



Rift-sawn boards move more than quartersawn boards but less than flat-sawn boards. Lumber is rift sawn when all the growth rings meet the face of the board at angles between 30 degrees and 60 degrees.

Flat-sawn boards are most susceptible to movement. Lumber is flat sawn when the growth rings meet the face of the board at angles less than 45 degrees.

Quartersawn boards move the least during the seasons, but there is more effort and waste in cutting them. Lumber is quartersawn when all the growth rings meet the face of the board at angles more than 45 degrees.

# The Way Wood Works

Everything you wanted to know about wood but didn't know what to ask.

**W**ood is a cantankerous substance; there's no two ways about it. Its virtues, of course, are legendary. It's attractive, abundant and easy to work. Pound for pound, it's stronger than steel. If properly finished and cared for it will last indefinitely. But none of that makes up for the fact that it's a complex and often perplexing building material.

Unlike metals and plastics, whose properties are fairly consistent, wood is wholly inconsistent. It expands and contracts in all directions, but not at the same rate. It's stronger in one direction than it is in another. Its appearance changes not only from species to species, but from log to log — sometimes board to board.

That being so, how can you possibly use this stuff to make a fine piece of furniture? Or a fine birdhouse, for that matter? To work wood — and have it work for you — you must understand three of its unique properties:

- Wood has grain.
- Wood moves more across the grain than along it.
- Wood has more strength along the grain than across it.

Sounds trite, I know. These are “everyone-knows-that” garden-variety facts. But there is more grist here for your woodworking mill than might first appear.

## Wood Has Grain

As a tree grows, most of the wood cells align themselves with the axis of the trunk, limb or root. These cells are composed of long thin bundles of fibers, about 100 times longer than they are wide. This is what gives wood its grain direction. Additionally, a tree grows in concentric layers, producing annual rings. You must pay close attention to these two characteristics — grain direction and annual rings — the way a sailor watches the wind. Ignore them, and they'll bite you big time.

Sawyers commonly use two methods to cut trees into boards, each revealing a different type of grain.

by Nick Engler

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*Nick Engler has been writing about woodworking for a quarter of a century, and is the author of more than 50 books on the subject. His workbench, which is made from hard rock maple and white oak, is rated to withstand a five-alarm tantrum.*

## ASTOUND YOUR FRIENDS

Want to predict exactly how much a given board will move in a year's time? Look up the specific movement rate for the wood species in the *Wood Handbook*. Then call the National Oceanic and Atmospheric Administration to find how much the relative humidity changes from summer to winter. Multiply the change in humidity (as a decimal) times the movement rate (another decimal) times the width of the board. Of course, this level of precision is completely unnecessary, but the chicks dig it.



- Plain-sawn boards are cut tangent to the annual rings. The sawyer “cuts around” the log, turning it for each series of cuts so the faces of the boards will show mostly flat grain (also called tangential or plain grain).

- Quartersawn boards are cut through the radius of the growth rings. The sawyer cuts the logs into quarters or bolts, and then saws each bolt so the boards show quarter grain (or radial grain) on their faces.

Lumber doesn't always show a single type of grain on its face. Plain-sawn boards in particular may show mixed grain — flat grain in one area and quarter grain in another. The grain between the two, where the surface is cut at a 30- to 60-degree angle to the annual rings, displays rift grain.

Each type of grain has a distinct pattern, depending on the wood species. You can use these grain patterns to enhance the design of your furniture or your birdhouses. More importantly, if you know how to “read” the patterns, you can predict which way the wood will move and how much.

### Wood Moves Across the Grain

Because of its unique structure, wood is constantly expanding and contracting. And you must cope with this movement in everything you build.

Wood moves as its moisture content changes. After the tree is felled and the sap has evaporated, the wood fibers continue to absorb and release water like a blotter. How much water they hold depends on the relative humidity of the surrounding environment. The more humid it is, the more moisture the fibers soak up. This moisture content is the ratio of water to wood. In extremely humid conditions,

## GLUE STEPS: AT LAST, A PRACTICAL SOLUTION TO AN AGE-OLD DILEMMA!

Want to see a practical application of this information? With what you now know about wood grain and movement you can solve a persistent problem that has dogged too many woodworkers for too long: glue steps. These are tiny changes in the surface level from one board to another at glue joints. They are especially unattractive in table tops where boards are joined edge to edge.

The common misconception is that these are caused by improper gluing technique. A talented and experienced craftsman once spent hours trying to convince me that glue steps are caused by the adhesive outgassing. (In my shops the adhesives are better behaved.) Despite his ardor, the glue steps are the result of uneven wood movement.

Sometimes a woodworker fails to shop-dry his lumber — let it rest in the shop long enough for all the boards to reach the same moisture content. When parts with dissimilar moisture contents are joined, the moister part moves more than the drier one. Or a craftsman glues flat grain to quarter grain, joining two surfaces that move at different rates, even when they have the same moisture content. In both cases a step results.

To avoid glue steps, shop-dry your lumber for a week or more before using it so the moisture content of the wood has a chance to reach an equilibrium with the relative humidity in your shop. When gluing boards edge to edge, always glue flat grain to flat grain and quarter grain to quarter grain.



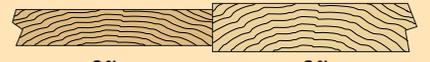
12%

10%

Moisture Content

Moisture Content

When two boards of uneven moisture content are formed edge to edge...



8%

8%

Moisture Content

Moisture Content

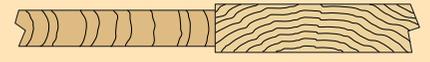
...the board with the higher moisture content shrinks more and a glue step develops.



Quartersawn

Flat-sawn

A similar thing happens when you joins boards with a different grain...



Quartersawn

Flat-sawn

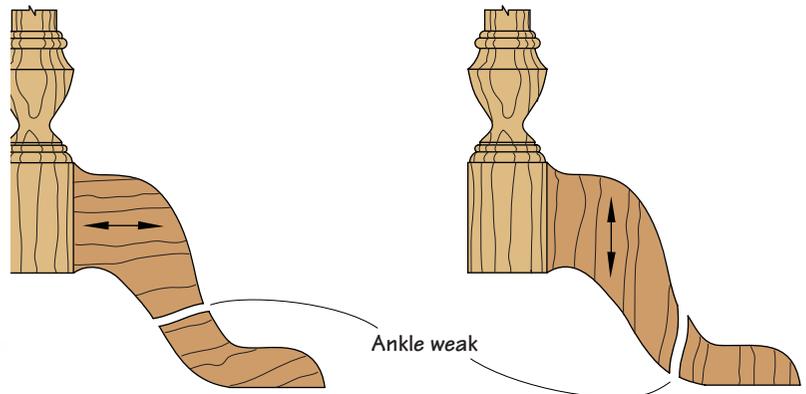
...The plain-sawn boards change thickness less than the quartersawn and a glue step appears.

as much as 28 percent of the total weight of a board may be water — 28 parts water, 72 parts wood. The rule of thumb is that the moisture content of wood changes 1 percent for every 4 to 5 percent change in the relative humidity.

The more moisture a board absorbs or releases, the more it swells or shrinks. However the surface of a board moves differently depending on the grain direction and type of grain. Wood movement along

the grain is almost negligible. From 0 to 28 percent moisture content, a typical board will move only 0.01 percent of its length. However it will move about 8 percent across flat grain and 4 percent across quarter grain. This is why woodworkers consider quartersawn lumber more stable. It's also why boards with mixed grain (and mixed expansion rates) tend to cup.

So how do you predict how much a board will move and in what direction?



Wrong

Wrong

The wood grain in the legs of this pedestal table runs parallel to the longest dimension, making the legs as strong as possible. Were the grain to run parallel or perpendicular to the pedestal, the legs would be weakest at their narrowest point, the ankles.

## WOOD PROPERTIES

This chart shows some important properties for 18 common species of wood. Specific gravity is the ratio of the mass or weight of the wood to that of an equal amount of water. Tangential and radial movement are given as a percentage (%) of a board's measurement across the grain as it dries. To find compressive strength, engineers load a block parallel to the grain until it breaks. They find bending strength by loading a block perpendicular to the grain. Both are measured in pounds per square inch (psi). Stiffness is determined by applying a load perpendicular to a beam until it deflects a certain distance. This is measured millions of pounds per square inch (Mpsi). For hardness, a metal ball is driven halfway into a wood surface. The force required to do this is recorded in pounds (lbs).

Wood Species	Specific Gravity	Tangential Movement (%)	Radial Movement (%)	Compressive Strength (psi)	Bending Strength (psi)	Stiffness (Mpsi)	Hardness (lbs)
Alder, Red	0.41	7.3	4.4	5,820	9,800	1.38	590
Ash	0.60	7.8	4.9	7,410	15,000	1.74	1,320
Basswood	0.37	9.3	6.7	4,730	8,700	1.46	410
Birch, Yellow	0.62	8.1	3.6	8,170	16,600	2.01	1,260
Cedar, Red	0.32	5.0	2.4	4,560	7,500	1.11	350
Cherry	0.50	7.1	3.7	7,110	12,300	1.49	950
Fir, Douglas	0.49	7.3	4.5	7,230	12,400	1.95	710
Mahog, Honduras	0.45	4.1	3.0	6,780	11,500	1.50	800
Maple, Hard	0.63	9.9	4.8	7,830	15,800	1.83	1,450
Oak, Red	0.63	8.9	4.2	6,760	14,300	1.82	1,290
Oak, White	0.68	10.5	5.6	7,440	15,200	1.78	1,360
Pine, White	0.35	7.4	4.1	4,800	8,600	1.24	380
Pine, Yellow	0.59	6.1	2.1	8,470	14,500	1.98	870
Poplar	0.42	8.2	4.6	5,540	10,100	1.58	540
Redwood	0.35	4.9	2.2	5,220	7,900	1.10	420
Spruce, Sitka	0.40	7.5	4.3	5,610	10,200	1.57	510
Teak	0.55	5.8	2.5	8,410	14,600	1.55	1,000
Walnut	0.55	7.8	5.5	7,580	14,600	1.68	1,010

That depends on the grain direction, type of grain and time of year. In most areas, the relative humidity climbs as the weather turns warmer. This causes the wood to expand. The rule is to allow for 1/4" of movement across 12" of plain grain and 1/8" across the same amount of quarter grain. If you're working in the summer, the wood shrinks as winter approaches. When building in the winter, count on the wood expanding when summer comes. (Thus the old saw, "Work tight in summer, loose in winter.")

### Wood is Strong Along the Grain

The wood cells are made from long, tough cellulose fibers, bound together by a glue-like substance, lignin. The cellulose is a lot tougher than the lignin. Consequently, it's much easier to split a board along the grain (separating the lignin) than it is to break it across the grain (snapping the cellulose).

This botanical trivia plays an enormous role in woodworking design. Can you imagine what might happen if you cut mortise-and-tenon joints in which the grain ran across the tenons? They'd snap if you just looked at them sideways. Yet tenons cut parallel to the grain will far outlast the woodworkers who cut them.

But wait there's more — when strength is paramount, grain direction may not be

your only consideration. Some species of woods are naturally stronger than others. Windsor chairmakers, for example, typically use hard maple, birch and hickory for legs, rungs and spindles. Because these parts are fairly slender, weaker woods won't do.

A good indicator of a wood's strength is its density — the weight of a given volume of substance. Wood density is measured by calculating its specific gravity — the weight of a volume of wood compared to the same volume of water. Generally, the higher the ratio, the denser — and stronger — the wood.

Specific gravity, unfortunately, doesn't predict when a wooden board will break, sag or dent. For this, there are measurements of strength.

- Compressive strength tells you how much load a wood species will support parallel to the grain. If a corpulent relative sits in the chair, will the legs buckle?

- Bending strength shows the load wood can withstand perpendicular to the grain. How many kids can stand on that chair rung before it's firewood?

- The stiffness indicates how much the wood will deflect when loaded perpendicular to the grain. How far will those shelves sag when you display your col-

## GOTTA HAVE IT

All this information is in the **Wood Handbook: Wood As An Engineering Material**. This woodworking classic was written by the Forest Products Laboratory, an arm of the U.S. Department of Agriculture. Much of it reads like an income tax form, but you won't find a more complete reference. Write the Government Printing Office, Superintendent of Documents, Washington, DC 20402-9325.

lection of cannonballs?

- The hardness reveals how resistant the surface is to abuse. How hard can you pound when taking your frustrations out on the workbench?

### A Parting Thought

Too often we approach our craft as if it were a collection of recipes. Take two boards, chop them up on a table saw, add a dash of glue and — presto! — a birdhouse. Or a Chippendale highboy, depending on how many boards and how finely you chop. But woodworking is more than knowing how to use a tool or follow a plan. It's the accumulated insights and inspirations of 5,000 years of craftsmanship. And at the heart of this craft is a surprising material that has yet to reveal all of its mysteries. **PW**