3,690 N)	8,980 lb$_f$/in^2 (61.9 MPa)	1,235,000 lb$_f$/in^2 (8.52 GPa)	6,400 lb$_f$/in^2 (44.1 MPa)	Radial–5% Tangential–7% Volumetric–13% T/R Ratio–1.4
Sweet Birch *Betula lenta*	46 lbs/ft^3 (735 kg/m^3)	1,470 lb$_f$ (6,540 N)	16,900 lb$_f$/in^2 (116.6 MPa)	2,170,000 lb$_f$/in^2 (11.59 GPa)	8,540 lb$_f$/in^2 (58.9 MPa)	Radial–6.5% Tangential–9.0% Volumetric–15.6% T/R Ratio–1.4
Alaska Paper Birch *Betula neoalaskana*	38 lbs/ft^3 (610 kg/m^3)	830 lb$_f$ (3,690 N)	13,600 lb$_f$/in^2 (93.8 MPa)	1,900,000 lb$_f$/in^2 (13.10 GPa)	7,450 lb$_f$/in^2 (51.4 MPa)	Radial–6.5% Tangential–9.9% Volumetric–16.7% T/R Ratio–1.5
River Birch *Betula nigra*	37 lbs/ft^3 (590 kg/m^3)	970 lb$_f$ (4,320 N)* **estimated*	13,100 lb$_f$/in^2 (90.3 MPa)	1,580,000 lb$_f$/in^2 (10.90 GPa)	No data available	Radial–4.7% Tangential–9.2% Volumetric–13.5% T/R Ratio–2.0
Paper Birch *Betula papyrifera*	38 lbs/ft^3 (610 kg/m^3)	910 lb$_f$ (4,050 N)	12,300 lb$_f$/in^2 (84.8 MPa)	1,590,000 lb$_f$/in^2 (10.97 GPa)	5,690 lb$_f$/in^2 (39.2 MPa)	Radial–6.3% Tangential–8.6% Volumetric–16.2% T/R Ratio–1.4
Silver Birch *Betula pendula*	40 lbs/ft^3 (640 kg/m^3)	1,210 lb$_f$ (5,360 N)	16,570 lb$_f$/in^2 114.3 MPa)	2,024,000 lb$_f$/in^2 (13.96 GPa)	No data available	No data available
Gray Birch *Betula populifolia*	35 lbs/ft^3 (560 kg/m^3)	760 lb$_f$ (3,380 N)	9,800 lb$_f$/in^2 (67.6 MPa)	1,150,000 lb$_f$/in^2 (7.93 GPa)	4,870 lb$_f$/in^2 (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^3 (745 kg/m^3)

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

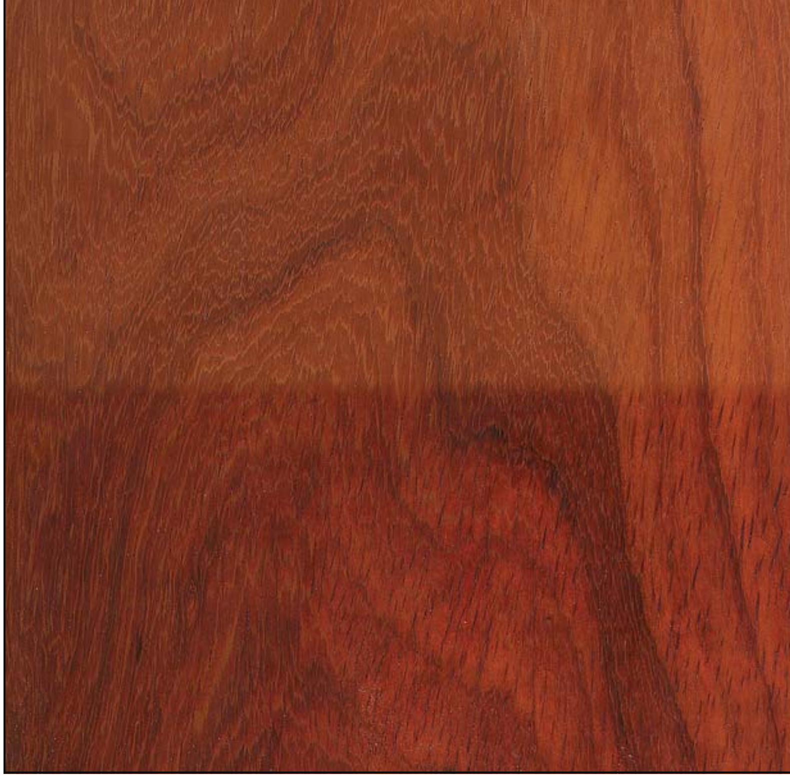
JANKA HARDNESS: 1,970 lb$_f$ (8,760 N)

MODULUS OF RUPTURE: 16,830 lb$_f$/in^2 (116.0 MPa)

ELASTIC MODULUS: 1,700,000 lb$_f$/in^2 (11.72 GPa)

CRUSHING STRENGTH: 8,130 lb$_f$/in^2 (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

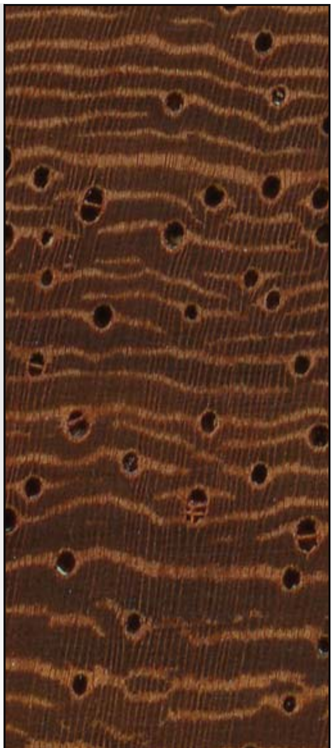
Vessels: very large, very few, orange/brown deposits present

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.

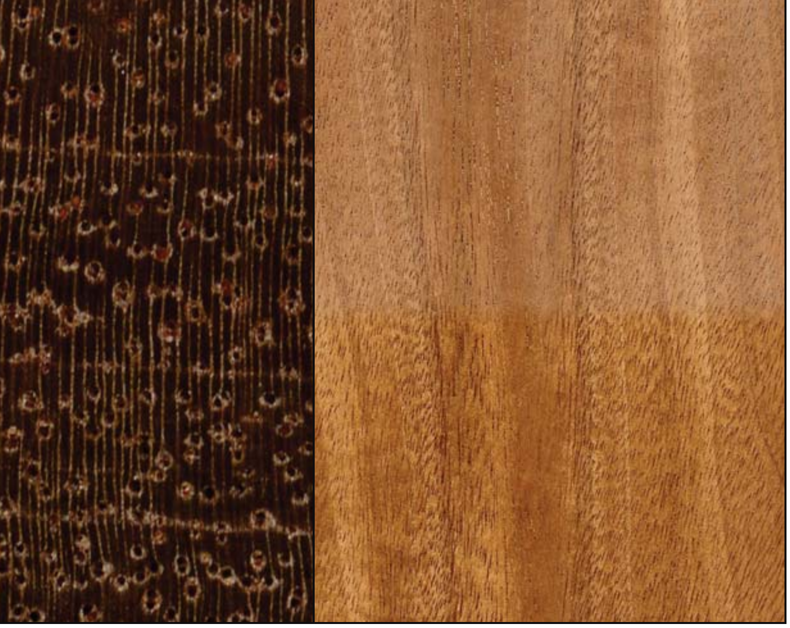
PRICING/AVAILABILITY: Widely imported as lumber in a variety of sizes, as well as turning and craft blanks. Prices are in the mid range for an imported hardwood.

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^3 (800 kg/m^3)

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

JANKA HARDNESS: 1,780 lb$_f$ (7,940 N)

MODULUS OF RUPTURE: 15,780 lb$_f$/in^2 (108.8 MPa)

ELASTIC MODULUS: 1,771,000 lb$_f$/in^2 (12.21 GPa)

CRUSHING STRENGTH: 7,500 lb$_f$/in^2 (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^3 (690 kg/m^3)

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

JANKA HARDNESS: 1,660 lb$_f$ (7,380 N)

MODULUS OF RUPTURE: 12,080 lb$_f$/in^2 (83.3 MPa)

ELASTIC MODULUS: 1,131,000 lb$_f$/in^2 (7.80 GPa)

CRUSHING STRENGTH: 6,400 lb$_f$/in^2 (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 *Rosaceæ* 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 earlywood 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 ⅛" to ½" high, rarely ever more than ¾" to 1" in height. White oaks, on the other hand, will have much taller rays, frequently exceeding ¾" 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^3 (755 kg/m^3)

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

JANKA HARDNESS: 1,360 lb_f (6,000 N)

MODULUS OF RUPTURE: 15,200 lb_f/in^2 (104.8 MPa)

ELASTIC MODULUS: 1,780,000 lb_f/in^2 (12.30 GPa)

CRUSHING STRENGTH: 7,440 lb_f/in^2 (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 flatsawn 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.

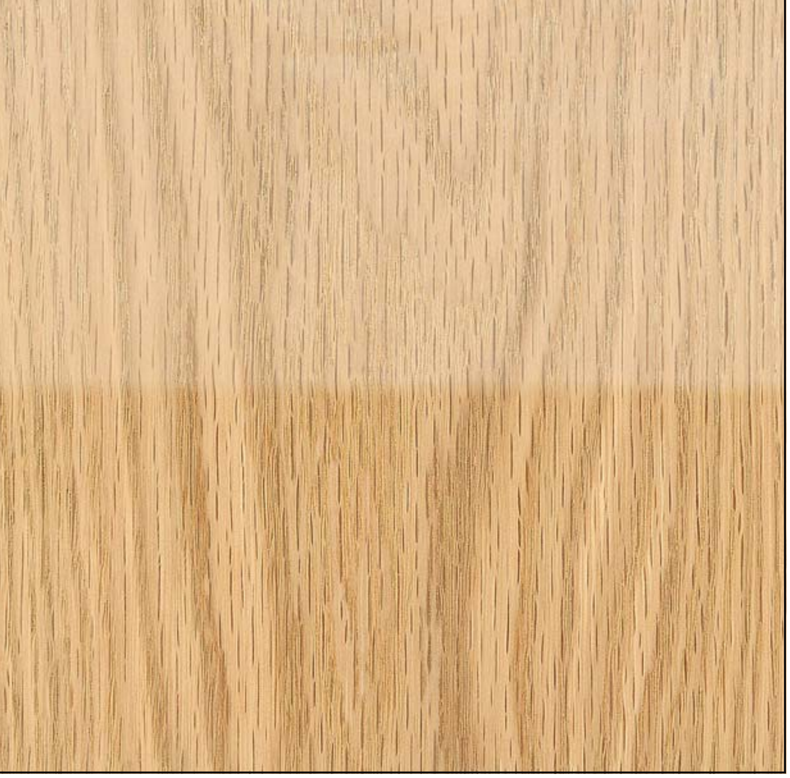
- Swamp White Oak *(Quercus bicolor)*
- Overcup Oak *(Quercus lyrata)*
- Bur Oak *(Quercus macrocarpa)*
- Swamp Chestnut Oak *(Quercus michauxii)*

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. petræa)* 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
Swamp White Oak *Quercus bicolor*	48 lbs/ft³ (765 kg/m³)	1,600 lb_f (7,140 N)	17,400 lb_f/in^2 (120.0 MPa)	2,029,000 lb_f/in^2 (13.99 GPa)	8,400 lb_f/in^2 (57.9 MPa)	Radial–5.5% Tangential–10.6% Volumetric–17.7% T/R Ratio–1.9
Oregon White Oak *Quercus garryana*	51 lbs/ft³ (815 kg/m³)	1,640 lb_f (7,310 N)	10,200 lb_f/in^2 (70.3 MPa)	1,089,000 lb_f/in^2 (7.51 GPa)	7,320 lb_f/in^2 (50.5 MPa)	Radial–4.2% Tangential–9.0% Volumetric–13.2% T/R Ratio–2.1
Overcup Oak *Quercus lyrata*	47 lbs/ft³ (760 kg/m³)	1,190 lb_f (5,290 N)	12,600 lb_f/in^2 (86.9 MPa)	1,420,000 lb_f/in^2 (9.79 GPa)	6,200 lb_f/in^2 (42.8 MPa)	Radial–5.3% Tangential–12.7% Volumetric–16.0% T/R Ratio–2.4
Bur Oak *Quercus macrocarpa*	45 lbs/ft³ (720 kg/m³)	1,360 lb_f (6,030 N)	10,920 lb_f/in^2 (75.3 MPa)	1,040,000 lb_f/in^2 (7.17 GPa)	5,890 lb_f/in^2 (40.6 MPa)	Radial–4.4% Tangential–8.8% Volumetric–12.7% T/R Ratio–2.0
Swamp Chestnut Oak *Quercus michauxii*	49 lbs/ft³ (780 kg/m³)	1,230 lb_f (5,460 N)	13,760 lb_f/in^2 (94.9 MPa)	1,753,000 lb_f/in^2 (12.09 GPa)	7,200 lb_f/in^2 (49.6 MPa)	Radial–5.2% Tangential–10.8% Volumetric–16.4% T/R Ratio–2.1
Sessile Oak *Quercus petræa*	44 lbs/ft³ (710 kg/m³)	1,120 lb_f (4,990 N)	14,080 lb_f/in^2 (97.1 MPa)	1,518,000 lb_f/in^2 (10.47 GPa)	6,860 lb_f/in^2 (47.3 MPa)	Radial–4.5% Tangential–9.7% Volumetric–14.2% T/R Ratio–2.2
Chestnut Oak *Quercus prinus*	47 lbs/ft³ (750 kg/m³)	1,130 lb_f (5,030 N)	13,300 lb_f/in^2 (91.7 MPa)	1,590,000 lb_f/in^2 (10.97 GPa)	6,830 lb_f/in^2 (47.1 MPa)	Radial–5.3% Tangential–10.8% Volumetric–16.4% T/R Ratio–2.0
Post Oak *Quercus stellata*	47 lbs/ft³ (750 kg/m³)	1,350 lb_f (5,990 N)	13,070 lb_f/in^2 (90.1 MPa)	1,495,000 lb_f/in^2 (10.31 GPa)	6,530 lb_f/in^2 (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^3 (700 kg/m^3)

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

JANKA HARDNESS: 1,290 lb_f (5,700 N)

MODULUS OF RUPTURE: 14,300 lb_f/in^2 (98.6 MPa)

ELASTIC MODULUS: 1,820,000 lb_f/in^2 (12.50 GPa)

CRUSHING STRENGTH: 6,760 lb_f/in^2 (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.

Red Oak and Sapele veneer segmented bowl

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.

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
Scarlet Oak *Quercus coccinea*	46 lbs/ft³ (735 kg/m³)	1,400 lbf (6,230 N)	16,080 lbf/in² (110.9 MPa)	1,766,000 lbf/in² (12.18 GPa)	8,250 lbf/in² (56.9 MPa)	Radial–4.4% Tangential–10.8% Volumetric–14.7% T/R Ratio–2.5
Southern Red Oak *Quercus falcata*	42 lbs/ft³ (675 kg/m³)	1,060 lbf (4,720 N)	12,040 lbf/in² (83.0 MPa)	1,480,000 lbf/in² (10.20 GPa)	6,090 lbf/in² (42.0 MPa)	Radial–4.7% Tangential–11.3% Volumetric–16.1% T/R Ratio–2.4
California Black Oak *Quercus kelloggii*	39 lbs/ft³ (620 kg/m³)	1,090 lbf (4,840 N)	8,610 lbf/in² (59.4 MPa)	980,000 lbf/in² (6.76 GPa)	5,640 lbf/in² (38.9 MPa)	Radial–3.6% Tangential–6.6% Volumetric–10.2% T/R Ratio–1.8
Laurel Oak *Quercus laurifolia*	46 lbs/ft³ (740 kg/m³)	1,210 lbf (5,380 N)	14,330 lbf/in² (98.8 MPa)	1,793,000 lbf/in² (12.37 GPa)	6,980 lbf/in² (48.1 MPa)	Radial–4.0% Tangential–9.9% Volumetric–19.0% T/R Ratio–2.5
Water Oak *Quercus nigra*	45 lbs/ft³ (725 kg/m³)	1,190 lbf (5,290 N)	16,620 lbf/in² (114.6 MPa)	2,034,000 lbf/in² (14.02 GPa)	6,770 lbf/in² (46.7 MPa)	Radial–4.4% Tangential–9.8% Volumetric–16.1% T/R Ratio–2.2
Cherrybark Oak *Quercus pagoda*	49 lbs/ft³ (785 kg/m³)	1,480 lbf (6,580 N)	18,100 lbf/in² (124.8 MPa)	2,280,000 lbf/in² (15.72 GPa)	8,740 lbf/in² (60.3 MPa)	Radial–5.5% Tangential–10.6% Volumetric–16.1% T/R Ratio–1.9
Pin Oak *Quercus palustris*	44 lbs/ft³ (705 kg/m³)	1,500 lbf (6,650 N)	13,860 lbf/in² (95.6 MPa)	1,713,000 lbf/in² (11.81 GPa)	6,750 lbf/in² (46.6 MPa)	Radial–4.3% Tangential–9.5% Volumetric–14.5% T/R Ratio–2.2
Willow Oak *Quercus phellos*	48 lbs/ft³ (770 kg/m³)	1,460 lbf (6,490 N)	14,860 lbf/in² (102.4 MPa)	1,804,000 lbf/in² (12.44 GPa)	7,040 lbf/in² (48.6 MPa)	Radial–5.0% Tangential–9.6% Volumetric–18.9% T/R Ratio–1.9
Shumard Oak *Quercus shumardii*	46 lbs/ft³ (730 kg/m³)	1,290 lbf (5,750 N)* **estimated*	17,830 lbf/in² (123.0 MPa)	2,154,000 lbf/in² (14.86 GPa)	No data available	No data available
Black Oak *Quercus velutina*	45 lbs/ft³ (715 kg/m³)	1,210 lbf (5,380 N)	14,430 lbf/in² (99.5 MPa)	1,736,000 lbf/in² (11.97 GPa)	6,450 lbf/in² (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_f/in^2	GPa
Swartzia cubensis	3,715	25.62
Chlorocardium rodiei	3,573	24.64
Swartzia benthamiana	3,535	24.38
Brosimum guianense	3,364	23.20
Manilkara bidentata	3,344	23.06
Dipteryx odorata	3,237	22.33
Handroanthus spp.	3,200	22.07
Dalbergia stevensonii	3,190	22.00
Acacia omalophylla*	3,118	21.50
Brosimum rubescens	3,013	20.78
Krugiodendron ferreum	2,966	20.46
Eucalyptus diversicolor	2,965	20.44
Manilkara zapota	2,960	20.41
Peltogyne spp.	2,937	20.26
Koompassia malaccensis	2,913	20.09
Roupala montana	2,887	19.91
Platymiscium spp.	2,837	19.56
Zygia racemosa	2,818	19.43
Bambusa spp.	2,755	19.00
Lophira alata	2,754	18.99
Lonchocarpus spp.	2,745	18.93
Hymenaea courbaril	2,745	18.93
Metopium brownei	2,733	18.85
Eucalyptus globulus	2,721	18.76
Caesalpinia paraguariensis*	2,712	18.70
Dalbergia retusa*	2,712	18.70
Guibourtia ehie	2,701	18.63
Anadenanthera colubrina	2,672	18.43
Guibourtia spp. (Bubinga)	2,670	18.41
Acacia cambagei	2,610	18.00
Dalbergia melanoxylon	2,603	17.95
Vouacapoua americana	2,586	17.83
Olea spp.	2,577	17.77
Caesalpinia platyloba	2,574	17.76
Millettia laurentii	2,550	17.59
Caesalpinia echinata	2,544	17.54
Prosopis kuntzei	2,520	17.38
Diospyros celebica	2,515	17.35
Buxus sempervirens	2,494	17.20
Combretum schumannii	2,494	17.20
Bobgunnia fistuloides	2,480	17.10
Shorea spp. (Balau)	2,457	16.95
Diospyros crassiflora	2,449	16.89
Euxylophora paraensis	2,413	16.64
Schinopsis spp.	2,407	16.60
Astronium graveolens	2,401	16.56
Ebenopsis ebano	2,398	16.54
Myroxylon balsamum	2,380	16.41
Piptadenia spp.	2,380	16.41
Dalbergia cochinchinensis	2,375	16.38
Microberlinia brazzavillensis	2,374	16.37
Julbernardia pellegriniana	2,334	16.09
Intsia bijuga	2,310	15.93
Dipterocarpus spp.	2,293	15.81
Calycophyllum candidissimum	2,284	15.75
Millettia stuhlmannii	2,281	15.73
Quercus pagoda	2,280	15.72
Bulnesia arborea	2,272	15.67
Borassus flabellifer	2,262	15.60
Carya glabra	2,260	15.59
Apuleia leiocarpa	2,257	15.57
Gonystylus spp.	2,255	15.55
Carya tomentosa	2,220	15.31
Pinus oocarpa	2,209	15.23
Berchemia zeyheri	2,193	15.12
Betula lenta	2,170	14.97
Centrolobium spp.	2,164	14.93
Pinus merkusii	2,161	14.90
Carya ovata	2,160	14.90
Maclura tinctoria	2,160	14.90
Quercus shumardii	2,154	14.86
Acacia melanoxylon	2,148	14.82
Eucalyptus marginata	2,132	14.70
Acacia mearnsii	2,117	14.60
Chloroxylon swietenia	2,111	14.56
Afzelia spp.	2,094	14.44
Fagus sylvatica	2,075	14.31
Eucalyptus obliqua	2,071	14.29
Eucalyptus grandis	2,052	14.15
Robinia pseudoacacia	2,050	14.14
Eucalyptus urograndis	2,049	14.13
Eucalyptus robusta	2,047	14.12
Guaiacum officinale	2,043	14.09
Diospyros ebenum	2,040	14.07
Quercus nigra	2,034	14.02
Eucalyptus regnans	2,033	14.02
Eucalyptus melliodora	2,030	14.00
Guibourtia hymenaeifolia	2,030	14.00
Quercus bicolor	2,029	13.99
Betula pendula	2,024	13.96
Dalbergia nigra	2,020	13.93
Carya aquatica	2,020	13.93
Prosopis africana	2,019	13.92

Botanical name	×1,000 lb_f/in^2	GPa
Diospyros virginiana	2,010	13.86
Betula alleghaniensis	2,010	13.86
Aspidosperma polyneuron	2,002	13.81
Pinus elliottii	1,980	13.66
Pinus palustris	1,980	13.66
Carapa spp.	1,965	13.55
Quercus virginiana	1,960	13.52
Palaquium spp.	1,939	13.37
Cornus florida	1,922	13.26
Tamarindus indica	1,918	13.22
Colophospermum mopane	1,917	13.22
Gluta spp.	1,915	13.21
Betula neoalaskana	1,900	13.10
Carya laciniosa	1,890	13.03
Larix occidentalis	1,870	12.90
Parashorea spp. (Wht. Seraya)	1,841	12.70
Albizia lebbeck	1,836	12.66
Acer saccharum	1,830	12.62
Nothofagus cunninghamii	1,830	12.62
Magnolia acuminata	1,820	12.55
Quercus phellos	1,804	12.44
Quercus laurifolia	1,793	12.37
Carya cordiformis	1,790	12.34
Pinus taeda	1,790	12.34
Fraxinus excelsior	1,785	12.31
Tectona grandis	1,781	12.28
Pinus kesiya	1,776	12.25
Distemonanthus benthamianus	1,773	12.23
Pterogyne nitens	1,771	12.21
Cordia spp. (Ziricote)	1,767	12.19
Quercus coccinea	1,766	12.18
Pseudotsuga menziesii	1,765	12.17
Quercus alba	1,762	12.15
Quercus rubra	1,761	12.14
Prosopis juliflora	1,759	12.13
Pterocarpus dalbergioides	1,754	12.10
Quercus michauxii	1,753	12.09
Pinus echinata	1,750	12.07
Pinus serotina	1,750	12.07
Casuarina cunninghamiana	1,747	12.05
Entandrophragma cylindricum	1,746	12.04
Betula pubescens	1,745	12.03
Pinus caribaea	1,745	12.03
Shorea spp. (Dk. Red Meranti)	1,743	12.02
Dalbergia baronii	1,742	12.01
Eucalyptus leucoxylon	1,740	12.00
Fraxinus americana	1,740	12.00
Quercus velutina	1,736	11.97
Carya illinoinensis	1,730	11.93
Pterocarpus indicus	1,724	11.89
Araucaria heterophylla	1,723	11.89
Agathis australis	1,721	11.87
Pericopsis elata	1,715	11.83
Quercus palustris	1,713	11.81
Eucalyptus camaldulensis	1,711	11.80
Araucaria cunninghamii	1,706	11.77
Pterocarpus soyauxii	1,700	11.72
Carya myristiciformis	1,700	11.72
Ostrya virginiana	1,700	11.72
Tilia x europaea	1,698	11.71
Carpinus spp.	1,693	11.68
Maclura pomifera	1,689	11.64
Entandrophragma utile	1,689	11.65
Abies amabilis	1,681	11.59
Juglans nigra	1,680	11.59
Cinnamomum camphora	1,676	11.56
Mangifera indica	1,672	11.53
Dalbergia latifolia	1,668	11.50
Fraxinus pennsylvanica	1,660	11.45
Endiandra palmerstonii	1,656	11.42
Cocos nucifera	1,654	11.41
Shorea spp. (Lt. Red Meranti)	1,652	11.39
Ulmus alata	1,650	11.38
Araucaria angustifolia	1,648	11.37
Chamaecyparis lawsoniana	1,646	11.35
Acer rubrum	1,640	11.31
Liquidambar styraciflua	1,640	11.31
Larix larcina	1,640	11.31
Magnolia virginiana	1,640	11.31
Gleditsia triacanthos	1,630	11.24
Tsuga heterophylla	1,630	11.24
Pinus resinosa	1,630	11.24
Ailanthus altissima	1,623	11.19
Acer nigrum	1,620	11.17
Abies procera	1,619	11.17
Ulmus glabra	1,615	11.14
Turraeanthus africanus	1,614	11.13
Acacia mangium	1,605	11.07
Fraxinus nigra	1,600	11.03
Picea sitchensis	1,600	11.03
Quercus prinus	1,590	10.97
Betula papyrifera	1,590	10.97
Pouteria spp.	1,588	10.95

Botanical name	×1,000 lb_f/in^2	GPa
Cordia dodecandra	1,585	10.93
Guarea cedrata	1,582	10.91
Senna siamea	1,581	10.90
Albizia ferruginea	1,581	10.91
Betula nigra	1,580	10.90
Liriodendron tulipifera	1,580	10.90
Machaerium spp.	1,574	10.86
Mansonia altissima	1,570	10.83
Juglans regia	1,568	10.81
Weinmannia trichosperma	1,568	10.81
Pinus nigra	1,568	10.81
Lagerstroemia spp.	1,566	10.80
Eucalyptus deglupta	1,565	10.79
Picea rubens	1,560	10.76
Tieghemella heckelii	1,552	10.71
Pinus pungens	1,550	10.69
Shorea spp. (Yellow Meranti)	1,548	10.68
Quercus robur	1,544	10.65
Ulmus thomasii	1,540	10.62
Khaya spp.	1,537	10.60
Abies grandis	1,530	10.55
Picea mariana	1,523	10.50
Pinus virginiana	1,520	10.48
Terminalia superba	1,520	10.49
Quercus petraea	1,518	10.47
Dalbergia sissoo	1,508	10.40
Acacia koa	1,503	10.37
Simira salvadorensis*	1,497	10.32
Quercus stellata	1,495	10.31
Ulmus rubra	1,490	10.28
Prunus serotina	1,490	10.28
Shorea spp. (White Meranti)	1,485	10.24
Abies concolor	1,485	10.24
Abies magnifica	1,483	10.23
Ulmus crassifolia	1,480	10.21
Quercus falcata	1,480	10.20
Spirostachys africana	1,478	10.19
Prunus domestica	1,478	10.19
Cedrus libani	1,465	10.10
Pinus patula	1,463	10.09
Pinus sylvestris	1,461	10.08
Pinus monticola	1,460	10.07
Tilia americana	1,460	10.07
Swietenia macrophylla	1,458	10.06
Pinus radiata	1,458	10.06
Acer macrophyllum	1,450	10.00
Taxodium distichum	1,440	9.93
Acer pseudoplatanus	1,438	9.92
Pinus rigida	1,430	9.86
Populus grandidentata	1,430	9.86
Quercus lyrata	1,420	9.79
Cupressus nootkatensis	1,420	9.79
Gymnocladus dioicus	1,420	9.79
Platanus occidentalis	1,420	9.79
Populus tremula	1,414	9.75
Pinus clausa	1,410	9.72
Picea abies	1,406	9.70
Pinus glabra	1,405	9.69
Fraxinus quadrangulata	1,400	9.66
Magnolia grandiflora	1,400	9.66
Ocotea porosa	1,394	9.61
Abies balsamea	1,387	9.57
Mitragyna ciliata	1,386	9.56
Alnus rubra	1,380	9.52
Populus deltoides	1,370	9.45
Picea engelmannii	1,369	9.44
Milicia spp.	1,360	9.38
Fraxinus latifolia	1,360	9.38
Terminalia ivorensis	1,355	9.34
Morus spp.	1,352	9.32
Callitris columellaris	1,351	9.32
Swietenia mahogani	1,351	9.31
Taxus brevifolia	1,350	9.31
Pinus banksiana	1,350	9.31
Lovoa trichilioides	1,340	9.24
Ulmus americana	1,340	9.24
Pinus contorta	1,340	9.24
Lagarostrobos franklinii	1,339	9.23
Toona ciliata	1,336	9.22
Abies lasiocarpa	1,324	9.13
Cedrela odorata	1,323	9.12
Hevea brasiliensis	1,315	9.07
Picea glauca	1,315	9.07
Alnus glutinosa	1,303	8.99
Melia azedarach	1,300	8.97
Cardwellia sublimis	1,293	8.92
Platanus x acerifolia	1,291	8.90
Populus alba	1,290	8.90
Pinus ponderosa	1,290	8.90
Malus sylvestris	1,270	8.76
Populus trichocarpa	1,270	8.76
Pterocarpus angolensis	1,267	8.73
Nyssa aquatica	1,251	8.62

Botanical name	×1,000 lb_f/in^2	GPa
Castanea sativa	1,248	8.61
Pinus jeffreyi	1,240	8.55
Pinus strobus	1,240	8.55
Pinus pinaster	1,238	8.54
Betula alnoides	1,235	8.52
Baikiaea plurijuga	1,230	8.48
Arbutus menziesii	1,230	8.48
Castanea dentata	1,230	8.48
Aucoumea klaineana	1,228	8.47
Enterolobium cyclocarpum	1,226	8.46
Umbellularia californica	1,225	8.45
Dyera costulata	1,224	8.44
Sequoia sempervirens	1,220	8.41
Catalpa speciosa	1,210	8.34
Abies alba	1,200	8.28
Tsuga canadensis	1,200	8.28
Fraxinus mandshurica	1,195	8.24
Celtis occidentalis	1,190	8.21
Rhus spp.	1,190	8.21
Pinus lambertiana	1,190	8.21
Nyssa sylvatica	1,188	8.19
Populus tremuloides	1,180	8.14
Juglans cinerea	1,180	8.14
Pinus flexilis	1,170	8.07
Aesculus spp. (Buckeye)	1,170	8.07
Ulmus pumila	1,154	7.96
Grevillea robusta	1,151	7.93
Betula populifolia	1,150	7.93
Samanea saman	1,149	7.92
Acer saccharinum	1,140	7.86
Pinus edulis	1,140	7.86
Cupressus macrocarpa	1,133	7.81
Roseodendron donnell-smithii	1,133	7.81
Juglans neotropica	1,132	7.81
Pyrus communis	1,131	7.80
Dalbergia tucurensis	1,125	7.76
Sassafras albidum	1,120	7.72
Prosopis nigra	1,117	7.70
Ilex opaca	1,110	7.66
Thuja plicata	1,110	7.66
Cryptomeria japonica	1,109	7.65
Populus balsamifera	1,100	7.59
Quercus garryana	1,089	7.51
Acer negundo*	1,050	7.24
Quercus macrocarpa	1,040	7.17
Calocedrus decurrens	1,040	7.17
Aesculus hippocastanum	1,036	7.14
Ulmus procera	1,032	7.12
Salix nigra	1,010	6.97
Cupressus x leylandii	989	6.82
Quercus kelloggii	980	6.76
Triplochiton scleroxylon	970	6.69
Rhamnus spp.	960	6.62
Chamaecyparis thyoides	930	6.41
Prosopis alba	882	6.08
Juniperus virginiana	880	6.07
Thuja occidentalis	800	5.52
Juniperus deppeana	650	4.48
Paulownia spp.	635	4.38
Ochroma pyramidale	538	3.71

***Estimated/strength group values**

All values are for wood at 12%MC

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Donations:

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

KEN FORDEN: Located in Whitethorn, California, Ken has a small hardwood mill that specializes in native Californian woods. His website features slabs, flooring, molding, and lumber: www.californiahardwoods.net.

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
Afzelia
Avodire
Canarywood
Machiche
Makore
Mansonia (endgrain)
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.

Donations:

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

DONATION KEY:

wood or veneer sample donated

finished wood object photo

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