SECTION ONE:

UNDERSTANDING THE BASICS

CHAPTER ONE

My son, Isaac, helps out with a new way of sizing lumber in my shop. The board breaks along the grain lines.

UNDERSTANDING THE WOOD

Working with wood can be extraordinarily rewarding. When all goes well, your work can produce sensuously smooth furniture that begs to be touched, glows with a natural warmth, and that, with care, can last for centuries. But wood can also be a source of incredible frustration as pieces crack, warp, twist, expand, contract, and joints fail. Although wood occasionally does behave as if it were intentionally creating mischief, most often, the problems come from a lack of knowledge of the material. Wood is not a stable, inert material. It gains and loses moisture, reacts to temperature, and ages over time. Rarely can you take it for granted. But the more you know about wood's structure and how that structure defines its properties, the more you'll be able to deal with almost all of the difficulties it can cause.

The Big Bundle of Straws

The single-most important thing to understand about wood is that it is not a homogeneous material, and it doesn't behave like one. If you cut it in one direction you've got one set of properties. Turn it around and it's as if you've got a different material in your hands. Rotate it 90°, and you've got something else entirely. Wood has distinctly different sets of properties when worked on in each of four orientations: with the grain, against the grain, across the grain and across end grain. And on some boards, you don't even have to rotate the wood; you'll find all of these different properties within inches on the same surface.

Why is this? Wood is fibrous. The best way to picture it is as a giant bundle of loosely connected straws. When wood is part of a living tree, some of the fibers act as straws, drinking up water and minerals from the soil and transporting them to the crown of the tree. Other fibers carry sugars from the leaves back through the tree to the various growing cells.

Of course, this is an over-simplification. However, this basic mental image is enough to tell you an awful lot about how wood behaves, and it can help you to work more successfully with wood.

Let's start with one of the most important properties of our bundle of straws. Although the straws themselves can certainly break, they are significantly stronger than the connections between them. In other words, individual wood fibers are stronger than the bond between them. This is very important in understanding many different characteristics of wood. Most obviously, a board will be much stronger if the fibers run along its length than if they run across its width.

Photo by Peter Follansbee

Fig. 1-1 - This is a different kind of "board breaking," and one that is much more useful. The log has been split into wedge-shaped boards.

Working with Wood

Knock a wedge into the end of a log or parallel to the fibers and it will split along the fibers. Follow this process to create a rough board, and you'll wind up with a piece of wood whose fibers run in exactly the same direction as the edges of the board, and therefore gives you a very strong board (Fig. 1-1).

You might think that this would be common knowledge, and incredibly useful knowledge at that. But these days, only a few shops that specialize in chairs, period furniture or steam bending do much splitting of lumber. The vast

Board Breaking

On a large scale, a good demonstration of wood's greater strength along its fibers is unrelated to woodworking. Various martial arts require one to break boards as a test of strength and accuracy (see photo, p. 10). Breaking a board where the fibers run along the length of the board (held at the ends) is very difficult indeed. But board breaking in martial arts is done with boards that have the fibers running the short way across the board (in other words, it's held at the sides). It still takes good aim and a sharp blow to break the board, but it snaps between the fibers surprisingly easily.

majority of boards that are available have been sawn out of a log. Wood fibers in sawn boards rarely line up perfectly parallel to an edge.

Fibers don't necessarily grow straight either. Wood fibers can curve, twist and head off in all directions, based on how the tree grew. This can make splitting the wood pretty much impossible, and is certainly one reason that sawing wood is the norm. Sawmills cut the boards along the length of the tree, but that doesn't guarantee that the fibers will run in that direction. Trees are not simple cylinders either. Even the straightest trees are fatter at the bottom and taper toward the top. They also grow in response to their environment, which is constantly changing.

There are many instances in woodworking where you might end up with a board that has fibers running the 'wrong' way, across the board. This is most common if you cut out a shape that has curves. Whatever the cause, if the fibers go across a board the short way, it is called short grain, which creates a point of weakness you need to be aware of. Plenty of woodworkers seem to feel that wood is generally strong enough to ignore these problems. But the fact that some people don't pay attention to fiber direction doesn't mean it's not important. You'll do much better if you watch out for it and take it into account.

Woodworkers use plenty of tools besides wedges, although most of these tools are, in essence, very sharp wedges. The wedging action and the fibrous nature of wood play an important role in how tools actually work. The exaggerated model of how this works – the bundle of straws – can help clarify this interaction.

As mentioned above, the fibers in wood don't necessarily grow straight, and the board that's cut from the tree only rarely has fibers that run straight from end to end. So a better model for the bundle of straws would include this information: The straws may angle up toward the surface, or curve this way and that. It's not hard to imagine what might happen if you try to slice into the bundle with a cutting edge. If the straws angle up toward the edge, it is likely that the edge will catch on the straws and pry them up rather than slice them cleanly; it takes less force to wedge them apart from their neighbors than it does to cut them. (Fig. 1-2).

On the other hand, if the straws emerge from the surface angled away from the cutting edge, the edge can slice through them. There's nothing for the cutting edge to catch on or wedge apart. In addition, the straws that are behind and beneath the surface support those at the surface, and the cutting edge can sever them cleanly (Fig. 1-3).

Cuts that go across the bundle (on the surface, and perpendicular to the length of the fibers) will separate straws more than slice them. Imagine peeling up a layer of them (Fig. 1-4). Unless the cut happens to be the full

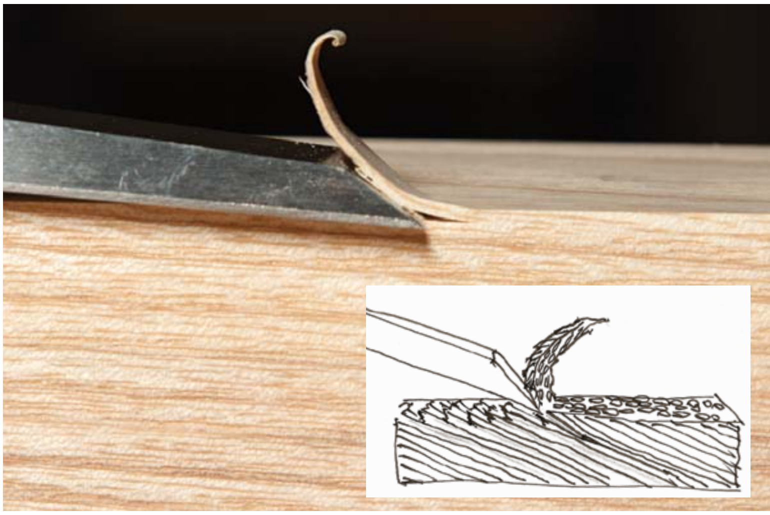


Fig. 1-2 - Paring with a chisel against the direction of the fibers, the wood splits out ahead of and below the intended cut.

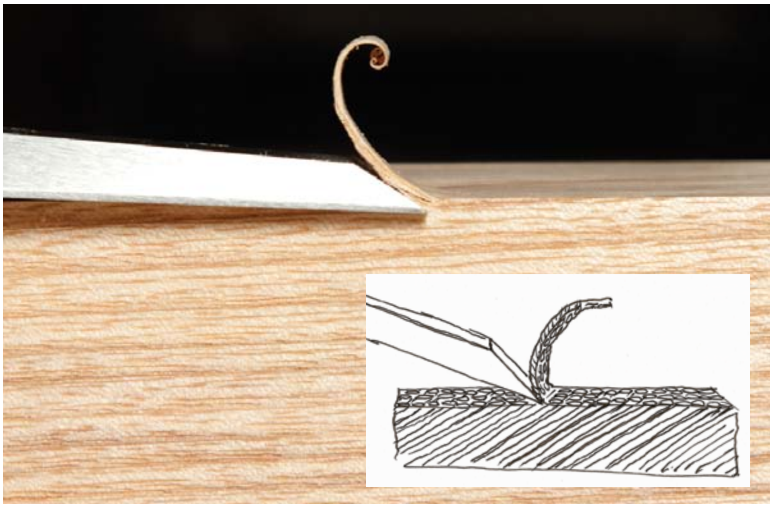


Fig. 1-3 - Paring with the direction of the fibers does not split below the intended cut.

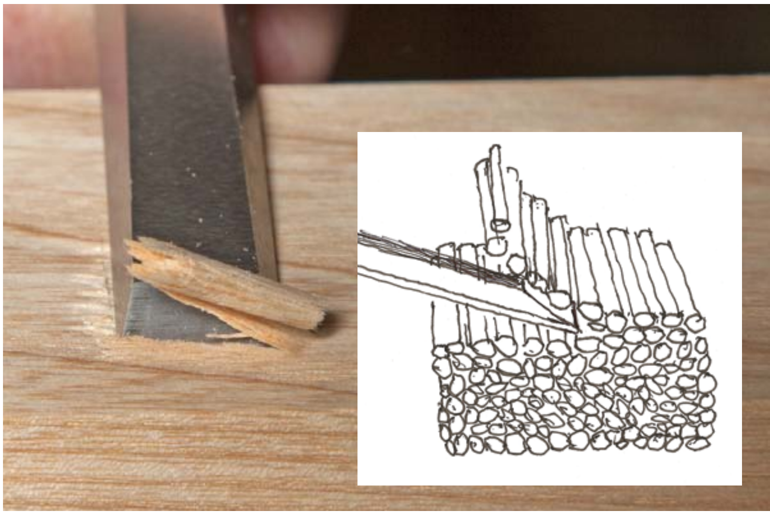


Fig. 1-4 - Notice how the fibers break off beyond the sides of the cut when you pare across the fibers.

width of the bundle, the cut will have ragged edges. The straws will likely break off beyond the tool at either end, At the far end of the bundle, the straws may break off rather significantly.

When you cut across the grain on a piece of wood, the shavings have a very different look and feel from those cut with the grain. You can imagine them as a pile of connected miniature straws. And they feel different, too. They are sharp and surprisingly irritating if they get down your shirt (Fig. 1-5).

You might have to score a piece of wood to sever the fibers before attempting to plane or chisel across the grain. There are also some highly specific rabbeting planes designed for cutting across the grain, which incorporate an additional cutting edge (a nicker) to score the wood fibers at the edge of the cut.

There are still other issues that come up when cutting across the end of a board. The bundle of straws also helps explain these. Starting the cut won't pose a problem; the bulk of the bundle backs up the initial part of the cut. As you reach the far side of the bundle, however, there are fewer and fewer straws backing up the ones you are attempting to cut. A point will finally come where the force needed to push the cutting edge through the straws is greater than the adhesive force holding the straws on the back of the bundle together. The result is predictable:

Fig. 1-5 - You get a real sense of the fibers when you plane across the grain. Notice that the back edge of the board is splitting off (spelching) as well.

Fig. 1-6 - Planing end-grain will split the unsupported fibers at the far edge of the board.

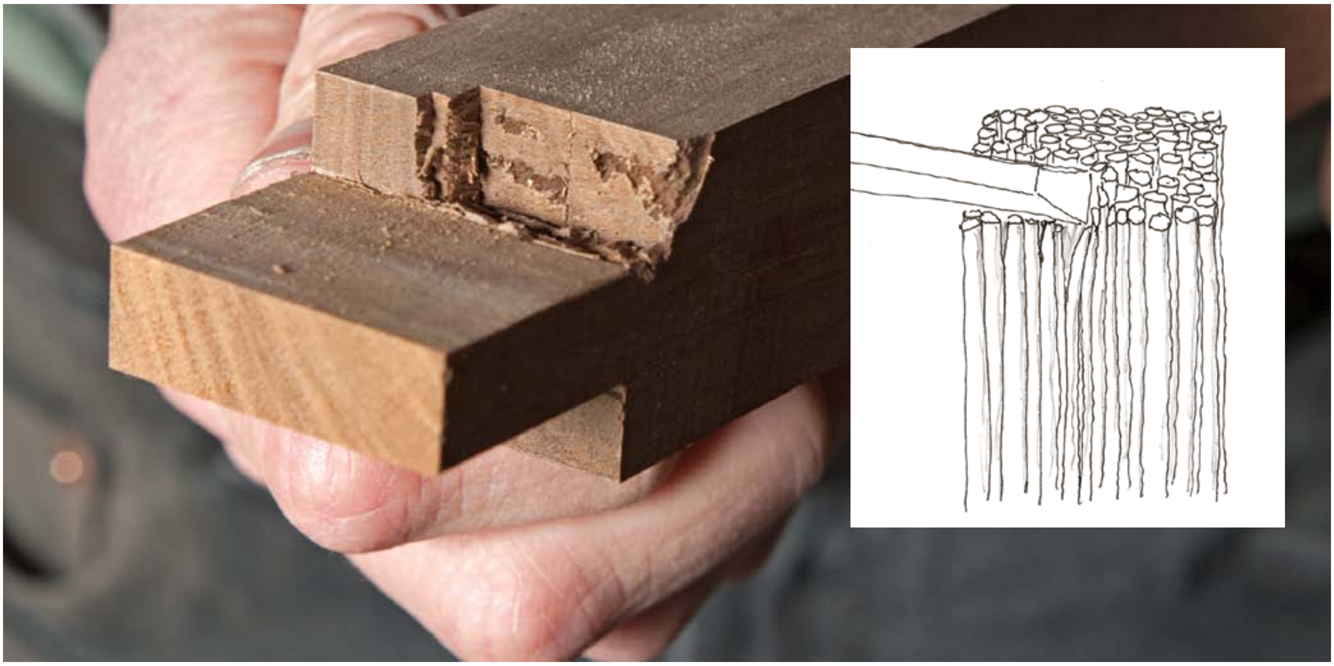


Fig. 1-7 - Chop too aggressively with a chisel and you'll have a mess like this, too.

Straws will simply split off and break as you get to the far end of the bundle. And fibers do indeed break off as you get to the far edge of a board. (Fig. 1-6)

The straws in the bundle (and fibers in a board) also compress a little as the edge of a tool starts to cut. This is actually true on all cuts, but is most obvious on the end of the bundle. Even with the sharpest of edges, the straws will compress a little bit before the tool starts to cut through; there needs to be enough force pushing back against the edge of the cutting tool for it to be able to cut. A larger wedge angle, a duller edge, or a cut that is too fast may compress the straws even more before they actually cut, and may completely separate straws from their neighbors before any cutting happens. This makes for a much rougher cut. If you try to cut even harder, the straws may simply break off below the surface instead of cutting. (Fig. 1-7)

It's not uncommon when dealing with wood to find boards with fibers that seem to wander all over the place. The fibers emerge on the surface of the board in one direction in one spot, and emerge in a different direction just a short distance away. This can be very frustrating, and it becomes difficult to avoid tear-out. In general, the solution is to use a steeper cutting angle. The higher angle does not wedge up fibers as easily. And depending on the angle, the wood is subject to a different cutting action; instead of the slicing action of a lower angle, the high angle will cause compression failure and then a smashing off of the fibers. This is less likely to tear up fibers, but does not leave as good a surface as one you've successfully planed clean. There are more specific recommendations in the chapter on using your tools.

Gluing Wood Together

The fibrous nature of wood also is important when considering how to glue pieces together. The straw analogy continues to be helpful in explaining this. In order to glue together bundles of straws successfully, the long sides of the straws must be glued together. They don't need to be parallel – angles are fine – but sides of the straws must be

Planing Across End Grain

One way to deal with the real-world issue of separating fibers when planing end grain is to moisten the end of the board just before cutting (water and mineral spirits, both work, but mineral spirits will evaporate off quicker, and won't rust your tools). This will swell up the fibers enough to cut down on the compression, and usually allows for a cleaner cut. Of course, a very sharp blade and a more acute cutting angle help as well.

Fig. 1-8 - Only a few fibers actually adhered to the end-grain in this long-grain-to-end-grain glue joint. The joint failed right at the glue line.

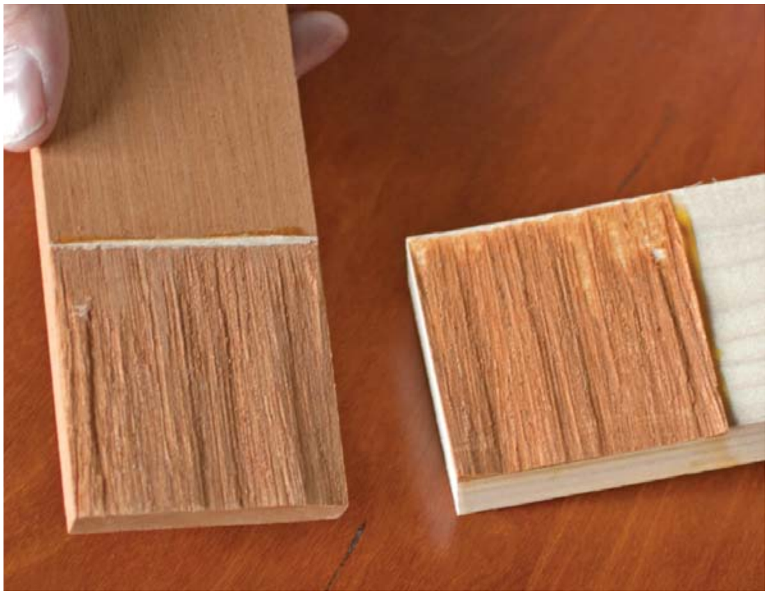


Fig. 1-9 - This long-grain-to-long-grain joint broke next to the glue line, but not on it.

glued to other sides. It's easy to imagine that gluing the ends of the straws will lead to problems. There's less actual surface there, and the straws will actually soak up most of the glue. A glue joint on the end of the bundle won't form a strong connection to anything else.

That's not as obvious with wood, but it's no less true. We'll certainly be able to get end grain to stick to something (even other end grain), but it won't hold well, and will break apart under stress or shock (Fig. 1-8). None of the end-grain fibers will attach to other fibers, and the joint will break apart right at the glue line.

Glue bonds that are from fiber to fiber are generally stronger than the wood itself. In other words, good glue bonds tend to be stronger than the bonds that naturally occur between the fibers. This is true with just about any wood glue. Breaking apart a good fiber-to-fiber joint (a long-grain-to-long-grain joint) you'll almost always break apart the wood next to the joint, not the joint itself. (Fig. 1-9)

Beyond the Bundle of Straws

There are a few properties of wood that the bundle of straws model can't explain fully. In order to understand these properties of wood, we need to elaborate a little bit on our simple model of how wood works.

A tree is constantly adding new fibrous cells just underneath the bark. This new wood accumulates at different rates based on growing conditions. There is quicker growth and larger and thicker-walled cells during moderate and wetter months with more available nutrients, and slower growth with smaller and thinner-walled cells during dryer, hotter months. It's worth noting that in tropical conditions, where the difference in seasons is minimal or subtle, the cell growth is much more consistent. Annual climate conditions will also have an effect, with drier years (or multi-year periods) showing less overall growth than wetter ones.

The difference between these growth periods is variously called earlywood and latewood, or springwood and summerwood, and in most of the woods we're familiar with, is noticeably different in either density, porosity and/or color. This is the difference we saw in the growth rings we counted on a tree stump as children. These are called annual rings if the growth pattern changes annually. And it is the difference between these layers that is a major factor in the grain patterns that we see in wood.

What we typically think of as wood grain is the result of slicing a board out of a tree, and cutting across these growth rings in various ways. Different ways of cutting the board out of the log result in very different appearances, and somewhat different structural characteristics as well. The fact that a tree is not cylindrical, but is instead somewhat conical, also affects the patterns created from cutting wood from the tree.

Heartwood and Sapwood

After a certain number of years have added more and more outer layers, the now-inner layers transition from being active transporters of nutrients to more of a structural role in the tree. This defines the difference between sapwood (the active transport component near the bark) and heartwood (the inner, structural wood), which often have different colors both in the tree and in the wood. While this difference is functionally significant in the tree,

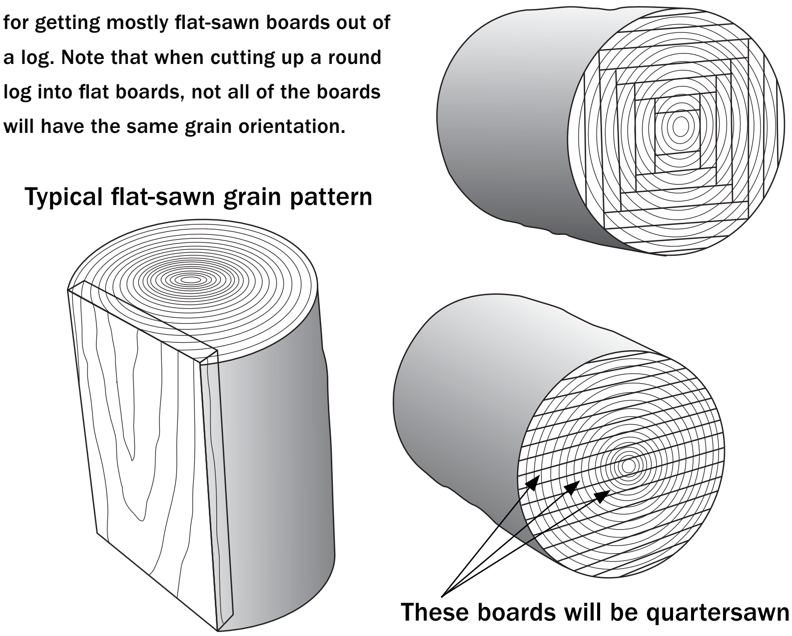
Plain-sawn or Flat-sawn, Quartersawn and Rift-sawn Wood

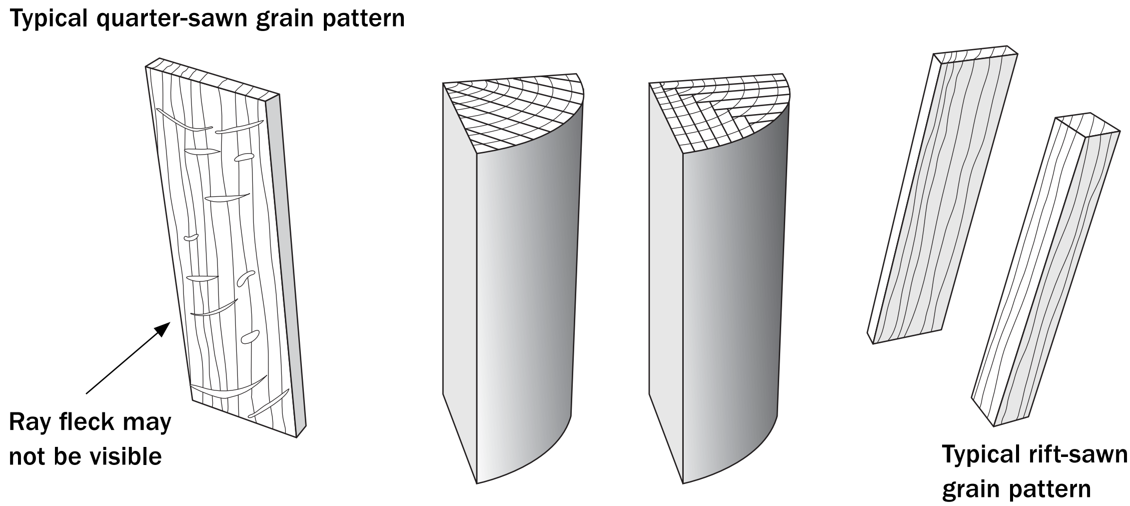
Wood is most often plain-sawn (or flat-sawn, the terms are interchangeable). The appearance of the surface is generally characterized by arches, vees and ellipses in the grain patterns. The ends of the boards will usually show the curvature of the tree's annual rings.

Wood can also be quartersawn. This term comes for the practice of first cutting the log into quarters, and then sawing each quarter into boards. The alignment of the annual rings tend to be perpendicular to the surfaces. The surfaces usually display straight grain, with some additional figure (see below).

Rift-sawn grain (a less-precise term) covers wood with the annual rings oriented somewhere between 45° to 90° to the surface. This displays straight grain on the surfaces, but usually without the additional figure. When the growth rings are at roughly 45° to the surface, the wood is idea for table and chair legs, because it will display the same basic grain pattern on all four sides. Note that a flat-sawn board will have edges that show quartersawn grain, and vice versa.

Here are two possible cutting patterns for getting mostly flat-sawn boards out of a log. Note that when cutting up a round log into flat boards, not all of the boards will have the same grain orientation.





Two possible cutting patterns for quartersawn and rift-sawn boards. Both patterns yield some of each type of grain.

Fig. 1-10 - Cherry, poplar and walnut all display the difference between sapwood and heartwood with different colors.

Fig. 1-11 - Quartersawn white oak (right) shows more ray-fleck that the quartersawn walnut (at left).

and can result in very different relative moisture levels between heartwood and sapwood in a freshly cut board, by the time the board is dried, the differences are mostly cosmetic. (Fig. 1-10)

Radial Cells and Their Effects

All of the cells in a tree don't run up and down the trunk. There are important cells that radiate out from the center, providing lateral transfer of nutrients and water. The prominence and size of these radial cells vary from species to species, and can be almost invisible or a defining characteristic of certain quartersawn boards. The radial cells also have an effect on the wood, changing its behavior, as we'll see in the next section. (Fig. 1-11)

Wood Movement

Wood responds in significant ways to changes in its moisture content. And the moisture content of the wood is affected by the changes in the moisture content of the air around it. The wood is constantly releasing or absorbing moisture from the air as it seeks to establish equilibrium. This is a fundamental property of wood, and one that has a major impact on many aspects of woodworking.

When freshly cut from a log, a typical hardwood board can have a relative moisture content (defined as the relation between the weight of the board as freshly cut to its weight completely dried out in an oven) of somewhere between 60 and 100 percent. For most woodworking, the wood is dried to somewhere around 6 to 15 percent. This can happen either by letting it sit exposed to the air for a significant amount of time, which usually results in a in 10 to 15 percent relative moisture content (depending on the climate), or by placing it in a special kiln that will, through a combination of heat and dehumidification, remove moisture in a carefully controlled way, usually down to 6 to 8 percent.

Our more complete bundle of straws model can help us understand how this change in moisture affects the wood. The straws are, for the most part, tubular cell structures. These cellular structures shrink down as the cell walls dry out, but are capable of swelling back up when they regain moisture. They do not lengthen appreciably with added moisture, but they do get fatter. A substantial amount of this movement is confined by the radial cells – the cells that extend outward from the center of the tree. It's as if these cells tie our bundle together a little tighter between the growth rings. That means that most of the swelling of cells is directed perpendicular to those radial cells, or tangent to the growth rings. In other words, the straws become more oval in cross section as they dry out. The overall effect is that the bundle changes dimension the most in this tangential direction, less so radially and hardly at all lengthwise.

The difference in the amount of change in different directions is a major factor in woodworking. Most furniture isn't made from wood that's all aligned the same way; it's made from many pieces of wood oriented in different ways. The fibers in the aprons of a table run horizontally between the legs, whose fibers run vertically. The top is in a dif-

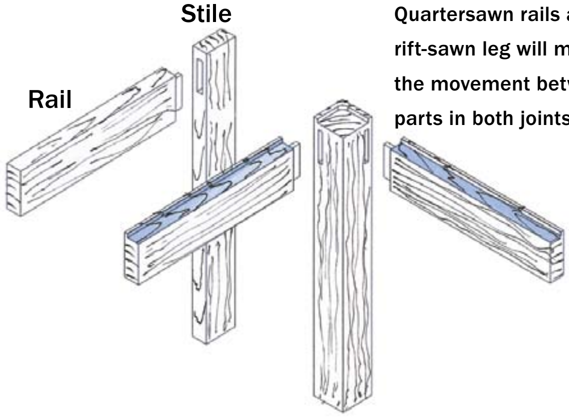
Wood Movement Issues to Watch For

The most common problems caused by wood movement came from confining wood movement. You have to let the wood move. Wood that can't expand and contract will inevitably cause trouble. The force behind this expansion and contraction is stronger than the wood itself. Cracks, blown-apart frames, split tabletops, and more are almost always the result of not making allowances for the wood to move with seasonal changes in humidity.

Try to limit cross-grain joinery to 3" or less. This is a fairly safe joint size, and larger cross-grain joints are prone to breaking apart or cracking due to constrained cross-grain movement.

There is some movement in all joints that have grain at right angles, but most wood glues are designed with enough flexibility to accommodate small amounts of movement. Over the course of decades, most glues will fail due to this differential movement. You should consider grain orientation in your joints, if possible, as a way of minimizing this movement.

Quartersawn rails and stiles mean minimal change in the width of the rail tenons and minimal change to the depths of the mortises.



Quartersawn rails and a rift-sawn leg will minimize the movement between parts in both joints.

In joints between panels (dovetails, finger joints, sliding dovetails, etc.) the grain should be similar on both parts. Flat-sawn-to-flat-sawn, or quartersawn-to-quartersawn.

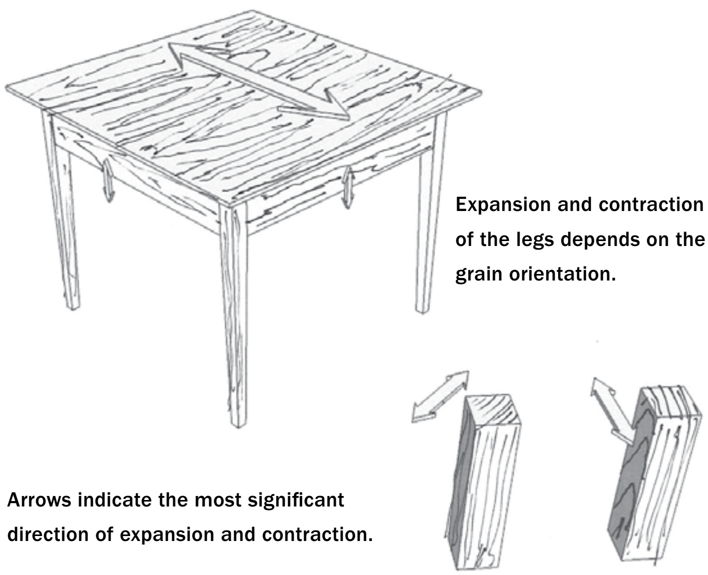
Don't glue up a panel with quartersawn grain and flatsawn grain right next to one-another – the difference in the direction of movement from one piece to the next will show up as a ridge between the boards once they start to move; ultimately, this disparity will work to destroy this glue joint as well.

ferent plane from any of the other pieces. All of these pieces expand and contract in certain dimensions, but not in others. And we want the table to stay together despite this. (Fig. 1-12)

The expansion and contraction of wood is the major reason wood gives us so much trouble – at least in environments where there is a great deal of seasonal change in moisture content. In fairly constant climates (the desert, the tropics or other similar areas with little seasonal moisture change) wood movement just isn't a big factor. The moisture content of the air is almost always the same, and the wood (once it has acclimated to this humidity level) remains mostly the same as well. At least it does until the wood or the furniture is moved somewhere else.

But there are also other vexing problems with wood movement: Wood warps in various ways, and checks and cracks. Some of these problems are hard to avoid. But most of the time it comes back to a lack of awareness of how wood naturally behaves.

Why does wood move in these ways? There are a few factors involved, but most of the time



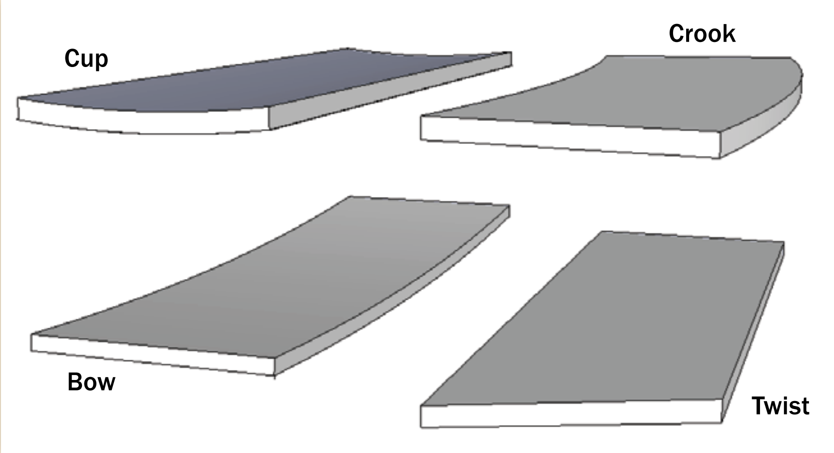
Expansion and contraction of the legs depends on the grain orientation.

Arrows indicate the most significant direction of expansion and contraction.

Fig. 1-12

Warping Wood

There are four descriptive terms that cover the various misbehaviors known collectively as warping (and plenty of other non-sanctioned words that might come to mind as well). These are cup, bow, crook and twist. Each defines a particular kind of wood movement. Sadly, they are not mutually exclusive. That's where some additional not-officially-sanctioned words come into play.



it comes back to the issue of moisture.

Any time the moisture content on one surface of a board is different from that on the other side, one side will expand or contract more than the other side. And that differential movement causes the board to cup. This happens in many different situations, some of them less than obvious.

How do you wind up with one side of the board wetter than the other side (other than actually wetting the board on one side)? One common way for this to happen is to finish one side of a board, but not the other. It can also happen if the two sides are finished differently. Finishes provide some protection for the wood, and also slow down (but only rarely eliminate) the exchange of moisture with the surrounding air. If the finish isn't balanced on both sides, when the atmospheric moisture content changes, one side will adjust more quickly than the other. This means that the fibers on one side will swell up or shrink down quicker than those on the other side. An unconstrained board may then warp.

Milling a board can also create a moisture imbalance if you're not careful. To understand this, let's examine more closely how wood dries. When freshly cut wood is placed either in a specialized kiln or out in the air, the wood immediately starts to lose moisture to the surrounding drier air as it seeks equilibrium with its environment. End grain loses moisture much faster than the sides of the fibers. Because of this, it is important to seal the ends of a board (a special paint, wax or other moisture-resistant finish is usually used), or the ends will shrink so much faster than the wood closer to the middle of the board that the ends will crack to accommodate the difference. When the ends are sealed, the bulk of the drying starts in the outer layers of the wood, and that in turn helps to pull moisture out of the inner layers.

Eventually, when equilibrium is reached, no further drying occurs. Any change in the environment, however, will cause either more moisture loss or moisture gain. Either way, the process starts on the outside of the board and moves in. If the wood does not reach a new equilibrium, there will be some imbalance between the inside and the outside of the wood. This is not necessarily a problem, and in fact, boards are in this state of flux much of the time in climates with significant swings in humidity. A board can go through this cycle over and over and not warp or cup.

If, however, one removes wood from one side of this board and not the other (or more from one side than the other), it is possible that the board will wind up in a situation where the moisture content of the two sides is not the same. One side will have the moisture content that was on

Glue-line Swelling

Water-based glues add a little bit of moisture to the wood around a joint, swelling the fibers up temporarily. This swelling subsides within a day or two as the small amount of moisture added to the wood dissipates. This is not normally an issue. However, if you glue up a panel and then smooth it before the moisture dissipates (this usually takes at least 24 hours), you may create a problem. Smoothing out the glue line when it is still swelled up means that when it dries back out, it will shrink down below the level of the rest of the panel. You'll see this as little valleys at each of the glue-lines. This will be most visible with glossy finishes, which tend to accentuate surface irregularities.

The top face has both flat-sawn grain (toward the middle) and rift-sawn (out at the edges), while the bottom surface has more quartered and rift grain. The top surface will move more than the bottom when the moisture changes.

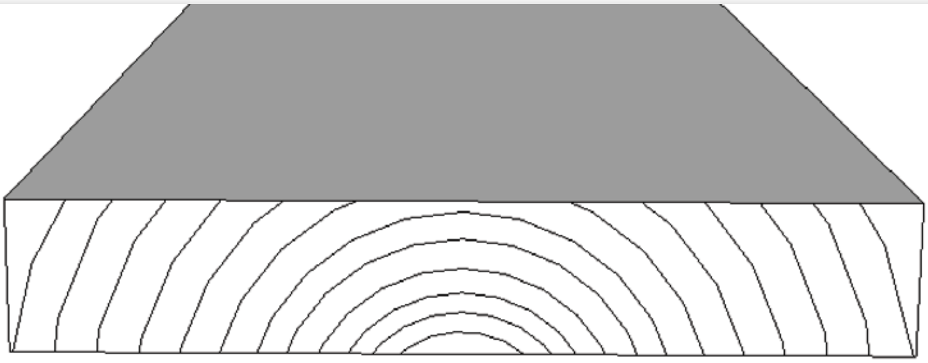


Fig. 1-13

the outside of the board, and the other side will wind up with the moisture content from the core of the board. The wetter side will then shrink more than the drier one, causing cupping. You can avoid this problem by balancing the milling process, and milling wood equally from both sides.

You can also run into moisture differentials from the inside to the outside of a wooden case, such as a box or a cabinet that is tightly closed. Atmospheric moisture changes on the outside may affect the inside of the piece more slowly, and cause problems on wider, unrestrained panels. Allowing air to circulate inside the case will solve the problem. Most traditional designs evolved to deal with this issue; these will be covered at the end of the chapter.

If a board is dried too quickly, you can also wind up with a different problem arising from moisture imbalance. The board will crack and/or check. This happens when one part of the board dries out faster than another part. We've already seen that moisture migrates out of a board much faster through the ends than it does through the sides of the fibers. If nothing is done to control this natural tendency, the ends of the board will shrink much faster than the wood that is closer to the middle. In order to adapt to the contraction at the end of the board adjacent to wood that is still swollen with moisture, the end fibers may split apart. It's amazing that the shrinkage of the wood is so strong it will pull the board apart. Standard practice when drying wood calls for sealing the ends of the boards to eliminate (or at least slow down) the faster moisture loss and to allow the wood to dry out evenly.

Too rapid drying can still cause trouble even if the ends of the boards are sealed, however. The accelerated drying may cause the outer layers on the sides of the board to shrink too quickly for the moisture to migrate out from the inner layers. You may find cracks throughout the surfaces of the board as the wood deals with outer layers that have contracted around a core that is still moist and plump.

Growth Ring Orientation

Most wood (except some quartersawn wood) is cut from a tree so that we see the curvature of the growth rings in the end-grain. Wood that originated closer to the center of the tree will show more curvature (a tighter radius) than that cut closer to the bark. The more curvature, the more prone the board will be to cupping. This is not a moisture imbalance issue, but it is still moisture related. A board with pronounced curvature actually has significantly different grain orientation from one side to the other; the outside of the curve will show more movement along its surface, which is tangent to the curve. The inside of the curve has less movement along its face; the grain has changed enough that it behaves more like quartersawn wood and has more movement perpendicular to the face. The overall tendency then is for this board to cup as if the growth rings visible on end grain were trying to straighten out as the wood dries out, and to curve more as the board gains moisture. (Fig. 1-13)

There is another problem that can show up in a board that is cut too close to the center of the tree (the pith). The wood there actually has a somewhat different structure than wood cut from areas farther out in the tree, and it responds to losing and gaining moisture in notably different ways as well. This wood (known as juvenile wood) can cause serious warping in a board and should be avoided.

Environmental Factors

Trees don't always grow straight and tall. Their growth is influenced by what goes on around them in the surrounding forest, the terrain on which they grow, and the climate. At times, one (or several) of these factors can cause changes that affect the growth and resulting structure of the wood. In addition, physical stresses on a growing tree, such as consistently windy conditions, growing on a steep slope or with shifting soil, can also distort a tree significantly, creating a great deal of built-up stress in the wood. These trees may grow at an angle, or bend as they grow. Trees are also phototropic – they grow toward the light – and a tree will respond to changes in light due to a fallen or rapidly growing tree nearby. This, too, can cause

Make a Cutlist as the First Step Toward Understanding What You Should Be Doing With the Wood

One of the best things you can do as you start on a project is to make up your own cutlist. This is a perfect opportunity to consider all of the possibilities for grain choice. Sure, some projects come with a ready-made cut lists. But you do yourself a disservice by skipping this step and relying on someone else's idea of the project. Making your own cutlist is the best way to really get acquainted with the project you're about to build, and is especially important for making appropriate wood choices.

Making a cut list forces you to go through the project drawings and think about each piece and how it functions as part of the whole project. And this gives you an opportunity to think through exactly what wood (or wood grain) will suit that part best. This is the first step in your project toward doing a better job.
If you're simply interested in the efficiency of wood use, you can make choices based on that as well. But at least you'll be making your own choices. And you'll still have a better concept of the project, and a clearer idea of exactly where you're going.

Don't just make a list, either. Annotate that list with descriptions that will help you choose the best wood for each part of the job.

A SIMPLE TABLE WITH DRAWER

NUMBER	PART	THICKNESS X WIDTH X LENGTH	NOTES
4	legs	1½" x 1½" x 23¾"	Rift-sawn grain (so the grain appears straight on all four sides). Mortised for side and back aprons, half-blind dovetail at top of leg for front upper stretcher, twin tenons for lower stretcher
3	aprons	¾" x 4" x 13½"	Quartersawn or rift-sawn grain, ¾"-long tenons on both ends (12" between the tenons)
1	upper stretcher	¾" x 1½" x 13"	Dovetailed at ends (½" long) to attach to top of legs (12" between dovetails)
1	lower stretcher	¾" x 1½" by 13½"	Twin tenons at ends (oriented vertically for maximum long grain glue surface) – ¾" long (12" between tenons)
1	top	¾" x 18" x 18"	Made up of three or four pieces cut from the same board. Match the grain with care. Boards should be the same width
1	drawer front	¾" x 2 ½" x 12"	Symmetrical grain. Look for something interesting. Half-blind dovetails. Stopped groove for drawer bottom
2	drawer sides	½" x 2 ½" x 13$^{15}/_{16}$"	Secondary wood – maple, even grain. Stopped grooves for drawer bottom
1	drawer back	½" x 2" x 12"	Secondary wood as for sides. One less dovetail than at the front of the drawer.

Drawer bottom ⅜" x roughly 13$^{3}/_{16}$" x 11½" Secondary wood, grain runs from side to side. Rabbet three sides to fit in grooves in drawer sides and front

Examples of Good Wood Choice

A curved chair leg will look best with visible grain that follows the curve, and that is also better structurally. A curved leg with grain that goes against the curve will have "short grain" and will be much weaker. The patterns in the grain are a good clue to the structural in many cases. A frame-and-panel door will generally look best with the frame made from quartersawn lumber, with its straight lines. And this wood choice is ideal for minimizing the cross-grain stresses on the mortise-and-tenon joints.

Rift-sawn legs look great with straight grain on all four sides, and this balances the wood movement equally between the two joints. The bookmatched panels for a door are a purely visual choice – the panels are usually thinner than the stiffer frame that surrounds them to control the tendency to warp, and the construction should allow for the expansion and contraction of the panel in the frame.

This is the kind of board breaking you should try to avoid. The grain here runs across the bottom of this leg along the break line. This makes for a weak leg that is prone to break.

This leg is much stronger, because the grain runs with the curve.

stresses to build up in the wood. This abnormal growth is called reaction wood.

These stressed areas of the wood expand and contract with moisture variation at a very different rate than "normal," non-stressed wood. The internal stress will generally reveal itself through dramatic distortion in the wood. Try to avoid boards with major knots (remnants of large branches, which are under stress), unusually curved grain (sometimes indicative of a distorted tree trunk) and boards that have a wooly or furry surface. Unfortunately, some reaction wood isn't apparent until you try to cut the board, at which point the wood may warp suddenly to one side, or bind tightly on the blade. There isn't much you can do with a board like this short of cutting it up into very small pieces, and it's probably not worth trying. Luckily, it's not all that common. But you're still likely to encounter one once in a while, and forewarned is forearmed in dealing with this bizarre wood.

Even without unusual growing conditions there may be parts of a tree that yield wood prone to later movement or distortion. Wood sawn from parts of the tree near major branches may have compression or tension stresses as well as grain that heads in different directions. This wood can cause similar problems with warping and distortion.

Working with Wood Visually And Structurally

Up to this point, this discussion has mostly been about wood fibers. The concept of grain has been limited to discussions of end grain, and a brief mention of plain-sawn, rift-sawn and quartersawn grain patterns. The basic properties of wood are generally easier to understand using the concept of fibers. "Grain" is a term that has a huge number of different meanings, some of which are relevant to the discussion of wood behavior, and others of which are not. Certainly, one of the meanings of grain is a synonym for the fibers we've been discussing so far. But grain also describes how the pattern of growth rings appears when we cut boards out of the tree, the overall appearance of the board (also known as figure), how the fibers are oriented in the board, various wood defects and more. R. Bruce Hoadley, in his definitive book, *Understanding Wood*, lists more than 50 different usages of the word grain related to woodworking, falling into 10 different categories! These include: Long Grain, Side Grain, End Grain, Flat-sawn or Plain-sawn Grain, Quartersawn Grain, Rift-sawn Grain, Curly Grain, Rowed Grain, and Highly Figured Grain.

Using the wood's grain to its fullest advantage is an interesting combination of visual design and engineering. Carefully chosen wood grain can enhance the overall visual effect of the piece. But it is equally important to consider the structural and behavioral characteristics of each piece of wood as it will function in the piece. Fortunately, most of the time, the appearance and the structure of the grain go hand in hand.

Color Changes

Most wood changes color as it ages. This can be a pleasant surprise, as you might find when cherry ages from the initial pale salmon color to a rich, dark reddish-brown. It can also be a great disappointment, as when purpleheart or padauk go from brilliant purple or red to a fairly ordinary brown. The color change process is a combination of photosensitivity and oxidization – exposure to light and to oxygen. Different woods change in different ways. But almost all of them change over time. Many get darker (cherry, mahogany), some get lighter (walnut), some yellow (maple, ash), others change colors (purpleheart, padauk). Most woods will eventually lose color and look bleached out if left exposed to full sun for a long time. Be aware of the potential for change as you design with wood.

Working with Wood – Joinery

Traditional woodworking techniques arose out of a deep awareness of how wood behaves. And the tradition of working with wood goes back thousands of years. Traditional joints and construction techniques take advantage of wood's strengths, and for the most part, try to minimize its weaknesses. And although there have been many advances in woodworking, the only real improvements in these techniques have been in methods for cutting wood. Many of the modern advances in technique are advances only in speed (think dowel construction), and are actually less effective joinery. There are a few cases where older techniques come up short today; moisture-related wood movement was not always quite as much of a factor hundreds of years ago – before central heating – as it is now. But we can learn from and try to avoid the few techniques that ultimately led to problems.

All traditional wood joinery relies on the basic properties of wood that we've discussed already: wood's fibrous nature and its tendency to expand and contract with changes in atmospheric moisture content. The basic principles of joining wood are:

1. Join fibers to fibers (end grain doesn't count)
2. Create as much good glue surface (fiber-to-fiber surfaces) as possible
2. Create some sort of mechanical connection if possible

Raising Dents With Moisture

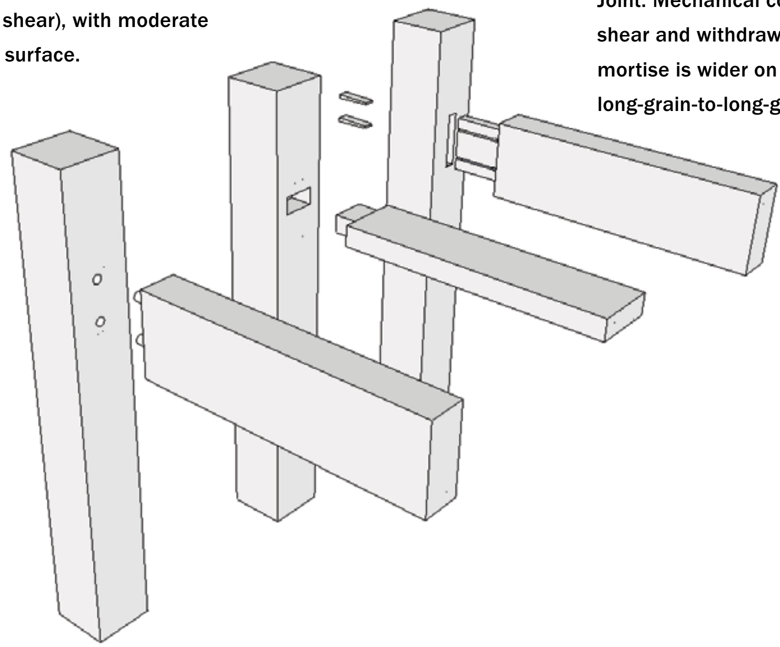
Fibers that have been compressed can often be restored to their original state with moisture. This means that you can often fix a dent with a little bit of water. It's more effective if you combine water and heat, in the form of steam. With smaller dents, you can apply a drop of water to the problem, then heat the water with the tip of a clothes iron or a soldering iron. You can steam out larger dents by applying a damp cloth to the surface, and then ironing over the dented area with a clothes iron. Make sure the wood is dry before you attempt to smooth out the surface again.

Dents are all too common in the shop, but they're usually easy to remove if you rely on the tendency of wood to swell back up if you force moisture into the cells.

Put a drop of water in the dent to start the repair.

Just add heat. Here, a soldering iron heats up the moistened wood and swells up the fibers.

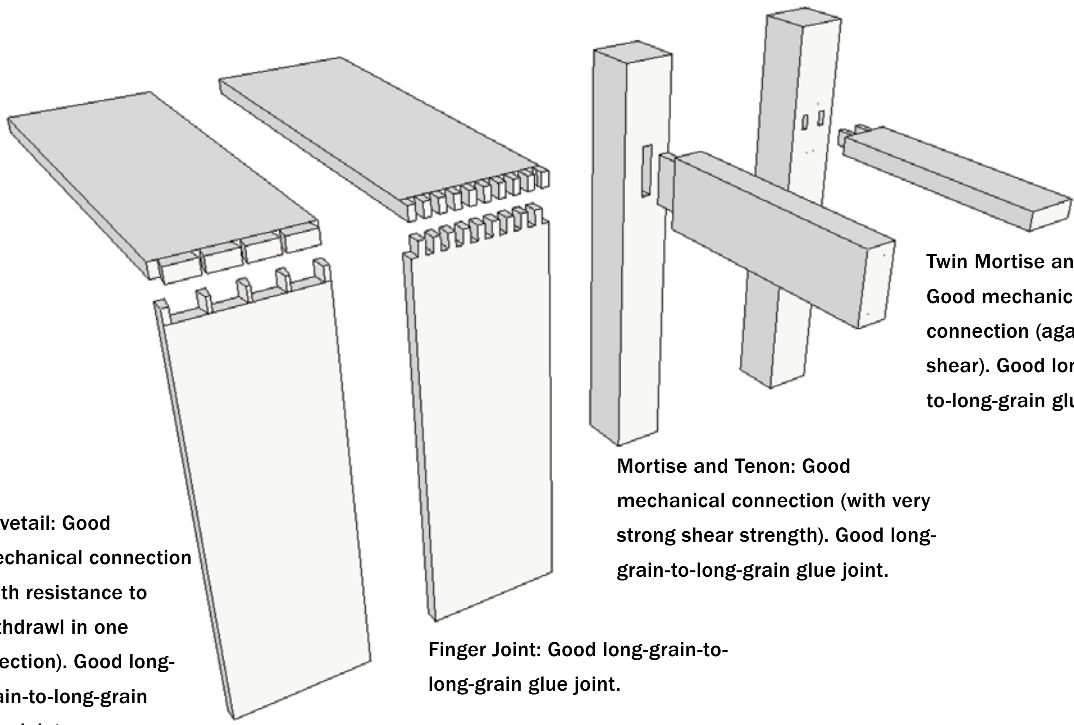
Examples of the Major Joints and How They Compare



Horizontal Mortise and Tenon (in leg): Mechanical connection (against shear), with moderate long-grain-to-long-grain surface.

Through-wedged Mortise-and-Tenon Joint: Mechanical connection (against shear and withdrawl), especially if the mortise is wider on the outside. Good long-grain-to-long-grain glue surface.

Dowel Joint: Mechanical connection (against shear), with minimal long-grain-to-long-grain glue surface.



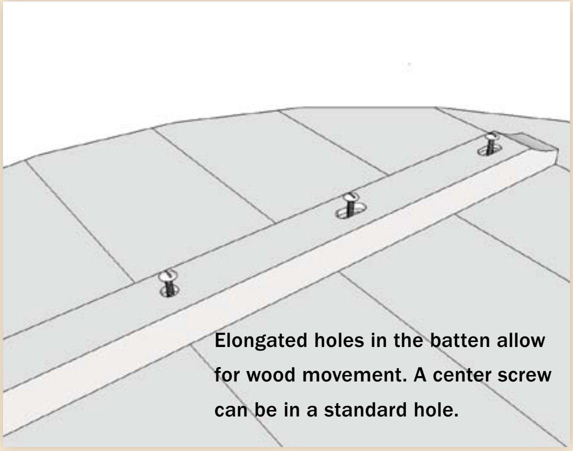
Twin Mortise and Tenon: Good mechanical connection (against shear). Good long-grain-to-long-grain glue joint.

Mortise and Tenon: Good mechanical connection (with very strong shear strength). Good long-grain-to-long-grain glue joint.

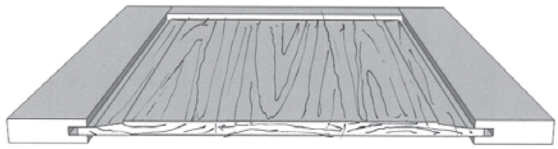
Dovetail: Good mechanical connection (with resistance to withdrawl in one direction). Good long-grain-to-long-grain glue joint.

Finger Joint: Good long-grain-to-long-grain glue joint.

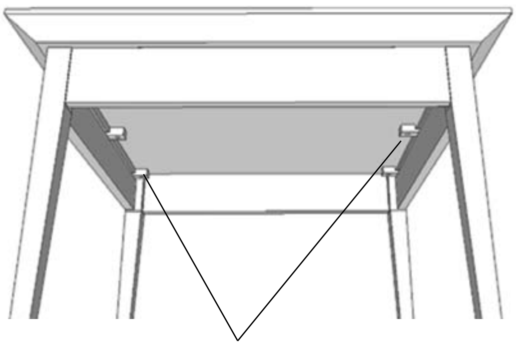
Designs That Have Evolved to Deal With Wood Movement



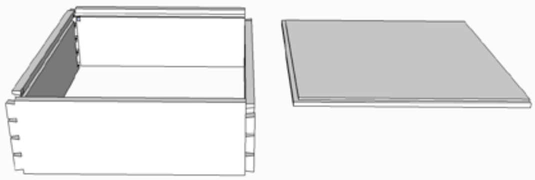
Elongated holes in the batten allow for wood movement. A center screw can be in a standard hole.



The panel has room to expand and contract in the grooves of the frame. Do not glue the panel in place; it must be free to move. It can be fixed with glue or a pin in the center, however.



L-shaped table buttons secure the top to the base. The tongues on the table buttons fit into grooves in the aprons on both ends of the table. Screws secure the buttons to the underside of the top, but still allow the top to expand and contract.



The back of the drawer is narrower than the front and sides. The drawer bottom can expand out the back if necessary.

3. Minimize the effects of wood movement
4. Avoid short grain

(See “Designs That Have Evolved...,” p. 26)

It even pays to remember these principles when using fasteners such as nails and screws with wood. These provide their own mechanical fastening, but all of the other principles still apply.

Just what happens when you hammer a nail into a board depends on the shape of the nail, how that shape relates to the fiber direction in the board and even where on the board you place the nail. For the most part, the tip of the nail either slices through or wedges apart fibers, then bends them over and compresses them to make room for the nail as it pushes into the wood.

Nail two boards together with the grain at right angles, using more than a single nail, and you should certainly be aware of cross-grain wood movement issues. Nails may accommodate some wood movement by compressing nearby fibers and pulling out a little bit, but they will also loosen up over time as a result of this accommodation.

Screws are probably a little better at holding boards together, but only if you're screwing into the fibers from the side. They will also be less accommodating of wood movement, because although they may compress adjacent fibers, they won't easily pull out of a piece that is trying to move. The best approach to allow cross-grain movement when screwing boards together is to create elongated pilot holes in the board that takes the heads of the screws. (See illustrations above)

But just because screws are less likely to pull out doesn't mean that they won't loosen up over time. Screws (and nails) don't change from season to season, but the wood, of course, does. When the wood expands in wetter months, the fibers will want to swell up. Because the fasteners don't accommodate that, the wood (between threads in particular) will have to compress. When the wood shrinks back, fasteners will loosen up due to both shrinkage and compressed fibers.

Screwing down into end grain is a problem. That's because the screw threads actually cut the end grain fibers into very short sections. These short sections are then subject to the typical problems of short-grain wood; they can easily shear off. And that's exactly what they will do when the screw is either screwed down too tightly or is subject to force pulling it out. And because we normally use screws with the intention of resisting that very force, screwing into end grain is not recommended. There is a work-around solution: Drill a hole for a dowel through the face of board you would like to screw into from the end; insert the dowel and then screw from the end of the board into the dowel. (Fig. 1-14)

Either fastener is capable of splitting a board if applied close to the end of a board. Beyond the fastener is "short grain," which is more likely to split apart than to compress to make room for the nail.

Coping With Wood-movement Issues

The best way to deal with wood movement is to start thinking about it right from the start. This process often begins before you even get to the lumberyard. You should look carefully at the plans (or your design) for the project and decide what wood grain will work best for each part – visually and structurally. Make up a cutlist with notes on ideal wood choices, so when you start to pick through boards you'll have a very clear idea of exactly what you need, and where each board is going to go in your project.

What should you look for? It's always better to avoid wood with the highest potential for problems. Check the end grain for significant growth-ring curvature and the rest of the board for unruly grain. Your goal should be boards with relatively straight, even grain (unless you're after a highly figured board for visual reasons). Check every board by sighting down the edge to see if it is straight. Sometimes you can get away with a board with some overall bow if you plan to cut the board up into short pieces. Do you want a specific grain orientation for certain parts? Make sure to mentally cut up your boards (or make a quick sketch to diagram your intentions) to see if you can get the desired pieces. As you become more experienced at this, you'll find it easier to see how to get what you want out of the wood. For example, the outer edges of wider boards can provide you with wood that is ideally suited for legs, because the end grain tends to run at about a 45° angle, and the four faces of the legs will then all have mostly straight, rift grain.

You should let your wood adjust to the basic climate it will experience when it is in place as a piece of furniture. If your shop is climate controlled, this can be as simple as stacking the wood up in your shop with thin strips of wood between the boards so that air can circulate freely around the boards (this is called stickering). (Fig. 1-15) If you work in a damp basement, outdoor shed or other space with conditions that are different than a typical home, it's better to let the wood acclimate somewhere in a controlled environment (unless the furniture is going into a damp basement). Leaving the wood for a week or two will give it some time to reach equilibrium with the surrounding air before you start to work on it, and will save headaches later.

As you begin to mill your lumber to size, you will often release some inherent stresses in the wood. Don't be surprised if there is some additional movement. Knowing that this will happen, you can plan to mill your wood a little bit oversized, let the wood sit for a couple of days to settle down, and then mill it again to final size. This "double milling" process is not something to do on every part of every project, but if there are critical parts (door frames or any other parts that you need to keep flat come to mind) you should definitely plan on it.

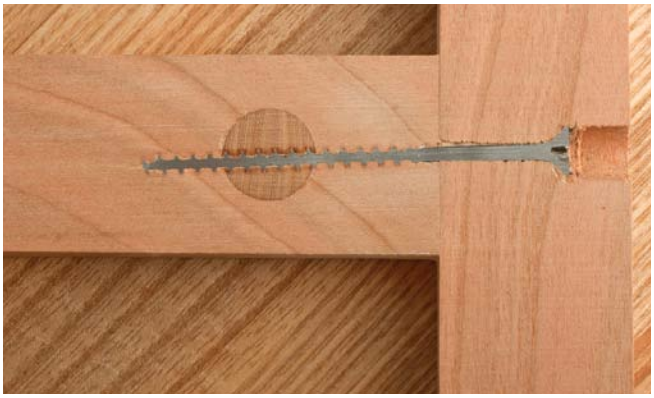


Fig. 1-14 - The dowel here in this cross-section greatly improves this screw joint by giving the screw long-grain fibers to grab.

Fig. 1-15 - Stickering a pile of wood allows air to flow evenly around all of the boards which allows for even moisture exchange.