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The Complete Book of Woodworking

Types of Wood & Cuts

FOX CHAPEL PUBLISHING

Introduction to Wood

Choosing lumber for your project is as much a part of woodworking as any other step in the process. Lumber is expensive, so it pays to know what your options are before you head to the lumberyard—sometimes an economical species will serve the same function as a more costly alternative.

In addition, each wood type has natural characteristics that influence workability, appearance and durability. It's important to be aware of these factors before you build. Hardwood and softwood lumber is sold in various industry grades based on the percentage of clear (knot-free) lumber the board must have, as well as whether or not the boards are planed at the mill or left roughsawn. You'll need to pick a lumber grade that is suitable for your project needs, tools available to you and your project budget, then sift through stacks of boards carefully—lumber within the same grade can vary widely in terms of color, figure and defects.

So how do you choose which species to use and which boards to buy? Making good lumber choices to some extent comes only by experience. You'll need to build with different species and grades of wood to know what truly works best for projects intended for different purposes. But familiarizing yourself with the various topics covered in this chapter is a good first step to buying smart.

In the pages that follow you'll become familiar with distinctions between hardwoods, softwoods and sheet goods and examine some of their different uses. Learn about figure and defects in lumber, see how mills cut logs into boards, and discover how wood reacts to changes in moisture. We'll cover how lumber is sized and sold, as well as overview the standardized lumber grading systems. Finally, the end of the chapter reveals some time-tested guidelines about where and how to shop for lumber like a pro.

Once you've read this chapter and calculated the quantity and quality of boards your project requires, you can venture more confidently off to the lumberyard to pilfer through stacks of boards. You may even save a bit of money in the process.

WOODWORKING WORKS

One of the distinctive features of this tool chest is how the design integrates contrasting wood types. While the majority of the project is made of white oak, the drawer pulls and lid edge are walnut. Generally, the most attractive approach is to pair light and dark woods and limit the contrast to two wood types.

Woodworking Wisdom

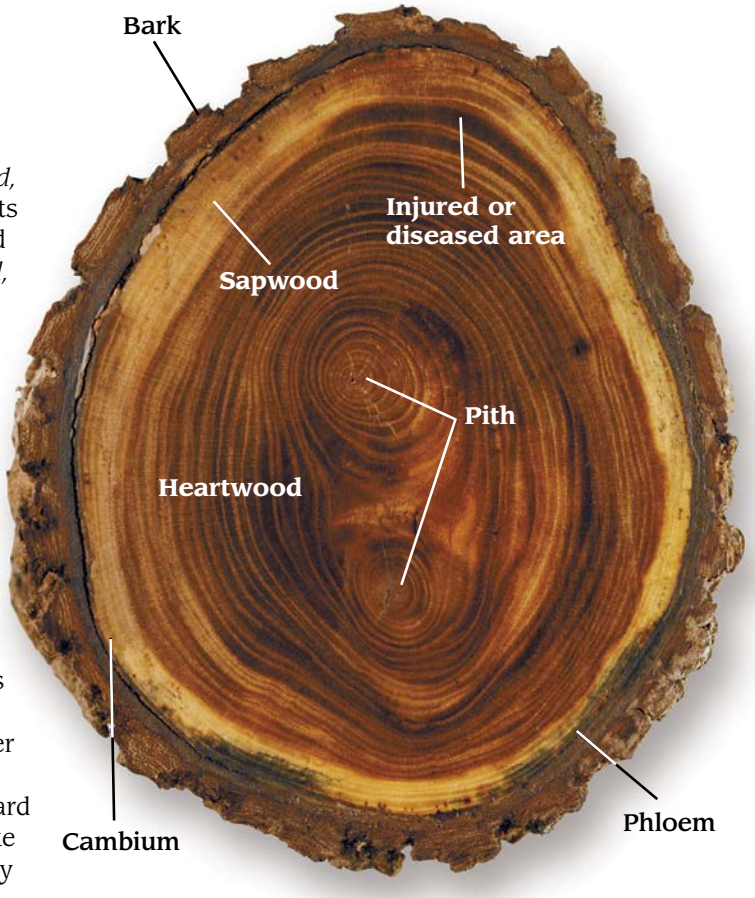
A woodworker in Wyoming once sent me some photographs of a cigar humidor he had built from a plan of mine. It was a Honduras mahogany box with brass inlay, a gift for his father-in-law who enjoyed an occasional stogie. The accompanying cover letter said that he was especially proud of the beautiful cedar lining that he had custom-fitted to the interior. But when I got to that photo, my heart sank. This well-intentioned fellow had unfortunately lined the humidor with aromatic instead of Spanish cedar. If the humidor had been used, his father-in-law's cigar collection would have been ruined by the strong cedar smell. Instances like this illustrate an important lesson when selecting wood for a project: Be sure to consider the characteristics of the wood species you choose before you build. It can make or break a project.

~John English

Anatomy of a Tree

At the very center of a tree is a small area of softer tissue called *pith.* Surrounding the pith are numerous annual rings of growth, already dead, that provide support and structure to the tree. This is the *heartwood,* the area most treasured by woodworkers because of its even density and grain pattern. Beyond the heartwood is a thinner section of still-living rings, called *sapwood,* that provide a conduit from the roots to the leaves for transporting soluble mineral salts. The outermost sapwood ring—the *cambium*—is the growth region in a living tree. Cambium contributes girth to the trunk over time, adding another new layer of sapwood each year. Between the cambium and the protective layer of bark is yet another thin region called the *phloem.* This is the conduit that brings food (made in the leaves through photosynthesis) back down to the root system.

Most mills remove all the exterior layers (bark, phloem, cambium and sapwood) from logs before milling them into boards or dimensional stock such as 2 x 4s. Today, most of the bark and sapwood is ground up and used as mulch in gardens, sold to paper mills, burned as fuel or even used as animal bedding. Occasionally you'll run across a board at the lumberyard that contains sapwood. In darker-grained varieties, like walnut or cherry, sapwood appears as a band of lightly colored, softer wood that runs lengthwise near one long edge of the board. If incorporated into a project, sapwood will become more prominent when you apply a finish unless you stain it to match the rest of the board. For this reason, sapwood is seldom used for furniture.

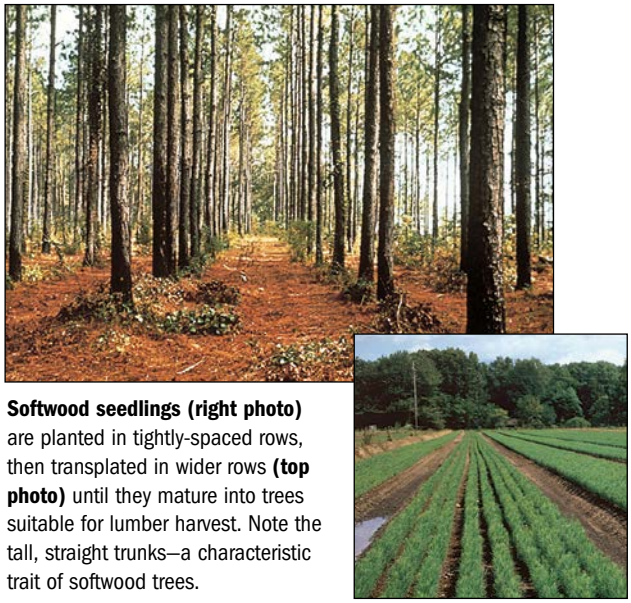


This Chinese Elm sample exhibits all the major anatomical areas of a tree: bark, phloem, cambium, sapwood, heartwood and pith. The cross-section shown here, with two pith regions, likely came from a tree whose trunk split into two major branches. Notice also the darker area, a sign that the tree experienced a period of injury or disease.

Forest Management

Softwoods (also called conifers) nearly always grow at a faster rate than hardwoods, and this fact helps explain how supply and demand influence prices of both softwood and hardwood lumber. The rapid growth rate of softwoods allows for frequent replanting and harvesting—sometimes in as little as 15 years—compared to a minimum of 75 years for most common hardwoods. Shorter harvest time helps to keep softwood quantities stable and costs below that of hardwoods—a benefit to both the construction industry and to softwood supplies for woodworking.

Because softwood trees reproduce with heavy cones rather than flowers or nuts, the seeds often fall close to the parent tree. This natural adaptation enables softwoods to grow close together—a fact that can be a boon to a lumber mill. The mill's forester can plant more trees per acre. Each plant, seeking light above the canopy created by its siblings, will tend to grow straight and true. Loggers have long taken advantage of this growth pattern, replanting conifers in tightly spaced rows that yield easily milled, straight logs.



Softwood seedlings (right photo) are planted in tightly-spaced rows, then transplated in wider rows **(top photo)** until they mature into trees suitable for lumber harvest. Note the tall, straight trunks—a characteristic trait of softwood trees.

Defining Hardwoods & Softwoods

Botanically speaking, trees are categorized as either hardwoods or softwoods. Here's a simple way to distinguish the two: hardwoods are deciduous (broad leafed), generally losing their leaves in late fall and reproducing with flowers and fruits or nuts. Softwoods, on the other hand, are coniferous; they retain their needle-shaped leaves in the winter and reproduce by spreading their seed through open cones. The terms 'softwood' or 'hardwood' have nothing to do with whether the wood is physically hard or soft.

All trees have two growth spurts each year. Their spring growth produces a light-colored material between the rings, called *earlywood.* The more dense cells produced in the late summer and fall are known as *latewood,* and these constitute the darker rings that every child has counted to determine a tree's age.

Softwood trees tend to grow more rapidly than hardwoods, and they have wider bands of earlywood than most slow-growing hardwoods. Softwood trees also have larger, less dense cells in the earlywood than hardwoods.

Hardwood vs. softwood

Despite what the categories imply, the distintion between hardwoods and softwoods has to do with leaf type and is not a measure of wood hardness. Oak, a common hardwood, has broad leaves that shed in the fall, while pine, a coniferous softwood, retains its needles all winter.

This helps explain why a nail can be driven into a wide-celled pine board more easily than a tight-grained oak board; the cell structure is less dense, allowing easier penetration.

Another property worth noting is that hardwood trees allow their branches time and space to grow in almost any direction, in order to maximize leaf exposure to sunlight. The internal stresses present in the wood, resulting from the weight of these outspread branches, create interesting figure and grain patterns in the wood (See below, left). However, there is a price to pay for that beauty: highly figured wood tends to distort more readily than straight-grained boards as the stresses are released.

Three centuries ago, colonial woodworkers cut their lumber from vast tracts of virgin coniferous forest. It wasn't uncommon for them to glean white pine boards measuring 2, 3 and even 4 ft. wide, with no knots or other disfigurement. It's no surprise that much of their early furniture was built from softwood. Boards culled from today's replanted pine forests, on the other hand, have knots every 12 to 18 in. along their length (one year's growth). Because of their minimal girth at harvest, boards often contain considerable sapwood as well.

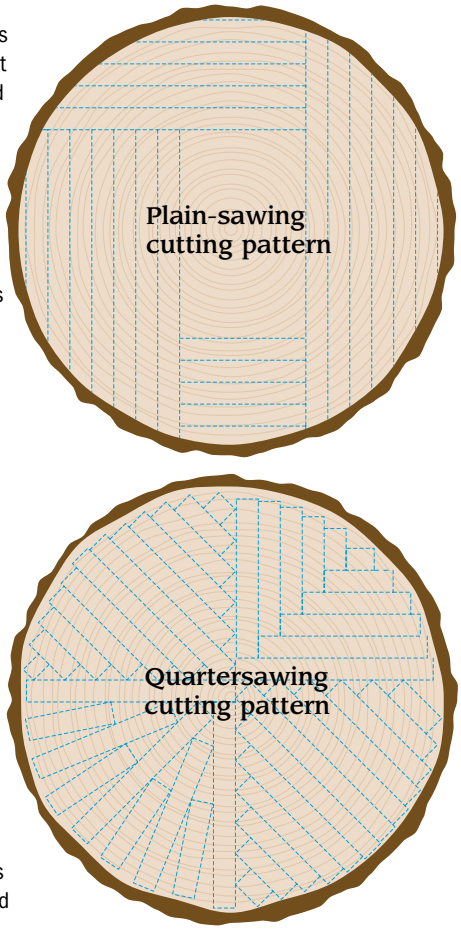
Color, figure & grain pattern

Part of the attraction of woodworking comes from the opportunity to work with wood displaying dramatic differences in color, figure and grain pattern. Wood color is a product of of how its tannins, gums and resins react to exposure to the air. Often, wood will continue to darken and change color over time, developing a rich patina. Figure—the surface pattern on a board—can be the result of numerous natural causes ranging from drought or freezing to prevailing winds, disease, age or insect damage. Grain display is dependent on the direction and regularity of the wood fibers relative to the center of the trunk as well as how the lumber is cut from the tree.

Massive sawmill blades make quick work of slicing a log into green lumber. Once cut, these boards will be graded, stacked, dried and possibly planed smooth on faces and edges before they're ready for sale.

Typical lumber cuts

Lumber is cut from logs in a number of different ways, to maximize yield or to control wood grain direction and avoid log defects. Plain-sawn boards are produced by rotating a log in quarter-turn increments and cutting around the center pith area. Quartersawing, a less efficient way to maximize board yield, nevertheless produces more dimensionally stable lumber. Quartersawn oak also displays prominent medullary rays that would not otherwise show if the boards were plainsawn. A third milling method, through-and-through cutting (not shown), involves simply slicing the log completely across, which produces a mix of plain-sawn and quartersawn lumber.

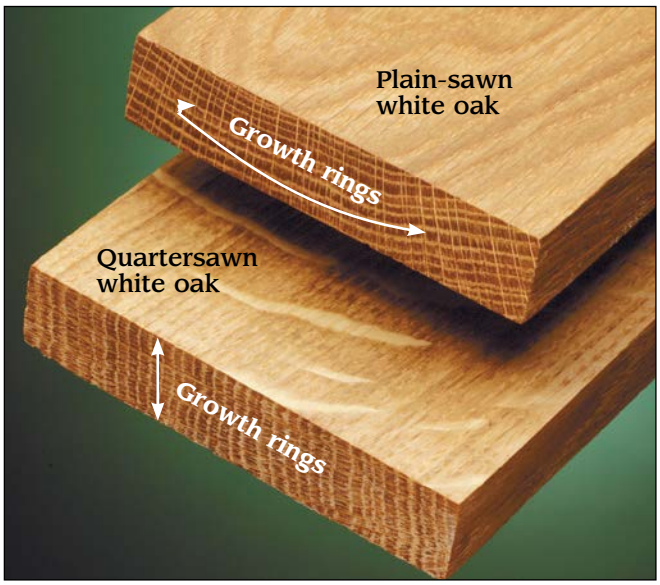


The best uses for today's softwoods are in applications where straight, abundant, less expensive lumber is needed. Mills cut softwoods largely into construction lumber for framing walls, floors and roofs or process it into plywood, chipboard and oriented strandboard to sheathe buildings. Of course, a percentage of this lumber also is headed for woodworkers, but premium-grade softwoods can command prices that compete with hardwoods.

Hardwoods, on the other hand, are most often sturdier, heavier, more figured and show a great variety of colors. So, it's no surprise that the more attractive, yet less available hardwoods are more costly and are the natural choice for furnituremaking, cabinetry and trim work. It also explains why hardwoods are not available in the same nominal dimensions as softwoods intended for construction purposes.

Cuts of Lumber

Mills saw lumber in a variety of ways, depending on the intended use of the boards and the species and quality of the logs. The most common cuts are plain-sawing and quartersawing. Plain-sawing (also called flat-sawing) involves cutting the log to maximize lumber without including the center pith area. The log is rotated to make successive series of cuts around the pith. Plain-sawing produces lumber most economically for both the mill. It is suitable for most construction and woodworking purposes, but since the cuts are made tangentially to the growth rings—the direction of greatest wood movement—the lumber is more prone to distortion than quartersawn lumber. (For more on wood movement, see page 40).



Plain-sawn lumber is cut so the growth rings run tangentially to the board faces, producing a wider, wavy grain pattern. The growth rings on quartersawn lumber, on the other hand, run radially to the board faces, resulting in a tigher, parallel grain pattern.

LUMBER DRYING METHODS

Air-drying: Short lengths of scrap wood, called stickers, are inserted between each board in a stack to allow air to circulate all around the boards. The stacks are left to dry fully exposed to the elements, are covered up or stored in open sheds for months or even years at a time. Without stickers, green lumber will dry unevenly or attract mold and slowly decompose.

Kiln-drying: Once stickered lumber is loaded into a kiln, the kiln is closed up and heated evenly for several weeks until the moisture inside is reduced to acceptable levels. Drying time will vary depending on wood species and the grade of lumber. Kiln-drying is a faster method of producing general-purpose lumber, and kiln-dried boards are what you'll find at all discount lumber outlets and home centers.

Quartersawn lumber is made by first sawing the log along its length to create four wedges. These are then ripped so the growth rings run more or less perpendicular (radially) to the board faces. Quartersawing yields boards with close, tight, straight grain. In some hardwoods, like oak, it also exposes beautiful, translucent medullary rays that have been coveted by woodworkers for generations. The downside to quartersawing is that it produces less lumber per log than plain-sawing, making the lumber more expensive to buy. Generally, quartersawn hardwoods are more common to find than quartersawn softwoods.

Methods of Drying Lumber

When boards are first cut from a log, they are considered "green", which means they contain a high percentage of water weight and must be dried before they are suitable for most uses. Lumber is dried commercially in two ways—by air or by kiln. Air drying is simply that: the stock is stacked in such a way that the air can circulate through and around it. Small pieces of lumber, called *stickers,* are inserted between the boards at regular intervals. The stack is then left to dry for a long time, sometimes several years, until the moisture evaporates to acceptable levels. Variations on the method involve covering the top layer with plastic or canvas, turning the sides to the prevailing wind, periodically dismantling and rebuilding the stack in reverse, all in an attempt to control the drying process. If lumber is improperly dried, it may begin to mold, which leads to a sometimes desirable defect called *spalling* (See page 41).

What is "green" lumber? The American Lumber Standards Committee classifies green wood as having 20% or higher moisture content, and dry lumber as 19% or less. Board moisture is measured in terms of weight, not volume.

Kiln-drying is done in a gas, electric or solar-powered oven. Kilns are expensive to operate, but they offer a precisely controllable drying environment. Some mills may be inclined to speed up the process to save money. However, rapid drying can lead to a multitude of defects, such as *case-hardening* (See page 41).

From a woodworker's point of view, air-dried lumber is a lot cheaper, but it is less common. Most lumber, including everything you'll find at a home center, is kiln dried, because it is ready for market in a shorter time. The kiln is also a more controllable method than air-drying, especially with large volumes of lumber.

Moisture & Wood Movement

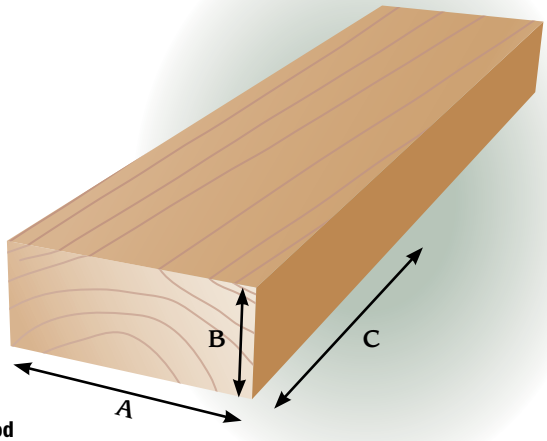
Regardless of whether boards are air- or kiln-dried once they are cut from a log, lumber will continue to seek what is known as *equilibrium moisture content* (EMC): it will absorb moisture or dry out until its moisture content matches the relative humidity in the surrounding air. A kiln-dried board will never absorb as much moisture as it initially had when it was green, but its sponge-like qualities cannot be stopped, even when a wood finish is applied.

The amount of moisture a board contains at the lumberyard is measured in percentages, which range from 6% to more than 20%. Framing lumber should be less than 18% moisture when purchased (about 14% is ideal), while stock destined for furniture or casework should be down around 6 to 8%. Moisture percentages are measured in terms of water weight vs. wood weight, not according to volume.

The only accurate way to check this is with a moisture meter (See *Evaluating Moisture Content,* below), a small electronic tool with two sharp pins that are inserted into a freshly cut surface of the wood (old cuts dry quickly and give a false reading, so a fresh cut is essential). Most fine hardwood vendors will loan you a meter to examine their stock before you buy, or you can ask them to take a reading in your presence.

EVALUATING MOISTURE CONTENT

A moisture meter will tell you immediately the moisture content of a board. The red glowing light on this meter indicates the moisture content in this board to be 10%, an acceptable level for cutting and for project use. Calibrated moisture meters aren't cheap, but you may want to invest in one if plan to do fine furniture work or if the humidity in your shop fluctuates widely. It's also a good idea to test the moisture content of air-dried lumber if you purchase it directly from the mill. Be sure to test the wood on a fresh-cut edge or end—old edges dry quickly and will not provide an accurate reading.



Wood expands and contracts in response to changes in moisture and temperature. Tangential movement (A) occurs parallel to the growth rings, while radial movement (B) happens across the rings. Wood moves very little along its length (C). Generally a board's tangential movement is about double its radial movement.

As wood absorbs moisture from the air, it expands, and as the moisture evaporates, it will contract. You may be surprised to learn that wood basically moves parallel to the growth rings (tangentially) and across the rings (radially), but almost never along it (longitudinally). Therefore, in a standard plain-sawn board (see *Lumber Cuts,* previous page), expansion or contraction essentially occur in just two directions: width and thickness. Movement across the width is normally about twice that in thickness. The "greener" the board, the more it will move. It is critical, when designing and building woodworking projects, to consider how these forces of expansion and contraction will affect your project; they cannot be entirely eliminated.

Lumber Distortion & Defects

Often lumber will not expand and contract uniformly, causing it to distort. Four types of distortion, caused largely by improper kiln drying, are cupping, crooking, bowing and winding. *Cupping* is where the two long edges of the board begin moving toward each other, while the middle remains flat. A cupped cross section resembles the letter C. About the only way to fix this is to rip the board into several small strips after they have attained equilibrium, joint their edges, and then reglue them, alternating the growth rings (See page 128).

Crooking is evident when a board's faces are flat but it warps from side to side. This is an easy fix: after the board reaches equilibrium, simply joint one edge of the board, then rip the second edge parallel (See page 58). Fixing both cupped and crooked boards will incur some degree of waste.

Bowing is a more difficult problem to deal with. In this case, a board cups along its length and resembles

a very wide rocking chair runner. About the only solution is to support the ends and place weights on the center with the board's convex side facing up. In some instances, the board will flatten when it reaches moisture equilibrium.

Sometimes the ends of a board will twist in opposite directions. Twisting is difficult to remedy, but you may be able to flatten the faces of thicker boards by running them repeatedly over the jointer (See page 56).

LET YOUR LUMBER ACCLIMATE

Once you have purchased lumber for a project, allow it to acclimate to its new environment for a few weeks before building with it. If your shop is particularly damp, insert sticking between each board so that the air can surround it evenly on all sides. Or wrap it completely in 6 mil plastic until you need to use it, then machine and finish the lumber immediately.

Distortions can be spotted easily at the lumberyard by simply sighting down the edges and faces of each board before you buy.

Defects like pitch pockets, spalling or loose knots are easy to spot if you look carefully. Boards with these defects are salvageable by simply cutting away the bad areas. One defect that can't always be seen until after the lumber is rip-cut is a condition called *case-hardening*. Case-hardening occurs when the outside faces of the board dry quickly while the center remains wet, causing tremendous internal stresses. Telltale signs of case-hardening are checks (small cracks), shakes (large cracks, most often radiating out from the center across the grain), and a problem referred to as honeycombing: when the board is ripped, the inside looks just like the inside of a beehive, full of tiny honeycombs. To safeguard against case-hardening, check boards along their edges and ends, paying close attention to honeycombing, the worst kind of case-hardening. If one board in a pile is affected, chances are several more from the same batch will have the same defect.

COMMON LUMBER DEFECTS

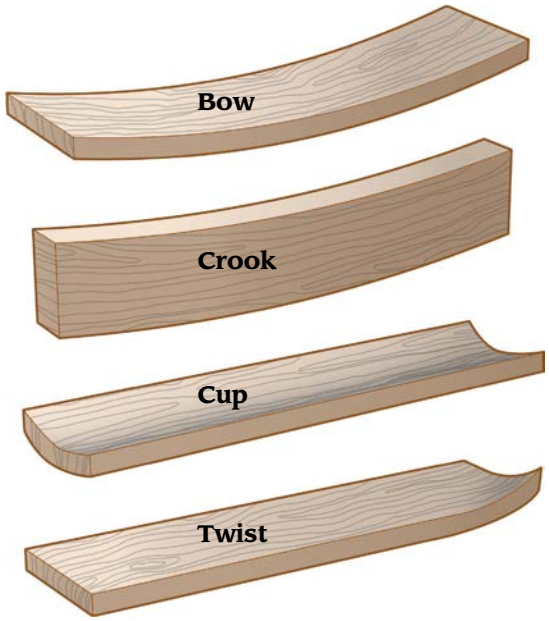
Spalling is a gray to green permanent discoloration of the wood caused by fungal growth. Be sure to keep spalled lumber dry, or the discoloration will continue and spread.

Knots are easy to cut out of clear sections of lumber. The lower the lumber grade, the higher will be the percentage of allowable knots.

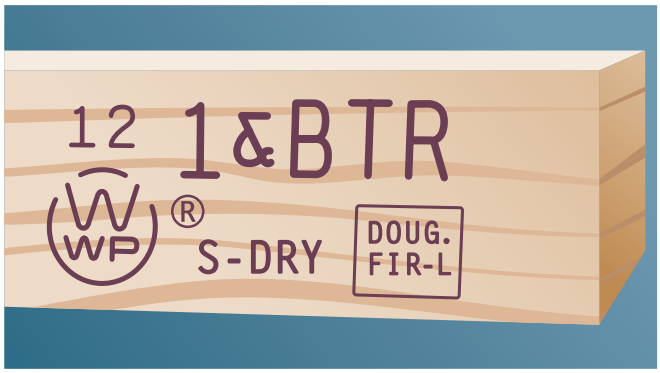
Case-hardened boards should be avoided when purchasing woodworking lumber. Case-hardening results from insufficient and hasty kiln-drying at high temperatures. The board dries too rapidly on the outside but stays wet within, creating stresses that literally cause it to pull itself apart until it reaches equilibrium.

COMMON LUMBER DISTORTIONS

Boards distort in four primary ways, due to how internal stresses are released when it is machined as well as how the board absorbs and releases moisture. Moisture distortion is largely a measure of how the wood was dried at the mill. Wood that bows is flat across its width but the faces curve lengthwise. A crooked board is flat across the face but curves along the edges in one direction or the other, like the rocker on a rocking chair. Cupping occurrs when a board is flat along its edges but curls across its width. Twist is the condition where one or both ends of a board twist so the board faces are no longer flat.



Reading softwood grade stamps



All construction lumber sold in the U.S. bears an industry grading stamp such as the Western Wood Products Association (WWP) stamp shown above. Nominal softwood lumber is graded similarly, but usually the stamp doesn't show. Here's how to decipher grade stamps:

12 — Identifies the mill. This can be letters or numbers.

1&BTR — This is the grade of lumber, in this case #1 Common and better, an excellent furniture grade.

WWP — The grading association that graded the board, in this case the Western Wood Products Association.

S-DRY — The condition of seasoning at the time of surfacing, in this case dry, or seasoned lumber below 19% moisture content. If the stamp read KD-15, it would denote kiln-dried lumber with a maximum of 15% moisture content. Product stamped S-GRN stands for unseasoned (green) lumber containing more than 19% moisture content.

DOUG FIR-L — Indicates the wood species, in this case, Douglas fir.

Softwood Lumber Sizes

Slide your measuring tape across a 2 x 4 and you'll discover that it doesn't actually measure two inches by four inches. In fact, it will be ½-in. shy in both directions. In its rough state, when the lumber was originally ripped into studs, this same piece was in fact a true 2 x 4. But after drying, it shrank a little. Then it was surfaced (planed) on all four faces, and it shrank a little more.

When you buy standard softwood lumber at your home center, surfaced and jointed on all faces and edges, the industry sells it to you in finished dimensions, but still describes it in *nominal* dimensions—the size it was before milling.

A piece of softwood lumber with a nominal 1-in. thickness is generally referred to as a board, while nominal 2-in.-thick softwood is called framing stock (as in studs, joists and rafters), or *dimension* lumber. The chart below lists nominal and dimension lumber sizes for the stock you'll find in home centers.

Softwood lumber is graded by strength and appearance as well as moisture content. For woodworking applications, the three common grades to know are Select, Finish and Common (See the chart, below left). While boards in the Common grade categories may contain some blemishes and knots, Select and Finish grades are clear or nearly clear of defects. Be aware, however, that boards within any grade may exhibit some degree of natural distortion (cupping, bowing, twisting), so it's important to examine each board carefully by sighting along its length and width before you buy.

SOFTWOOD LUMBER GRADES

Grade	Grading criteria
B Select and BTR	Highest quality lumber with little or no defects or blemishes. Nominal sizes may be limited.
C Select	Some small defects or blemishes permissible, but still largely clear and of high quality.
D Select	One board face usually defect-free.
Superior Finish	Highest grade finish lumber with only minor defects.
Prime Finish	High quality with some defects and blemishes.
No. 1 Common	Highest grade of knotty lumber; usually available by special-order.
No. 2 Common	Pronounced knots and larger blemishes permissible.

Nominal vs. dimension softwood lumber sizes

Nominal	Finished
1 x 2	¾ x 1½
1 x 3	¾ x 2½
1 x 4	¾ x 3½
1 x 6	¾ x 5½
1 x 8	¾ x 7¼
1 x 10	¾ x 9¼
1 x 12	¾ x 11¼
Dimension lumber sizes	
2 x 2	1½ x 1½
2 x 3	1½ x 2½
2 x 4	1½ x 3½
2 x 6	1½ x 5½
2 x 8	1½ x 7¼
2 x 10	1½ x 9¼
2 x 12	1½ x 11¼

Hardwood Lumber Sizes

While nominal dimensions are widely used for selling softwoods, some retailers have extended the practice to hardwood boards as well. Your local home center probably stocks a few species of hardwoods, like oak, maple and cherry. These boards generally are planed to ¾ in. thick, jointed flat on the edges and cut to standard widths and lengths. Within the lumber industry, lumber of this sort is categorized as "S4S", which stands for Surfaced Four Sides. All of this surface preparation at the mill translates to higher prices for you, but it may make the most sense to buy S4S lumber if you don't own a thickness planer or jointer to prepare board surfaces yourself.

To find specialty or thicker hardwoods, you'll need to shop at a traditional lumberyard. A good lumberyard will offer a wide selection of hardwoods in random widths and in an assortment of thicknesses and grades (See *Hardwood Lumber Grades,* below). In addition to S4S, you'll find S2S lumber (planed smooth on two faces but the edges are rough), and roughsawn boards that are simply cut from the log, dried and shipped to the lumberyard.

Because of their diverse uses, hardwoods are offered in a much larger variety of thicknesses than standard 1x and 2x softwoods. This has led to the quartering system for determining lumber thickness, which allows you to buy hardwoods in ¼-in. thickness increments from ¼ in. on up. Most yards offer popular hardwood species in three, four, five, six, eight, ten and even twelve quarter thicknesses (which read as ¾, ¼, ⅝, ⅝, ⅞, 10/4 and 12/4 on the label at the rack). These correspond to rough (pre-planed) thicknesses of ¾ in., 1 in., 1¼ in., 1½ in., 2 in., 2½ in. and 3 in.

Hardwood surfacing options: If the extent of your hardwood needs amounts to only an occasional project, buy S4S boards at the yard. They'll come planed on both faces and jointed flat on both edges, ready for cutting into project parts. If you have access to a jointer, consider buying S2S lumber, which still has rough edges but the faces are planed smooth. The most economical hardwood comes roughsawn to the lumberyard and will require you to do all of the surface preparation yourself. Some lumberyards will plane your stock for a nominal fee, if you don't own a planer.

HARDWOOD LUMBER GRADES

Hardwood lumber is graded using a different classification system than softwoods. Grades are based on the percentage of clear face cuts that can be made around a board's defects (knots, splits, pitch pockets, and so forth. From highest grade (clearest) to lowest (most allowable defects), the grades are:

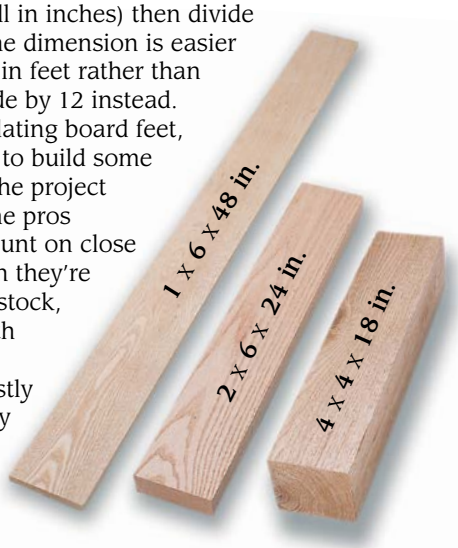
Grade	Percentage of clear cuts
FAS (Firsts & Seconds)	83⅓%
Select	83⅓%
No. 1 Common	66⅔%
No. 2A & 2B Common	50%
No. 3A Common	33⅓%
No. 3B Common	25%

Choose the lumber grade that best suits the needs of your project parts and your budget. It could be that a Common grade will provide all the knot-free lumber you need at a significant savings over FAS.

CALCULATING BOARD FEET

Hardwood lumber is sold at most lumberyards by the board foot, which can make calculating the amount of lumber you need a little confusing. The three boards below, for instance, all equal 2 board feet, though their physical dimensions are quite different. A board foot is actually 1/12 of a cubic foot of rough lumber, or 144 cubic inches. It is the equivalent of a piece of stock that is 12 in. wide, 12 in. long and 1 in. thick. But any combination of dimensions that multiplies to 144 is equivalent to one board foot.

To calculate the number of board feet a piece of lumber contains, its thickness times its width times its length (all in inches) then divide by 144. If one dimension is easier to calculate in feet rather than inches, divide by 12 instead. When calculating board feet, don't forget to build some waste into the project estimate. The pros generally count on close to 30% when they're buying S2S stock, and 40% with roughsawn lumber (mostly because they can't see the defects until after planing).



Large retail lumber outlets and home centers make shopping for lumber easy. Most of the lumber you'll find is fully surfaced and ready for building. Some larger home centers even stock lumber inside where it's kept warm and dry. The downside to all of this convenience is that species options are limited, especially for hardwoods.

Buying Lumber

It's important to know your options for where to shop for wood. Chain home improvement stores generally offer a basic variety of framing lumber and nominal softwood but very little hardwood. What they do carry is often priced lower than specialty yard stock, but the grades and dimensions are limited. Here are a couple of other options to consider:

Contractor yards, where framing and finish carpenters buy their materials, usually offer a wider array of lumber options, including an assortment of millwork products and custom moldings. Often they can special-order materials that the chain stores simply can't supply. The quality of the stock here is better, and the prices reflect the quality you'll find.

Specialty yards: Most metropolitan areas have specialty yards that sell only hardwoods and veneered sheet goods. Their primary customers are commercial cabinetmakers, architectural millwork shops and professional furniture builders. While the salespeople here are used to dealing with pros, they are usually willing to take a few minutes to explain the finer points to an interested amateur. However, time is money for these folks, so they won't appreciate spending too much time on what they by necessity must consider a minor sale. The stock sold here here is normally S2S or roughsawn, so you'll need a jointer or planer

Reclaimed lumber

In recent years there has been a lot of talk about reclaimed lumber. Most reclaimed lumber is salvaged from the beams and timbers of old buildings, and some is recovered from the chilly depths of the Great Lakes. Such lumber was culled from virgin forests a century or more ago, and it is generally very straight-grained and true. It is also extremely seasoned; only large swings in temperature or humidity seem to affect it. Reclaimed lumber is generally a great product, and numerous mills advertise on the internet. The price may be high, however, especially for premium cuts and grades.

Buying reclaimed lumber is by no means your only source for obtaining it. Before you toss an old piece of furniture or dispose of boards and trim from a big remodeling project, consider reusing the lumber for woodworking. Sometimes all it needs is to be stripped, sanded or run through a planer. Visually inspect any reclaimed lumber carefully or check it with a metal detector before passing it through a saw or router, to be sure there are no hidden metal fasteners present.

Don't overlook "diamonds in the rough": These mahogany boards, salvaged from a discarded couch and passed through a planer, will make excellent stock for a woodworking project.

Consider buying your lumber from a local saw mill. Here you'll find a wide range of species in a host of dimensions. Most mills will sell stock to you at a fraction of the price a lumberyard charges.

to prepare the lumber further. Be aware that, when buying roughsawn lumber, you can't tell much about the color, grain or quality of the board until after you expose it to the planer knives.

It's quite acceptable to rummage through the stock at a specialty yard, but make sure you rebuild the stacks as you found them. Longer, wider boards belong at the back of the rack. Don't mix the boards from different bins. Boards in two binds may look the same at first glance, but they may be different grades. Check the board ends to see if the yard has painted different colors there—the colors represent the grades.

Buying basics

Whether you buy from a chain store, specialty or contractor's yard or by mail, keep a few basic rules of thumb in mind when shopping for project lumber:

1. Develop a realistic shopping list. Base your list on a clear understanding of common lumber proportions and grades (See pages 42 to 43 for more on common lumber sizes and grades). Make a preliminary visit to your lumberyard, acquire a catalog, or call the city desk before leaving home to verify that the dimensions and species you need are available. Know ahead of time what compromises you can make to your cutting and shopping lists, if what you need isn't available in the right size or species.

2. Consider using less-expensive woods like poplar or pine in hidden areas of your project. Woodworkers have used "secondary" woods for centuries in fine furniture and cabinetry, saving premium lumber for prominent project parts like face frames, doors, drawer fronts and tabletops. Don't underestimate the versatility, economy and structural benefits of using sheet goods like plywood and particleboard over solid wood (See pages 46 to 47).

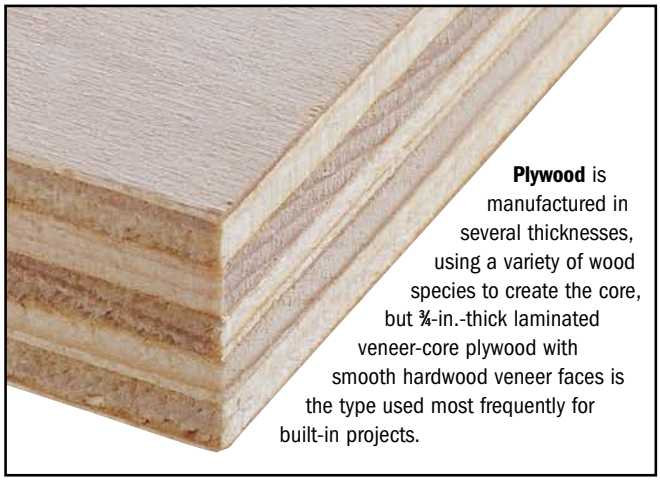
3. Factor in about 30% waste. As you become more practiced in estimating, you'll be able to reduce this percentage somewhat. If you are just getting started as a woodworker, buy more lumber than what you'll need for a project. Save your receipt and return what you don't use. Published plans occasionally have errors in shopping and cutting lists that will require you to have more material on hand. If you buy lumber roughsawn, you may not discover an unsightly blemish or pitch pocket until after you plane it, resulting in less usable lumber than you initially planned. And be honest about your own "fudge factor." One miscalculated cut late on a Saturday afternoon might put an end to your woodworking for the weekend if your lumberyard isn't open on Sundays.

4. Comparison shop before you buy. Once you are sure of your project requirements, check how the prices vary among suppliers. Yards may offer discounts on slightly damaged lumber or overstocks, especially at inventory time.

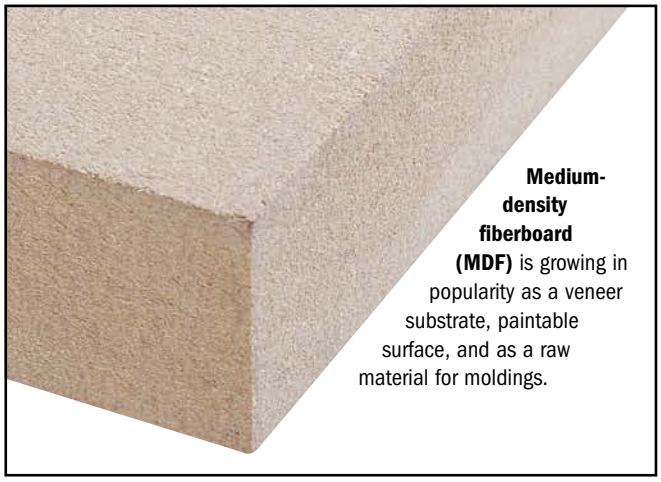
5. Plan for how you'll safely transport large materials home, especially sheet goods. If the yard offers delivery, take advantage of the service especially if your only other option is to tie several unwieldly sheets of plywood to the roof of the family sedan. Some yards will cut your lumber into more manageable proportions for free, or for a modest charge. If you go this route, double-check your cutting list so you can decide ahead of time what can be sized down without compromising your project needs.

MAIL-ORDER LUMBER

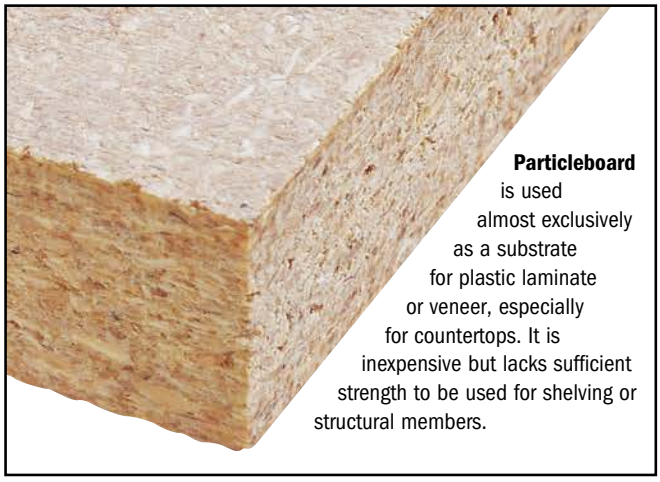
Lumber by mail: If you don't have a specialty lumberyard nearby or need a more unusual species for your project, consider ordering lumber by mail. The range of species offered is usually quite broad, and the prices are competitive. Thumb through the back of most woodworking magazines and you'll see numerous mail-order suppliers to choose from. One drawback to buying by mail is that you'll be ordering lumber sight unseen. As a safeguard, make your first order small, so you can inspect the quality. Ask about moisture levels, too, so you can use what you order right away without needing to let it dry first.



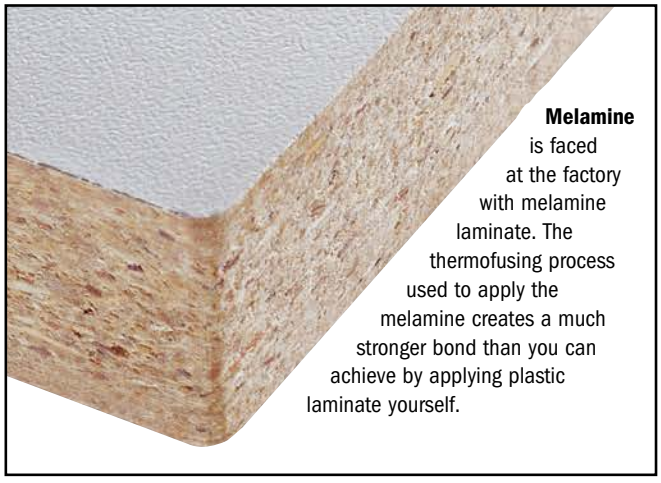
Plywood is manufactured in several thicknesses, using a variety of wood species to create the core, but ¾-in.-thick laminated veneer-core plywood with smooth hardwood veneer faces is the type used most frequently for built-in projects.



Medium-density fiberboard (MDF) is growing in popularity as a veneer substrate, paintable surface, and as a raw material for moldings.



Particleboard is used almost exclusively as a substrate for plastic laminate or veneer, especially for countertops. It is inexpensive but lacks sufficient strength to be used for shelving or structural members.



Melamine is faced at the factory with melamine laminate. The thermofusing process used to apply the melamine creates a much stronger bond than you can achieve by applying plastic laminate yourself.

Sheet Goods

The basic structural component of cabinetry is some form of sheet goods; most frequently plywood. Other commonly used sheet goods are particleboard, fiberboard, melamine panels and hardboard. These materials come in handy when you need to cover a broad project area without including seams. Sheet goods are dimensionally stable (there is no substantive wood grain to contend with) and relatively inexpensive, when compared to the price of solid lumber. You'll turn to them time and time again for different woodworking applications. Here is an overview of the options you'll find at most home centers and lumberyards:

Plywood. Plywood is fashioned from sheets of wood veneer, primarily pine and fir. By orienting the wood grain of each laminated sheet so adjacent sheets are perpendicular, the product is able to withstand greater stress than construction lumber of the same thickness. In addition, it is more dimensionally stable.

Most lumberyards stock furniture-grade plywood in several thicknesses and face veneer options (pine, red oak, birch and maple are the most common face veneers). Lumberyards can order plywood with dozens of additional veneer options.

Choosing the right plywood for your woodworking project is an important task. In addition to the various core, thickness and face veneer options, you'll also need to make a decision on the plywood grade. Basically, there are two grading systems in use today. The one most people are familiar with is administered by the APA (Engineered Wood Association, formerly the American Plywood Association). The APA grade stamps (See *Illustration,* next page) are found on sanded plywood, sheathing and structural (called performance-rated) panels. Along with grading each face of the plywood by letter (A to D) or purpose,

NOTICE

Particleboard and MDF usually contain urea formaldehyde resins that continue to emit low levels of formaldehyde gas for at least six months as they cure. People with high sensitivity to chemical vapors should limit the number of composite panels added to a room at one time. Always wear a particle mask or respirator as required and provide adequate dust collection and ventilation when cutting or shaping these products.

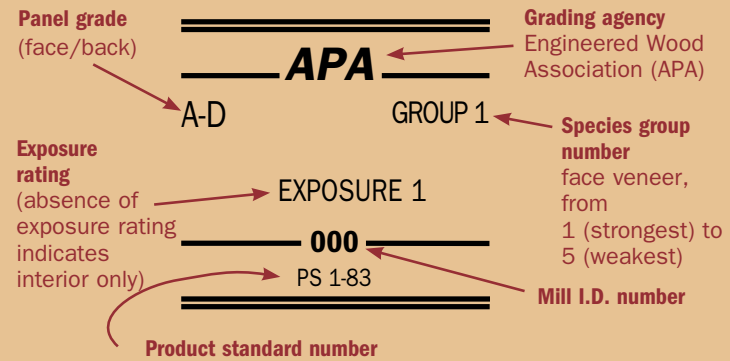
the APA performance-rated stamp lists other information such as exposure rating, maximum allowable span, type of wood used to make the plies and the identification number of the mill where the panel was manufactured. Many hardwood-veneer sanded plywood panels are graded by the Hardwood Plywood and Veneer Association (HPVA). The HPVA grading numbers are similar to those employed by APA: they refer to a face grade (from A to E) and a back grade (from 1 to 4). Thus, a sheet of plywood that has a premium face (A) and a so-so back (3) would be referred to as A-3 by HPVA (and AC by APA).

Particleboard: Particleboard possesses several unique qualities that might make it a good choice for your next built-in project—particularly if the project includes a counter or tabletop. Particleboard is very dimensionally stable (it isn't likely to expand, contract or warp); it has a relatively smooth surface that provides a suitable substrate for laminate; it comes in a very wide range of thicknesses and panel dimensions; and it is inexpensive. But particleboard does have some drawbacks: it lacks stiffness and shear strength; it has poor screw-holding ability; it degrades when exposed to moisture; it's too coarse in the core to be shaped effectively; and it's heavy.

Medium-density fiberboard (MDF): MDF is similar to particleboard in constitution, but is denser and heavier. The smoothness and density of MDF make it a good substrate choice for veneered projects; the rougher surface of particleboard and most plywoods do not bond as cleanly with thin wood veneer. You can even laminate layers of MDF to create structural components that can be veneered or painted. MDF is also increasing in popularity as a trim molding material.

Melamine board: Melamine is fashioned with a particleboard core with one or two plastic laminate faces. Thicknesses range from ¼ to ¾ in. Stock colors at most lumber yards and building centers generally are limited to white, gray, almond and sometimes black. The panels are oversized by 1 in. (a 4 x 8 sheet is actually 49 x 97 in.) because the brittle melamine has a tendency to chip at the edges during transport. Plan to trim fresh edges.

Understanding sanded plywood grade stamps



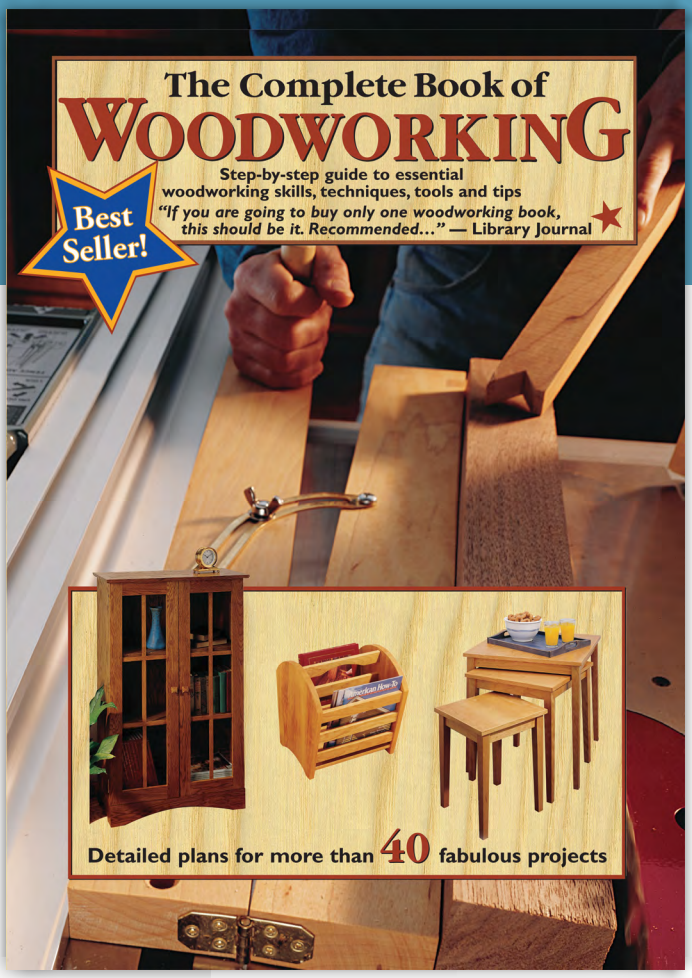
Every sheet of plywood is stamped with grading information. On lower-grade panels, such as exterior sheathing, the stamp can be found in multiple locations on both faces. Panels with one better-grade face are stamped only on the back, and panels with two better-grade faces are stamped on the edges.

Face grade descriptions

N	Smooth surface "natural finish" veneer. Select, all heartwood or all sapwood. Free of open defects. Allows not more than six repairs, wood only, per 4 x 8 panel, made parallel to grain and well-matched for grain and color.
A	Smooth, paintable. Not more than 18 neatly made repairs, boat, sled or router type, and parallel to grain, permitted. May be used for natural finish in less demanding applications. Synthetic repairs permitted.
B	Solid surface. Shims, circular repair plugs and tight knots to 1 in. across grain permitted. Some minor splits permitted. Synthetic repairs permitted.
C plugged	Improved C veneer with splits limited to ⅛-in. width and knotholes and borer holes limited to ¼ x ½ in. Admits some broken grain. Synthetic repairs permitted.
C	Tight knots to 1½ in. Knotholes to 1 in. across grain and some 1½ in. if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed. Stitching permitted.
D	Knots and knotholes to 2½ in. across grain and ½ in. larger within specified limits. Limited splits are permitted. Stitching permitted. Limited to Interior and Exposure 1 or 2 panels.

Source: Engineered Wood Association

Plywood veneer grain patterns



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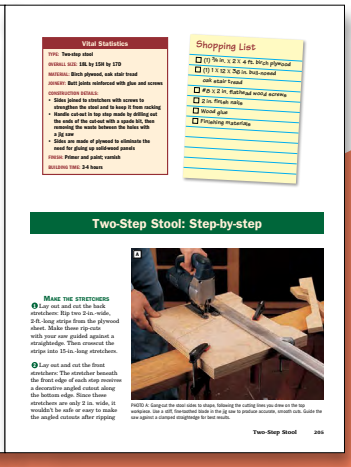
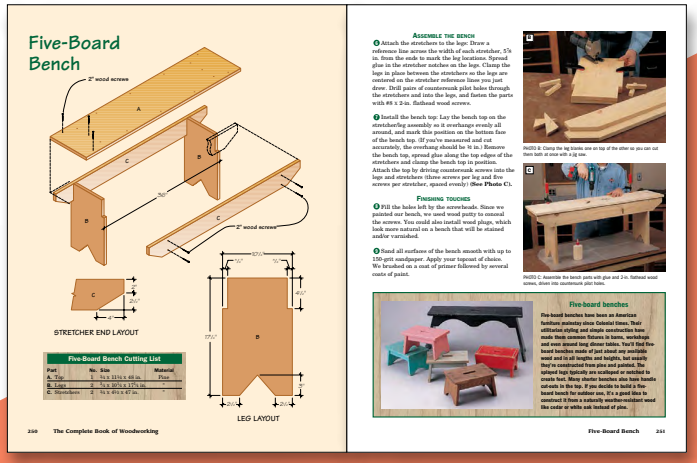
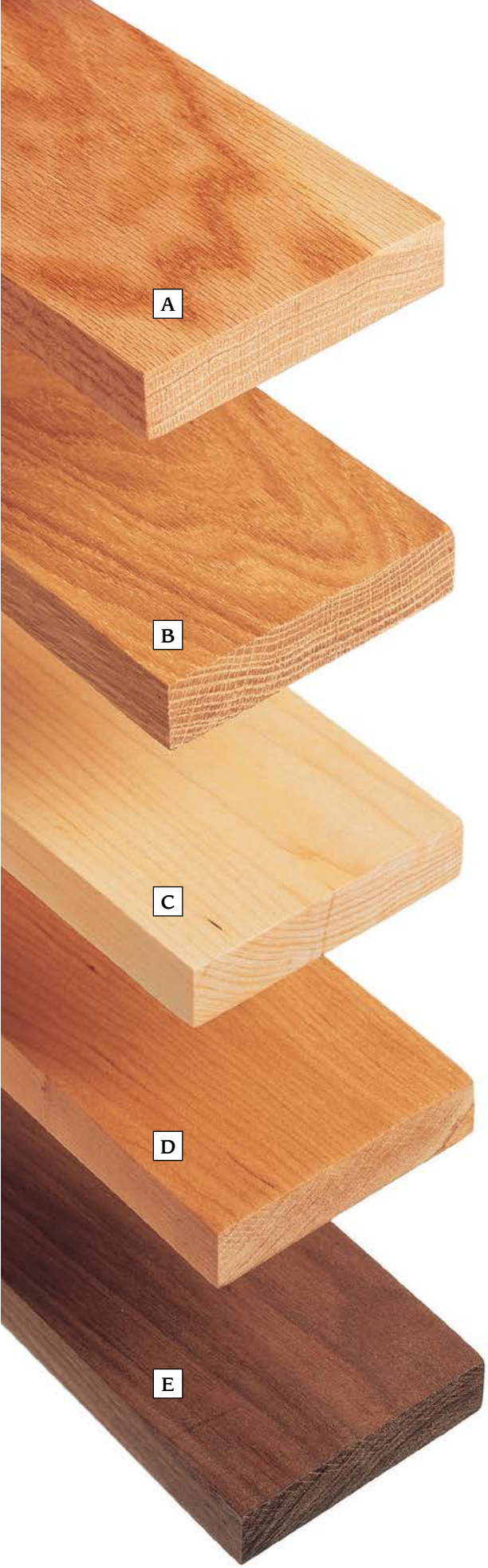






Common Hardwoods

A. Red Oak

Uses: Indoor furniture, trim, flooring, plywood and veneers
Sources: United States and Canada
Characteristics: Straight, wide grain pattern with larger pores. Tan to reddish pink in color. Quartersawing reveals narrow medullary rays.
Workability: Machines easily with sharp steel or carbide blades and bits. Not prone to burning when machined. Drill pilot holes first for nails or screws.
Finishing: Takes stains and clear finishes well, but pores will show through if painted unless they are filled
Price: Moderate

B. White Oak

Uses: Indoor and outdoor furniture, trim, flooring, plywood and veneers
Sources: United States and Canada
Characteristics: Straight, wide grain pattern, tan with yellow to cream tints. Quartersawing reveals wide medullary rays. Naturally resistant to deterioration from UV sunlight, insects and moisture.
Workability: Machines easily with sharp steel or carbide blades and bits. Not prone to burning when machined. Drill pilot holes first for nails or screws.
Finishing: Takes stains and clear finishes like red oak, but narrower pores reduce the need for filling
Price: Moderate to expensive

C. Hard Maple

Uses: Indoor furniture, trim, flooring, butcher block countertops, instruments, plywoods and veneers
Sources: United States and Canada
Characteristics: Straight, wide grain with occasional bird's eye or fiddleback figure. Blonde heartwood.
Workability: Difficult to machine without carbide blades and bits. Dull blades will leave burns.
Finishing: Takes clear finishes well, but staining may produce blotches
Price: Moderate to expensive, depending on figure

D. Cherry

Uses: Indoor furniture, cabinetry, carving, turning, plywood and veneers
Sources: United States and Canada
Characteristics: Fine grain pattern with smooth texture. Wood continues to darken as it ages and is exposed to sunlight.
Workability: Machines easily with sharp steel or carbide blades but is more prone to machine burns
Finishing: Takes stains and clear finishes well
Price: Moderate

E. Walnut

Uses: Indoor furniture, cabinets, musical instruments, clocks, boat-building, carving
Sources: Eastern United States and Canada
Characteristics: Straight, fine grain. Moderately heavy. Color ranges from dark brown to purple or black.
Workability: Cuts and drills easily with sharp tools without burning
Finishing: Takes natural finishes beautifully
Price: Moderate

F. Birch

Uses: Kitchen utensils, toys, dowels, trim, plywood and veneers
Sources: United States and Canada
Characteristics: Straight grain with fine texture and tight pores. Medium to hard density.
Workability: Machines easily with sharp steel or carbide blades and bits. Good bending properties. Drill pilot holes first for nails or screws.
Finishing: Takes finishes well, but penetrating wood stains may produce blotching
Price: Inexpensive to moderate

G. Hickory

Uses: Sporting equipment, handles for striking tools, furniture, plywood and veneers
Sources: Southeastern United States
Characteristics: Straight to wavy grained with coarse texture. Excellent shock-resistance.
Workability: Bends well, but lumber hardness will dull steel blades and bits quickly. Resists machine burning.
Finishing: Takes stains and clear finishes well
Price: Inexpensive where regionally available

H. Aspen

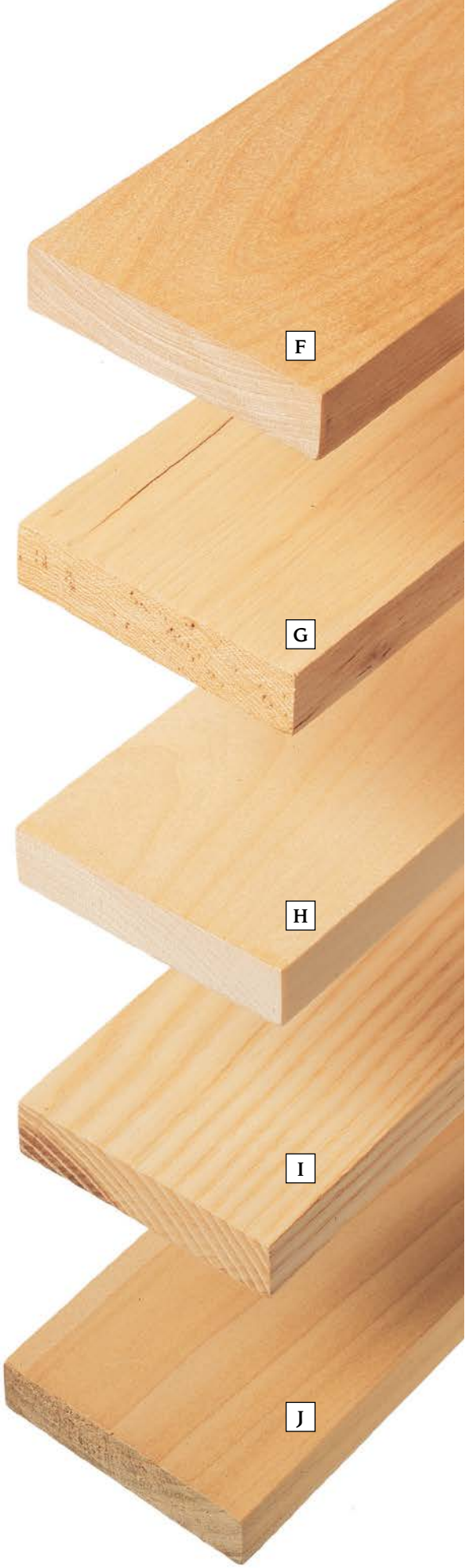
Uses: A secondary wood used for drawer boxes, cleats, runners and other hidden structural furniture components. Crafts.
Sources: United States and Canada
Characteristics: Indistinguishable, tight grain pattern
Workability: Machines easily with sharp steel or carbide blades and bits. Takes routed profiles well.
Finishing: Better suited for painting than staining. Tight grain provides smooth, paintable surface.
Price: Inexpensive

I. White Ash

Uses: Furniture, boat oars, baseball bats, handles for striking tools, pool cues, veneers
Sources: United States and Canada
Characteristics: Straight, wide grain pattern with coarse texture. Hard and dense with excellent shock-resistance.
Workability: Machines easily with sharp steel or carbide blades and bits. Drill pilot holes first for nails or screws. "Green" ash often used for steam bending.
Finishing: Takes stains and clear finishes well
Price: Inexpensive

J. Poplar

Uses: Secondary wood for furniture and cabinetry, similar to aspen. Carving, veneers and pulp for paper.
Sources: United States
Characteristics: Fine-textured with straight, wide grain pattern. Tan to gray or green in color.
Workability: Machines easily with sharp steel or carbide blades and bits. Not prone to burning when machined. Drill pilot holes first for nails or screws.
Finishing: Better suited for painting than staining. Tight grain provides smooth, paintable surface.
Price: Inexpensive



Common Softwoods

A. White Pine

Uses: Indoor furniture, plywood, veneers and trim, construction lumber
Sources: United States and Canada
Characteristics: Straight grain with even texture and tight pores
Workability: Machines easily with sharp steel or carbide blades and bits. Not prone to burning when machined. Lower resin content than other pines, so cutting edges stay cleaner longer.
Finishing: Stains may blotch without using a stain controller first. Takes clear finishes and paints well.
Price: Inexpensive

B. Western Red Cedar

Uses: Outdoor furniture, exterior millwork, interior and exterior siding
Sources: United States and Canada
Characteristics: Straight, variable grain pattern with coarse texture. Lower density and fairly light-weight. Saw- and sanding dust can be a respiratory irritant. Naturally resistant to deterioration from UV sunlight, insects and moisture.
Workability: Soft composition machines easily but end grain is prone to splintering and tear-out
Finishing: Takes stains and clear finishes well, but oils in wood can bleed through painted finishes unless primer is applied first
Price: Inexpensive to moderate where regionally available

C. Aromatic Cedar (Tennessee)

Uses: Naturally-occurring oils seem to repel moths, making this wood a common closet and chest lining. Also used for veneers and outdoor furniture.
Sources: Eastern United States and Canada
Characteristics: Straight to wavy grain pattern with fine texture. Red to tan in color with dramatic streaks of yellows and creams. Distinct aroma emitted when machined, and dust can be a respiratory irritant.
Workability: Machines similarly to western red cedar
Finishing: Takes stains and clear finishes well
Price: Inexpensive

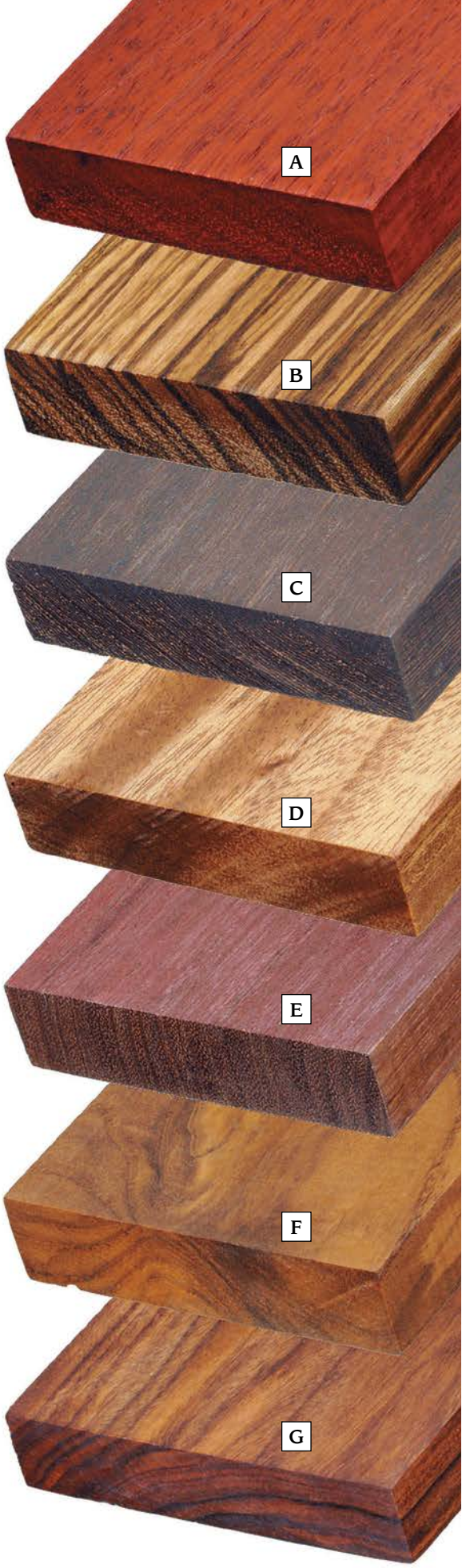
D. Redwood

Uses: Outdoor furniture, decks and fences, siding
Source: West coast of United States
Characteristics: Straight, fine grain with few knots or blemishes. Relatively light weight. Reddish brown with cream-colored sapwood. Naturally resistant to deterioration from UV sunlight, insects and moisture.
Workability: Machines and sands easily
Finishing: Takes stains and clear finishes well
Price: Moderate to expensive and not widely available in all nominal dimensions

E. Cypress

Uses: Exterior siding and boat building. Interior and exterior trim, beams, flooring, cabinetry and paneling.
Source: Mississippi delta region of the United States
Characteristics: Straight, even grain pattern with low resin content. Naturally resistant to deterioration from UV sunlight, insects and moisture.
Workability: Machines and sands easily
Finishing: Takes stains and clear finishes well
Price: Inexpensive where regionally available

Sampling of Exotics



A. Padauk

Uses: Indoor furniture, cabinetry, flooring, turning, veneer
Source: West Africa
Characteristics: Coarse texture, straight interlocked grain
Workability: Machines easily with sharp steel or carbide blades and bits
Finishing: Takes stains and clear finishes well
Price: Moderate to expensive

B. Zebrawood

Uses: Turning, inlay, decorative veneers, furniture and cabinetry
Source: West Africa
Characteristics: Interlocked, light and dark varigated grain pattern
Workability: Somewhat difficult to machine. Use carbide blades and bits
Finishing: Can be difficult to stain evenly
Price: Expensive

C. Wenge

Uses: Inlay, turning, decorative veneers
Source: Equatorial Africa
Characteristics: Hard, dense straight grain with coarse texture. Heavy.
Workability: Dulls steel blades and bits quickly, so carbide cutters are recommended. Drill pilot holes for screws and nails.
Finishing: Pores should be filled before finish is applied
Price: Moderate

D. Honduras Mahogany

Uses: Indoor and outdoor furniture, veneers and trim, boat-building
Sources: Central and South America
Characteristics: Straight, interlocked fine grain. Dimensionally stable.
Workability: Machines well with carbide blades and bits
Finishing: Takes stains and clear finishes well
Price: Moderate

E. Purpleheart

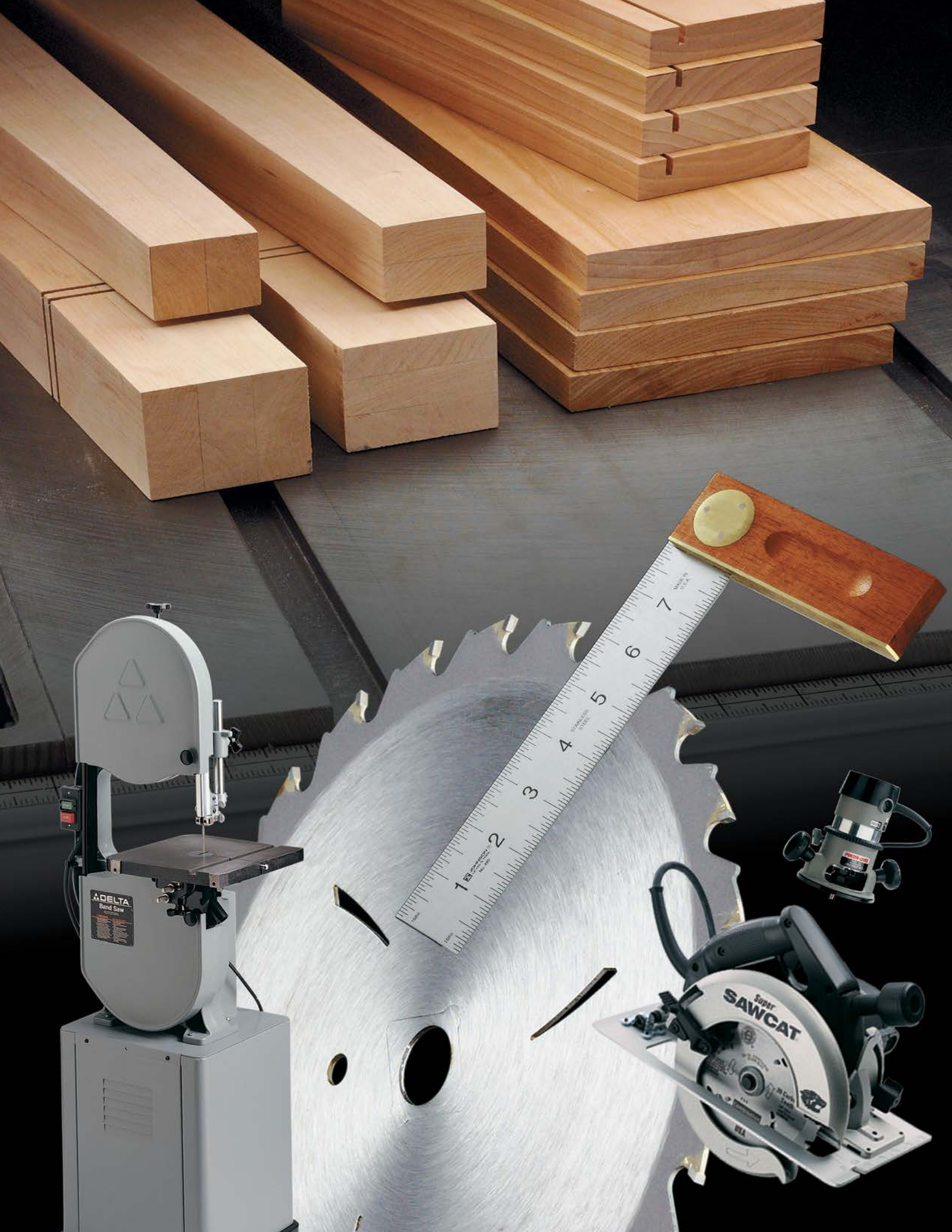
Uses: Pool cues, decorative inlay, veneers, indoor and outdoor furniture.
Sources: Central and South America
Characteristics: Straight grain with coarse texture
Workability: Gum deposits in the wood make it difficult to machine; cutting edges dull quickly
Finishing: Takes stains and clear finishes well.
Price: Moderate

F. Teak

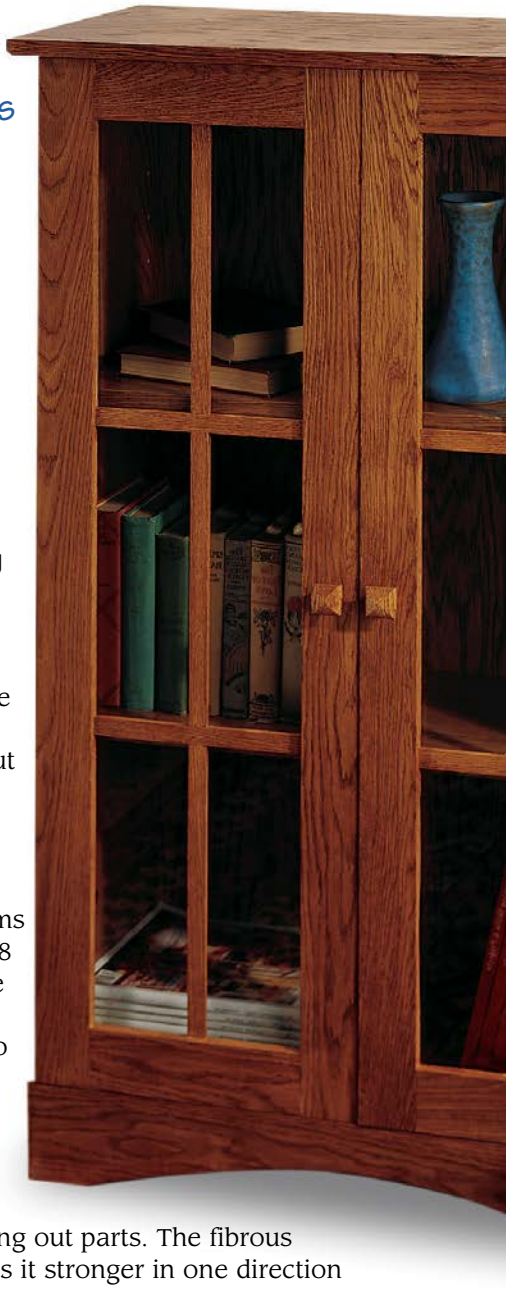
Uses: Boat-building, indoor and outdoor furniture, veneers, flooring
Sources: Southeast Asia, Africa, Caribbean
Characteristics: Straight grain with oily texture. Dense and hard.
Workability: High silica content will dull steel blades and bits quickly. Oily surfaces require cleaning with mineral spirits first or glue will not bond.
Finishing: Takes oil finishes well
Price: Expensive

G. Rosewood

Uses: Inlays, turning, veneers, cabinetry, furniture, musical instruments
Sources: Southern India
Characteristics: Interlocked grain with medium to coarse texture
Workability: Dense structure dulls cutting edges quickly
Finishing: Takes stains and clear finishes well
Price: Expensive


DELTA
Band Saw
Super
SAWCAT

Squaring, Marking & Cutting Stock



WOODWORKING WORKS
Thorough stock preparation followed by careful layout and cutting of project parts will have a dramatic impact on the success of your woodworking project. This Mission-style bookcase is a fine example of the pleasing results you can expect from doing careful work.

Creating parts for your woodworking project is a three-step process. First, the wood must be squared and sized for thickness. Second, the stock needs to be marked with layout and cutting lines. Finally, the boards must be cut and shaped into parts with a variety of woodworking tools.

Before embarking on the process of creating project parts, it's important to do a little planning. If you're working from a set of published plans, read it over thoughtfully. If you're building an original design, take this time to make up your own step-by-step plans. This minimizes eleventh-hour problems and enables you to order or purchase all necessary materials and have all necessary tools on hand.

Working from a cutting list is essential; if you don't have one, write one up. It organizes all parts with their correct dimensions and keeps minor parts from slipping through the cracks. Make a dimensioned drawing to work from (it doesn't have to be a Da Vinci, just clearly readable by you), and make a simple sketch. Calculate how you can most efficiently get your parts out of the rough materials with minimal waste. If any of the parts are angled, curved, or tapered, come up with a layout plan so they nest into each other and consume less of the board length than if they were laid out end-to-end. Plywood parts can be cut from full or half sheets in numerous ways. Draw plywood cutting diagrams (scale rectangles of 4 x 8 sheets) and map out the parts, remembering to slightly oversize them to allow for the saw blade kerf and any cutting errors.

Grain direction is a factor to contend with when planning and laying out parts. The fibrous structure of wood makes it stronger in one direction than the other. Parts should be laid out *long grain;* that is, with the wood fibers running along the length of the part whenever possible. If a narrow part were laid out and cut with the grain pattern running across the part's width—called *short grain*—it would be weak and break easily along the grain. Curved parts should be oriented to minimize short grain. This is why the sharply curved legs on traditional tripod pedestal tables often break, and why a Windsor chair back wouldn't last 10 minutes if it were bandsawn out of a wide board instead of being steam bent or laminated out of thin strips.

In short, it is very important to temper the excitement that accompanies the feeling of cutting that first project board. Take a reasoned, thoughtful approach to this critical step, and you'll find that you make more efficient use of your materials, and you get better results.

Woodworking Wisdom

Before introducing a board to a tool or machine, always thoroughly check the wood for nails or screws. Besides the obvious damage to the machine's cutting edges, these unnoticed hazards can pose other insidious threats. The protruding barbs can severely slash your fingers or your machine (a scar that won't heal). I learned this valuable principle early in my very first (and short-lived) woodworking job. I worked for a man who had filled his spanking-new shop with spanking-new state-of-the-art German woodworking machines. He was doing a furniture repair for a previous customer and I was asked to resurface a disassembled part. I didn't have the slightest idea what it was and how it fit together, but I sure loved to operate the 36 in. planer with push-button automatic table lift and LED digital readout. Well I didn't notice the four hidden #10 screws sticking out the bottom of the board until the noise drew a crowd to marvel at the troughs plowed into the surface of the planer's precision-milled table. Needless to say, that job didn't exactly get off to a flying start.

~Kam Ghaffari

Squaring Stock

Squaring up, or milling your wood four-square, is the important initial step in turning a piece of solid wood lumber into a part for a woodworking project. It involves taking a board to the proper thickness, width, and length; and making it flat, straight, and square-edged in the process. In this section we'll take you through the wood milling process.

Almost all lumber will have some type of warpage, whether cup, bow, twist, or crook. If you buy your lumber rough-milled, it will be oversized in all dimensions, and rather shaggy from the sawmill marks. Even if you buy lumber planed on two faces you may still get a bowed or twisted board. Rough or planed, the boards must be trued flat and square or you can have all sorts of problems—from mechanical headaches to visual eyesores.

Squaring stock is typically done with a power jointer, a thickness planer, and a table saw. Jointers and planers are relatively expensive machines. But if you plan on doing woodworking as a serious hobby, particularly fine furnituremaking, consider buying a 12-in. portable planer and at least a small jointer for truing edges. They are not out of reach anymore; nowadays good new ones can be had for a few hundred dollars, and used ones for even less. Combination jointer/ planer machines are also available. But lumber can also be squared using only the traditional hand-planing methods we'll show how in the pages that follow.

Squaring and sizing lumber is essentially a six-step procedure (See *Four Steps to Square Stock,* below).

1. Rough-cutting. No matter what milling methods you use, start by cutting your boards close to final dimension—but always leave them slightly oversized. Generally, allow about ¼ to ½ in. extra in width and at least 1 in. extra in length whenever possible. This provides enough material for fixing mistakes or jointing crooked edges, as well as removing accidental chip-out and corners or edges damaged or rounded in the milling process. If you have a planer that snipes, you may need to leave as much as an extra 2 in. on each end so the snipe marks can be cut off afterward. When jointing and planing rough lumber you'll usually lose between ⅛ and ¼ in. in thickness, so ¼ lumber generally gets reduced into ¾-in.-thick boards. Long or severely warped boards may require more material to true them up. Carefully examine the

Four steps to square stock

1. Rough cut the board to approximate size.
2. Flatten one face.
3. Straighten one edge square to the flat face.
4. Plane the board to desired thickness.

EDGE-JOINTING OPTIONS

A power jointer (top photo) makes fast, accurate work of the task of jointing board edges. But they are expensive, so you may want to start out with a hand jointer plane (bottom photo) then upgrade when the time is right.

Dealing with defects: Trim off the ends of boards containing cracks or checks before you spend a lot of time milling them. Make sure the trim cut is at least an inch or two past the point where the defect terminates. You can also cut around knots to create shorter, usable boards.

SURFACE PLANING OPTIONS

A power planer (top photo) can hog through a lot of stock quickly, and the benchtop models are not too expensive. But don't dismiss the hand planing option. A bench plane (bottom photo) has been the planing tool of choice for centuries.

Dealing with defects: Rip-cut cupped lumber on a table saw with the concave side facing up. In severe cupping situations, as with this board, saw the board into smaller flat pieces. Keep the board from rocking as you cut it, to reduce the chances of kickback.

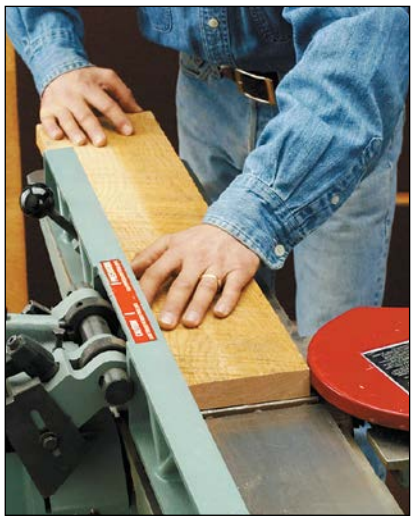
ends of your boards for any hidden checking and make your cuts well back from the apparent ends of the splits. You may have to sacrifice the first few inches of a board that has been stored for some time. For a few tips on salvaging usable lumber from defective stock, see the photos on the bottom of the next page.

2. Flattening. In order to make accurate, reliable rectangular parts, one face of the board must first be trued flat. The idea is to progressively plane down the high spots on an uneven board, using an assortment of tools until the surface is flat. Although it seems a little counterintuitive, the tool you don't want to use for the initial flattening of stock is the first one most people would think to use: the power planer. The problem with flattening on the power planer is that the workpiece rides on the planer bed while the cutters work on the opposite face from above. So if the face riding on the bed is not flat, the planed side won't be flat either. A jointer, on the other hand, tools the face that rides on the bed, flattening it with each pass. Hand planes, of course, can be used selectively on the board face to knock down high areas. If you have a jointer and your stock is narrower than the width of the cutterhead, use the jointer for the initial flattening of your stock.

Flattening on a power jointer: (See Step-by-step instructions, next page). A power jointer does an excellent job of flattening one side of stock (as long as the stock is within the cutting capacity of your jointer—6 in. on the most common home shop models. If you're flattening hardwood, set the cutters to remove no more than about 1/16 in. of stock per pass. If your jointer has no calibrated depth gauge, you can set the cutting depth manually: With the jointer unplugged, turn the cutterhead with a stick so all the knives are below the level of the infeed and outfeed tables. Lay a flat board or straightedge down on the outfeed table with its end protruding over the infeed table. The gap between the underside of the board and the infeed table will be

A good option to squaring lumber yourself is to do what many pros do: sub it out. Some large woodshops have thickness sanders (often called "timesavers") that work like planers but won't chip out the grain of figured wood. The machines are expensive to buy, so the shops often accept outside sanding work to help pay for them. Or, you may be able to use the equipment yourself for an hourly rate.

How to flatten a board on a jointer



1 Place the board flat on the infeed table of the jointer. If the wood is bowed or cupped, the concave face should be down so the board does not rock. The high corners or ends will contact the cutters and get planed first. Set the depth of cut to no more than about 1/16 in. for hardwood stock; with softwoods you can take a little deeper initial cut if you like. Feed the board so the blades cut with the grain.

2 Hold the front of the board firmly down against the infeed table with your left hand and in your right hand use a push block with a trailing lip hooked around the end of the board. Don't use excessive force; unless you're flattening a thin board, let the weight of the board do most of the work.

3 Guide the wood across the jointer with even pressure, walking slowly along the side of the machine as you go. If the board is long, you can feed it with both hands and pick up the push block as the end of the board approaches the cutter. With a narrow board, don't keep your hand on the board as it passes over the cutters. Instead, walk your hands along and raise each one over the cutter and onto the wood.

Which way is with the grain?

It's common knowledge in woodworking that wood should be planed or jointed *with the grain.* But determining which way the grain runs is not as easy as it sounds. You can sometimes tell grain direction by looking at the grain lines on the board's edge. But this is not foolproof. You will know the correct feed direction, though, once you make the first pass through the jointer or planer. If the stock is being fed against the grain, you'll hear the knives tearing out little chunks of the wood and you'll know to feed the board the opposite way (one or two passes will smooth out the surface).

your depth of cut at the current setting. Adjust the height of the infeed table until the gap is the same thickness as the depth of cut you want to make.

Before using the jointer, read the safety tips on page 58. And here are a couple more helpful tips to keep in mind when flattening on the jointer:

- Don't worry if there are a few small patches of rough wood surface left. It will be cleaned up when it's run through the planer.
- You generally want to remove as little material as possible when jointing for flatness. You can quickly end up with a board that's too thin.
- With a moderately warped board, take a deeper cut on the first pass, then switch to a shallower cut for the last pass or two to smooth the surface.
- Jointing a twisted board is tricky. Balance the board so the twist is distributed evenly along the length of the board. Try to keep the board riding on the same two or three points throughout the first pass or two until a stable, flat surface is established.

Flattening with a hand plane: Hand planing is a pleasant activity, and not at all difficult. The key is to start with

The shaggy surface of rough lumber is a good gauge for flattening stock on a jointer. Joint the board in shallow passes until fresh wood is exposed on the entire face. A little roughness here and there is okay: it can be removed with a plane or a power planer.

a well-tuned plane with a razor-sharp blade. For surface planing boards, longer bench planes (#5 or #6) work best because they have more surface area and can span the dips in uneven wood as you flatten the surface. It's generally easier to flatten the convex face on cupped stock.

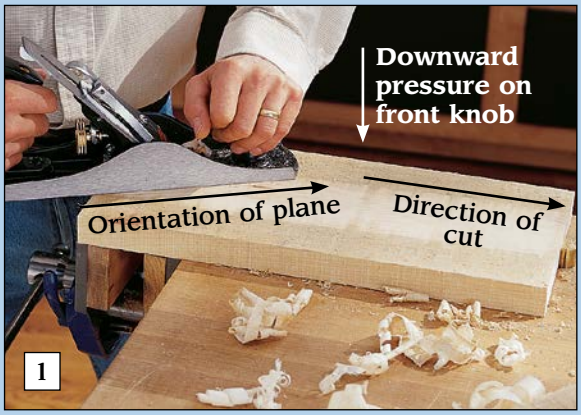
Use the basic planing technique shown in the photos to the right for all surface planing, including flattening. Here are a few tips:

- If the wood is uneven and rocks, shim beneath it.
- Set the blade for a fairly light depth of cut and hold the plane in a firm but relaxed grip.
- Begin by leveling any noticeable high spots, then focus on overall, even planing.
- Work at a diagonal, and overlap your strokes. When you reach the end of the board, plane diagonally the other way.
- Check the surface periodically with a straightedge at several points across the board, and sight down the board face from each end to check for twist.
- As the surface becomes flattened, switch to planing down the length of the board with the grain, but keep the sole of the plane at a slight angle for a smooth, shearing cut.

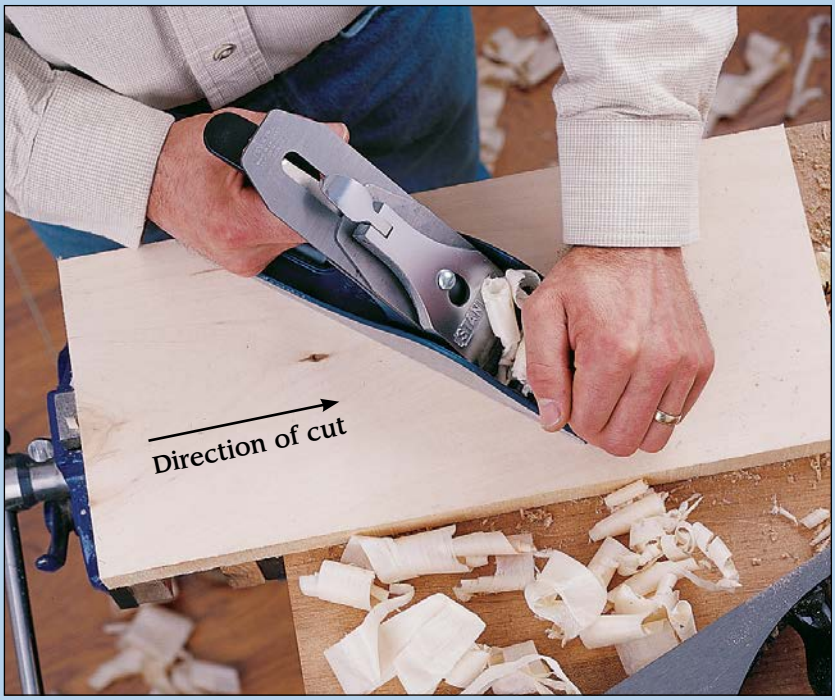
3. Straightening an edge. Once the face is flattened, choose the best edge and trim it so it's perfectly

Bench planes usually have a number prefix in their name: the smaller the plane, the smaller the number. Use a No. 4 or No. 5 bench plane (also called jack planes) for flattening. For edge-jointing, use a No. 6 fore plane or a No. 7 jointer plane.

How to use a hand plane



Orient the board so you're planing with the grain. Clamp the workpiece with bench dogs or clamped blocks below the surface of the wood so movement of the plane is unobstructed. Angle the body of the plane so it's at a diagonal to the direction of the cut. Begin the cut with downward pressure exerted on the front knob of the plane **(Photo 1, left)**. Then, as you near the end of the pass, lighten the pressure on the knob and exert heavier pressure on the handle at the back of the plane **(Photo 2, left)** until the pass is completed.



Smoothing with a hand plane: Final smoothing of a surface is done using the same general techniques shown in the two photos above. For best results, use a No. 4 or smaller smoothing plane. Make sure to work with the grain direction, keeping the body of the plane diagonal to the cutting direction.

Jointer safety tips

- As with all woodworking machines, wear eye and ear protection at all times.
- Make sure wood passing over the blades is snug between the fence and guard so no part of the cutterhead is exposed.
- Keep hands well away from the cutterhead at all times.
- Do not joint wood thinner than about ⅜ in. or shorter than 12 in., and avoid stock with loose knots.
- Use a push stick whenever possible (not your fingers) to move the board across the blades.
- Always turn off and unplug the machine before reaching up into the dust chute to clear out clogged chips.

How to edge-joint boards

With a jointer: Set the concave edge of the board on the infeed table, with the flattened face against the fence. As you push the board across the cutterhead, hold it against the fence with both hands and exert downward pressure directly over the infeed table. When most of the board has passed over the cutters, shift downward pressure over the outfeed table. Make shallow passes until the edge is flat, smooth and square to the flat face.

With a jointing plane: Clamp the workpiece securely in a bench vise, leaving plenty of clearance from the jaws of the vise. Start planing in the center of the board, then strike off the ends so they're even with the rest of the edge. Apply pressure on the front of the plane at the beginning of the stroke and gradually transfer the pressure to the back of the plane by the end of the stroke. Check your work regularly with a straightedge and a square.

The surfaces of rough lumber are shaggy and often embedded with grit and gravel that can wreak havoc on blades. Keep a wire brush within easy reach of your jointer and planer, and give the faces and edges of your boards a stiff brushing before you start milling.

straight and at right angles to the face. This square reference edge is known as the *face edge.* The straightening process, known as *edge-jointing,* was traditionally done with a large hand plane, but these days it is usually done on a stationary power jointer. If your board is less than 1½ in. thick, you can joint it cleanly and easily with a router and a flush-trim bit.

Edge-jointing with a jointer: Edge jointing is the most common task performed on the jointer. Set the jointer fence so it is perpendicular to the surfaces of the infeed and outfeed tables—check this with a square. Set the cutters for a shallow cut (no more than 1/16 in.) to avoid tearout. The goal should be to create a straight, square edge while removing as little material as possible. TIP: If the grain direction is wrong and you get too much tearout, feed the other (unflattened) face of they board through the planer so you can flip the board around and joint the other edge.

Edge-jointing with a plane: If you choose to square board edges with a

The name "jointer" refers to the common use of the tool to prepare the edges of boards for edge-gluing panels. In practice, you'll likely use it most often to square up rough stock.

COMMON PLANING PROBLEMS

Snipe (left photo) occurs when the infeed and outfeed planer tables are not exactly parallel. In many cases, simply making sure the tables are aligned will take care of it, but it's usually a good idea to allow for snipe by choosing raw stock that is long enough so the affected areas can be trimmed off after planing.

Tearout (right photo) is caused by feeding the board into the planer against the grain or by taking a cut that's too deep. If flopping your feed direction and decreasing the cutting depth don't stop the tearout, it's a good bet that the grain in your stock switches directions. In this case, switch to a hand plane so you can change planing directions to follow the grain.

hand plane, choose a No. 6 fore plane or, better yet, the longer No. 7 jointer plane—you may even be able to find a 24-in.-long No. 8 jointer plane, but these have become scarce in modern times. Set a shallow cutting depth and make sure the blade is straight (parallel to the sole). While it's not difficult to plane a straight edge, it requires a good deal of care to assure that the edge is also square to the flattened face. You can let your fingers curl under the sole of the plane and ride against the face of the wood to help stabilize the plane and keep its position constant throughout the length of the stroke.

4. Thickness planing. For this procedure a power thickness planer is a godsend. Not only will it plane the board to the proper thickness and make the second face absolutely parallel to the first, but it can machine as many boards as you need to exactly the same dimension—which is essential to properly fitting parts together for a furniture project. Plane all your parts to be brought to a common dimension at the same time. Lay them out in a pile on a table or sawhorses close to the planer with the unplaned faces up and the grain oriented properly to avoid tearout. This way you can just feed them through one at a time without having to think about which way each one goes.

NOTE: Don't feed stock that's less than 12 in. long through the planer—it won't reach the outfeed roller and will either get chewed into a mulch or the planer will spit it back out.

If you're trying to plane your stock to an exact thickness, stop planing when the stock is reduced almost to exact thickness. Run pieces of scrap through and adjust the planer setting until the scrap is the correct thickness. Then, run the actual workpieces through.

HOW TO OPERATE A POWER PLANER

1 Set the table height (which establishes cutting depth) so the thickest part of the thickest board fits snugly under the infeed roller. Then remove the board and raise the table slightly (about 1/16 in.) with the table height crank.

2 Stand to one side and use both hands to feed the board straight into the machine. Once the infeed roller grabs the board it can slap it down hard against the table, so don't let your fingers get between the board and the table. As the board passes through the planer, walk around to the other side and support the overhanging wood as it leaves the machine. If you have to remove a lot of material, take heavier cuts at first, but finish up with a fine cut for a better finish. Once you've flattened the top face turn the board over and take at least a skim cut off the first face (if you're removing lots of material, alternate faces to even out stock removal and avoid warping).

Careful planning and layout of project parts helps ensure pleasing, professional results. It also helps you make more efficient use of your building materials.

Laying Out Parts

Whether you're working from a set of plans or concocting your own design, the quality of your workmanship depends on accurately transferring the dimensions, lines, shapes, and angles of your parts to your building materials. These precise measurements and marks provide the guidelines for sawing, drilling, and shaping operations. To prevent serious problems always check and double check each measurement before you cut.

Measuring. While some woodworkers and carpenters still prefer using a traditional folding rule, the mainstays of measuring today are the tape measure and the steel rule. *Tape measures* are quick and convenient, and portable. Their flexibility also makes them useful for measuring along curved surfaces. A *steel rule* provides more accurate measurements than a tape measure. Some 1 or 2-ft.-long rules can be fitted with a *combination square* head, increasing their versatility many times over. In critical situations when you want to make certain you're getting a precise reading (or if your tape tip is damaged) you can measure from the 1 in. mark on the tape or rule. But remember to subtract that 1 in. from your measurement at the other end.

Marking tools. For general sketching, writing, and marking in the shop an ordinary *No. 2 pencil* is indispensable. The lead is soft enough to leave a bold line without denting the wood, as harder pencil lead will. For drawing layout lines, a mechanical pencil with 0.5 mm or 0.3 mm lead will maintain a fine point without requiring you to sharpen it every five minutes. Of course, none of these pencils shows up very well on dark materials like walnut or hardboard. For these, use a soft-lead, white colored pencil instead.

Knives are handy in the shop for a multitude of uses. A sharp knife can be used as a marking tool that not only lays out precise lines for cutting joints, but also leaves a dead-accurate incision that you can register your chisel

Layout tools for woodworking include: **(A)** steel rule calibrated to 1/16 in. or higher; **(B)** sliding bevel gauge (also called a T-bevel) for measuring and transferring angles; **(C)** steel tape measure; **(D)** marking gauge; **(E)** compass for drawing circles and arcs; **(F)** combination square; **(G)** marking pencils, including a lumber pencil for marking rough stock, a regular No. 2 pencil (not shown) and a white pencil for marking darker stock; **(H)** try square; **(I)** chalkline for marking sheet goods.

in for the final paring cut when doing hand work. Any kind of knife will work (pocket knife, utility knife, fine craft knife, or dedicated woodworker's marking knife) as long as it's sharp and comfortable to work with.

Drawing layout lines.

• *Straight lines.* You can draw a straight line anywhere with the aid of a steel rule or straightedge.

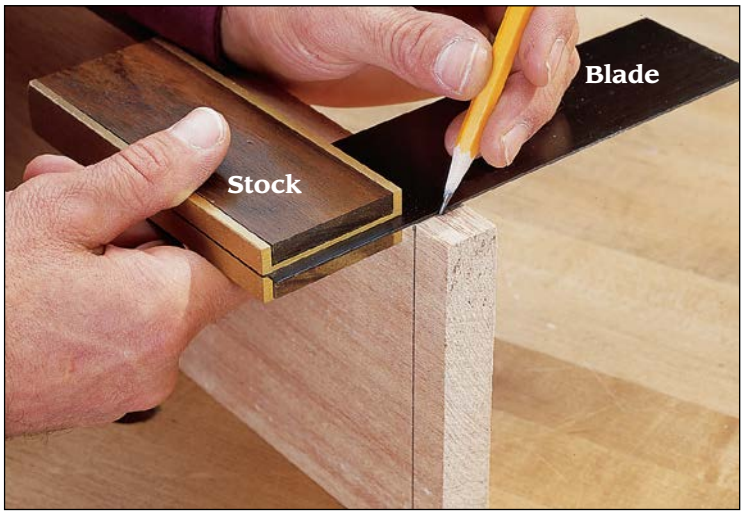
• *Parallel lines.* There are many tricks for drawing a line parallel to a board edge. One good method is to use a combination square: Hold your pencil against the end of the square's blade and, holding the square's head tightly against the edge of the wood with your other hand, slide the square and pencil together down the board. Marking and cutting gauges are fine woodworking tools that allow you to do this same operation one-handed. They accurately reproduce identical joint layout lines on multiple parts.

• *Perpendicular lines.* Successful woodworking depends on accurately drawn and cut 90° (right) angles. The square is the workshop tool used for laying out these lines and testing the precision of the subsequent cuts. Squares vary in quality. Inexpensive plastic-bodied squares are available for rough work and carpentry, but are not accurate enough for furniture and cabinetmaking. Quality *try squares* (usually with steel blades and metal-faced hardwood bodies, or stocks) and *engineer's squares* (with all-steel construction) are great shop tools for setting blade angles and jointer fences, and for many other uses in addition to layout. But the most versatile jack-of-all-trades is the *combination square.* The blade is a removable, graduated steel rule. The stock has a 90° face as well as a 45° face for laying out miters. The blade slides into the tool and can be locked at any position so it can also be used to check the squareness of tiny rabbets and gauge depth and height.

• *Angled lines.* When your two workpieces meet at 90°, it's generally common practice to join them with a butt joint. But for finer work where you want a more elegant, symmetrical joint, miter the ends of the mating workpieces at 45°. To lay out miters accurately and check the finished cuts, you'll need a miter square. This can be any square with its blade permanently mounted to give you both 45° and its complimentary angle, 135°; or you can use the versatile combination square, which is equipped with a 45° face opposite its 90° face. For angles other than 90° and 45° you'll need a *bevel gauge.* This is essentially an adjustable square that can be set to any angle and locked into position. Use a protractor as a guide to set the legs of the bevel gauge, or adjust the square to match an existing angle and transfer the angle to another workpiece.

PARALLEL LINES

To draw quick parallel lines when precision isn't critical, try this "freehand" trick: Hold your pencil normally and draw a line down the board toward you, letting one or more of your trailing fingers ride against the edge of the board as you go. If you keep these guide fingers in a constant position throughout you'll get a surprisingly straight line.



To square a line around a board, as for laying out a tenon shoulder or a making a four-sided cutoff line, start marking with the trued-up edge of the board. Press the stock of the square firmly against this edge, with the blade lying flat against the reference face at the required location. Mark a line along the blade with a pencil or knife. Then, draw square lines from the reference face across each edge. Finally, with the stock against the reference edge, square a line across the opposite face, connecting the edge lines.

To apply a marking gauge to your workpiece, extend your thumb so it backs up the cutter in the post. Tilt the tool forward slightly, and make the mark by pushing the tool. Your thumb provides forward pressure while your fingers push downward with just enough force to press the pins or blade into the wood.

Marking Curves & Circles

Laying out curved or round cutting lines accurately is mostly a matter of choosing the best marking guide or technique for the shape and size of the curve.

Curves & arcs. In order for a curve to be visually pleasing it must be *fair* (meaning smooth) and consistent without ripples or flats. To mark smooth, well proportioned curves of small to medium size, you can often use draftsmen's plastic *French curve* templates (See next page). Curves or arcs that are too large to be made with these tools can be marked using a flexible drawing guide. *Segmented flexible splines,* available from 14 in. to 48 in. long, can be found (along with French curves) at drafting supply stores. A flexible steel rule or even a thin strip of wood can be sprung to your desired curve through a series of plotted points (See photo below). Arcs and roundovers can be drawn with a standard compass (See photo, above right).

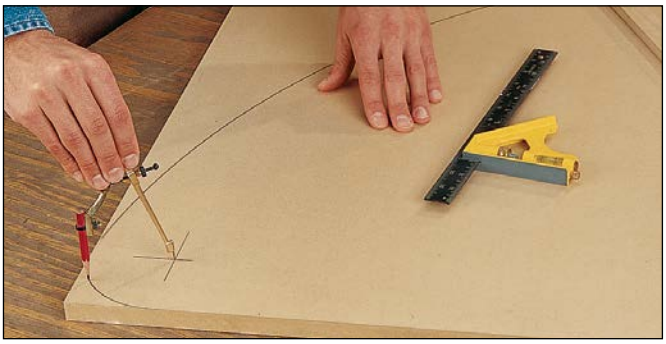
French Curves

A set of French Curves is used mostly for drafting and laying out scale versions of projects that feature lines of non-constant radius. Made of hard plastic or acrylic and usually sold in sets, French Curves can be used to draw many different arc shapes by tracing either the interior cutouts or the outer profiles.

A similar set of layout tools known as "ship curves" are used the same way, but have plainer, less complicated shapes.

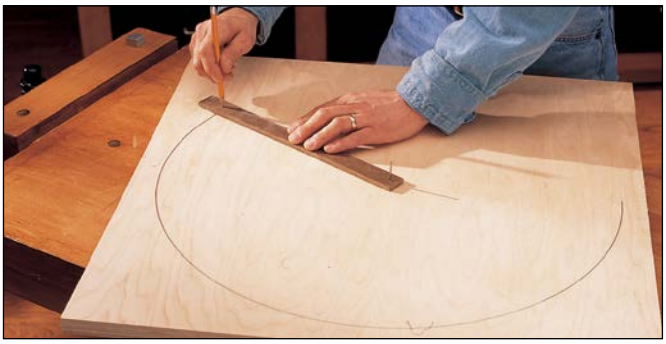
Circles. The best way to draw a perfect circle for layout depends on the size. For small circles of common diameter, a basic set of plastic circle templates is accurate and easy to use; for circles up to about 12 in. in diameter, a compass will do the job (you can get larger compasses with greater range); for larger circles (a foot or more in diameter), use a pair of *trammel points.* Woodworker's trammel points clamp onto a wooden bar. One of the points is fitted with a pencil holder, the other is a metal pin for pivoting. Measure and set the distance between the pivot point and the pencil to equal the radius of the circle. Or, you can make a simple trammel yourself with any piece of long, narrow wood scrap (See photo, lower right).

Of course, for quick-and-dirty curves and circles, a woodworker can always grab whatever is close at hand to trace around—a tin can, a roll of masking tape, a coffee mug...just about anything will do.



The infinitely adjustable compass

An ordinary compass is the tool of choice for marking arcs and roundovers of a defined radius and for drawing circles up to about 12 in. in diameter.



Quick & easy trammels

A homemade trammel pivots around a centerpoint (usually a finish nail) while the free end is fitted with a pencil for marking the circle. Just drive a nail through one end of the strip, then measure out from the nail toward the other end an amount equal to the radius of the circle. Mark a centerpoint for drilling a pencil guide hole at that point (usually, ⅜ in. dia.). Tack the nail at the center of the workpiece, insert the pencil into the guide hole, then make a single revolution around the nail with the pencil to draw the circle.

Laying out arcs

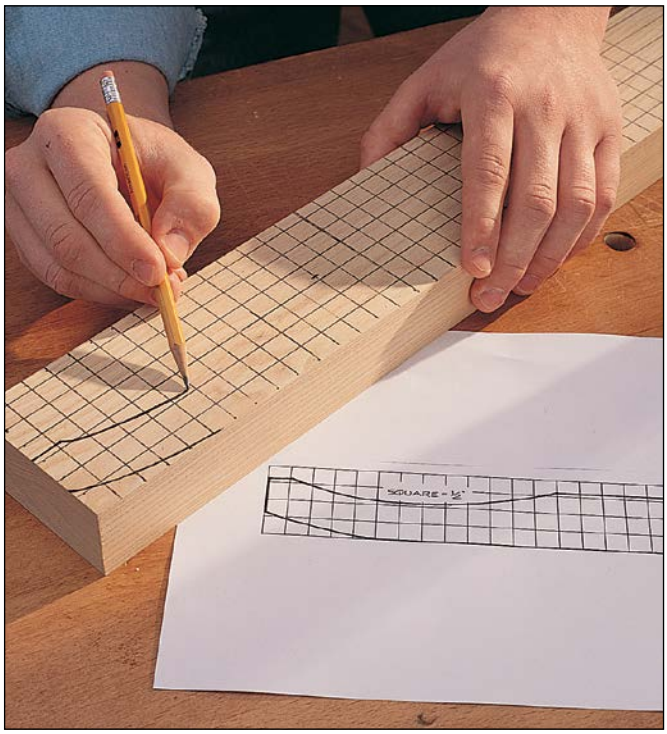
You don't need a fancy jig to draw a smooth arc—all it takes is a strip of hardboard and a few nails. Tack one nail at each endpoint of the arc, and tack the third nail at the apex of the arc. Cut a thin strip of hardboard a few inches longer than the length of the arc. Bend the strip between the the nails and trace along the inside edge.

Making & Using Patterns

For project parts with complex shapes, building plans often include patterns that are intended to be transferred to your stock or to material for making a template. If the pattern is actual size, you can transfer it directly to the workpiece by using carbon or transfer paper and tracing over the lines. More frequently, however, patterns are provided in a scaled down format, so they need to be enlarged. Typically, patterns are printed on scaled grid squares, with the size of the full-scale squares indicated. There are several methods for enlarging grid drawings. You can plot a grid pattern directly onto the workpiece or the template material (make sure to use the same scale noted with the drawing—if the scale is ¼ in. equals 1 in., for example, plot the grid with 1 in. squares). Once the grid pattern is laid out, draw the shape of the part, using the printed pattern as a reference. In some cases, you can enlarge the pattern to full size on a photocopier—if the scale is ¼ in. equals 1 in., for example, you'll need to enlarge the printed pattern 400%). Another option is to use an overhead projector to project the pattern onto larger paper. Patterns for large or very complex parts can be enlarged to actual size at any blueprint shop.

For symmetrical patterns, draw half the shape on paper, fold the paper in half along the centerline, and cut out the pattern. Or, make a half template then trace it first one way and then flipped over.

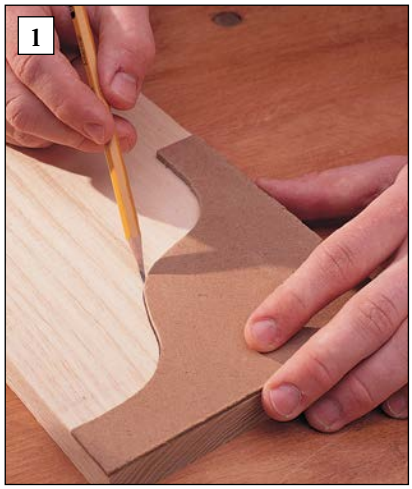
If you're making multiple parts of the same size and shape, it's generally a good idea to create a template (See *How to Make & Use a Template,* right). Templates can be created from just about any material, including cardboard or paper. Hardboard (⅛ or ¼ in. thick) works very well, as does thin MDF (medium-density fiberboard), or quality veneer-core plywood.



Following grid drawings

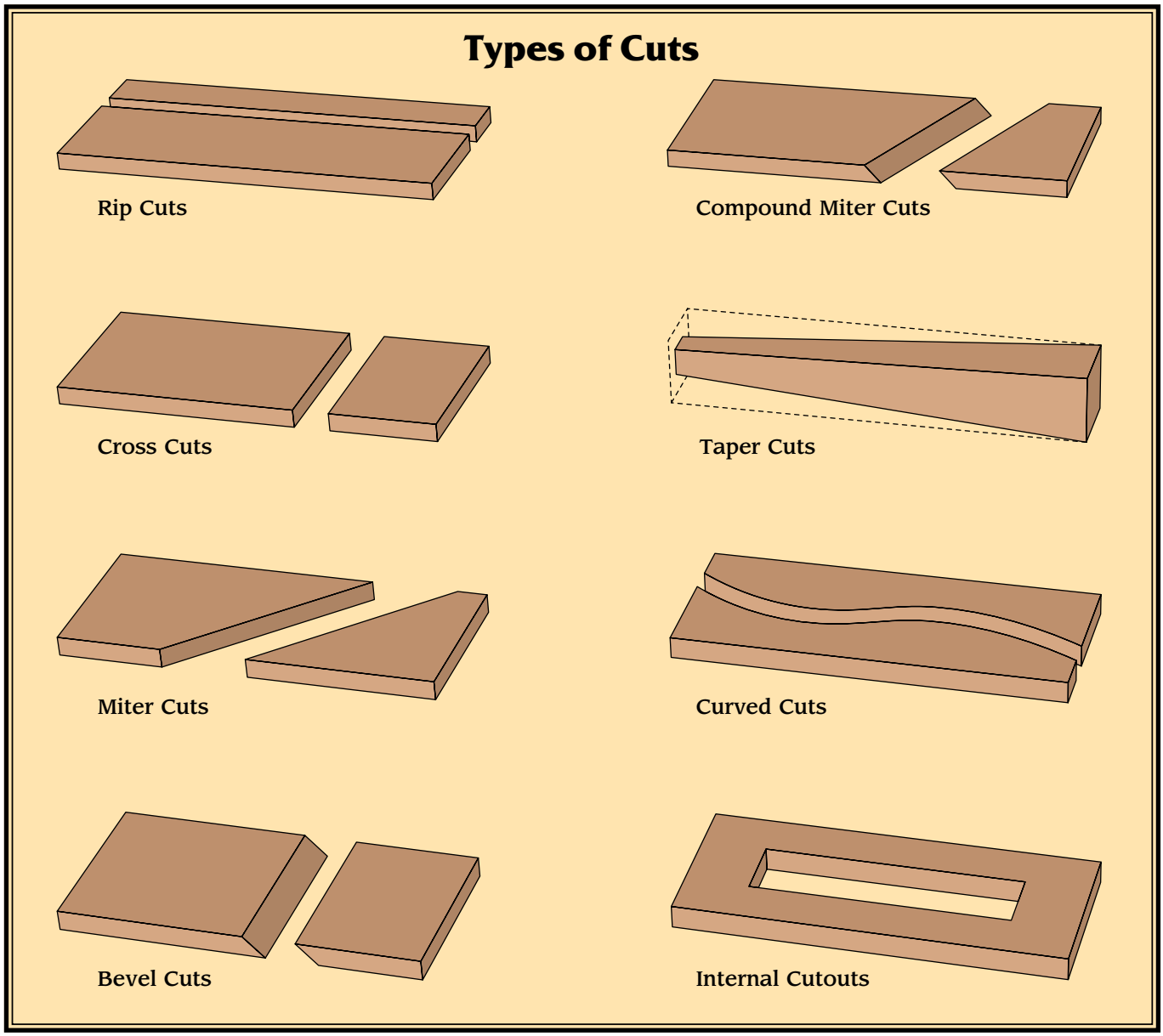
Transfer grid drawings to your workpiece by plotting a scaled grid onto the stock or the template material, then recreating the pattern using the printed pattern as a reference. You may find it helpful to use a compass or flexible ruler to draw curves.

How to make & use a template



1 Draw the full-sized shape onto template material (hardboard is shown here) then cut it out with a jig saw or coping saw. Sand or file the edges smooth, then trace the shape onto your wood stock.

2 Cut out the part, cutting just outside the layout lines. Use a wood file or sandpaper to smooth out the edges and remove waste wood up to the cutting lines.



Cutting Project Parts

Cutting parts to size usually involves making several different types of cuts with multiple tools. In this section we've described most of the standard cutting operations you're likely to encounter while woodworking. For each operation we've suggested what we believe to be the best method, as well as a few alternatives that can get the job done adequately if you don't own the suggested tool.

The essential cuts you'll make time and again are *rips cuts* (for width) and *cross cuts* (for length). As your skills advance and the complexity of the projects you undertake increases, you'll also need to make *miter* and *bevel cuts, tapers, curved cuts, pattern-following cuts, edge-profile cuts* and *resawing* stock for thickness.

All of these cuts can be made with portable hand tools. But you'll generally get faster, more accurate results with stationary sawing tools. Of these, the table saw and the power miter saw are the most versatile. A band saw and a scroll saw are also valuable additions as you develop your workshop.

> Each cutting machine excels at certain operations, performing the work more easily, safely, and accurately than other machines. Choosing the best tool for the cutting task at hand will go a long way toward ensuring good results.