THE WAY WOOD WORKS

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

By Nick Engler

Wood is a cantankerous substance; there's no two ways about it. It's 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.

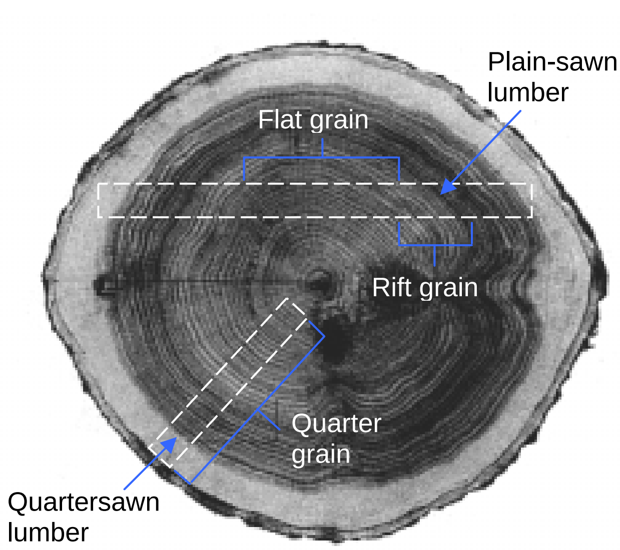
That being so, how can you possibly use this stuff to make a fine piece of furniture? Or a fine birdhouse, for that matter? To work wood — and have it work for you — you must understand three unique properties of wood that affect everything you make:

- 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.

- *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

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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 more across the grain that along it

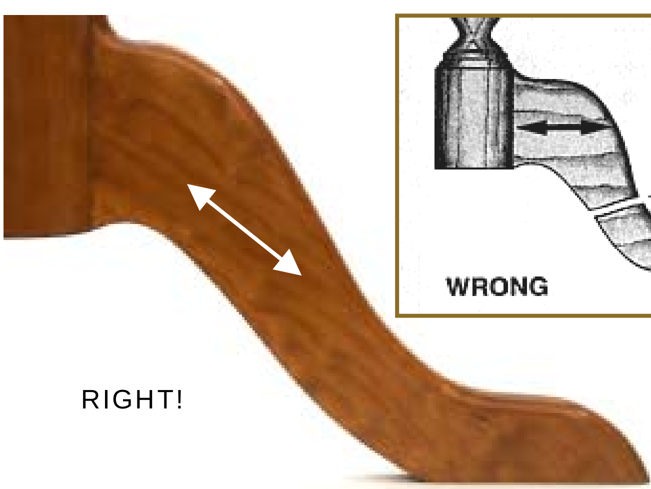
Because of its unique structure, wood is constantly expanding and contracting. And you must cope with this movement in everything you build.

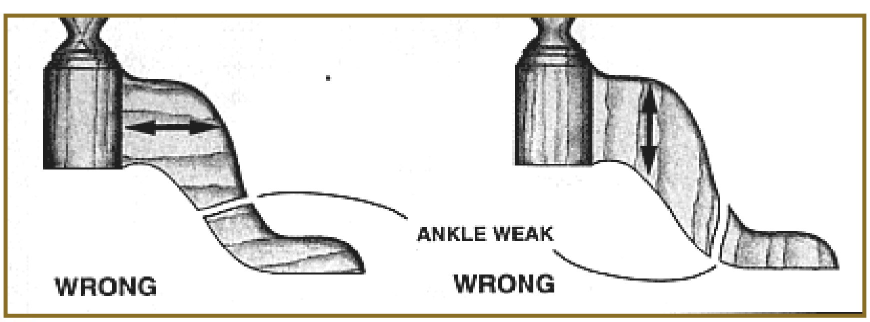
Wood moves as its *moisture content* changes. After the tree is felled and the sap has evaporated, the wood fibers continue to absorb and release water like a blotter. How much water they hold depends on the *relative humidity* of the surrounding environment. The more humid it is, the more moisture the fibers soak up. This moisture content is the ratio of water to wood. In extremely humid conditions, as much as 28 per cent of the total weight of a board may be water – 28 parts water, 72 parts wood. (The moisture content of a board never climbs above 28 per cent. If it did, you'd be able to buy lumber in gallon jugs.) The rule of thumb is that the moisture content of wood changes 1 per cent for every 4 to 5 per cent 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 per cent across flat grain and 4 per cent across quarter grain. This is why woodworkers consider quartersawn lumber more "stable" that plain sawn. It's also why boards with mixed grain (and mixed expansion rates) tend to cup as they move.

You heard wrong *Advertisements for popular finishing products create the impression that a finish seals the wood, preventing it from absorbing moisture and putting a stop to wood movement. As much as I wish it were true, this just isn't. Wood finishes are* semi-permeable. *They permit moisture to pass through, but slowly. The wood still moves as much as it ever did, but at a reduced rate.*

So how do you predict how much a board will move and it what direction? 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 inch of movement across 12 inches of plain grain and 1/8 inch across the same amount of quarter grain. If you're working in the summer, the





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 weak at their narrowest point, the ankles.

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.”) And if you’re working in southern California, the whole question is hypothetical because the relative humidity never changes.

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 in your area 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.*

Wood has more strength along the grain than across it

The wood cells are made for 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 fibers).

This botanical trivia plays an enormous role in wood working 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 out last the woodworkers who cut them, as Egyptian archeology proves.

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 a 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

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 “out-gassing.” (In my shop, the adhesives are better behaved.) Despite his ardor, 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 reaches 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.

When two boards of uneven moisture content are joined edge to edge…

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

A similar thing happens when you join boards with a different grain

The plain-sawn board changes thickness less than the quartersawn, and a glue step appears.

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

- *Compressive strength* tells you how much load a wood species will support parallel to the grain. If an especially corpulent friend or relative sits on that chair, will the legs buckle?
- *Bending strength* (also called *modulus of rupture*) 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* or *modulus of elasticity* indicates how much the wood will deflect when loaded perpendicular to the grain. How far will those shelves sag if your client uses them to display his collection of antique cannonballs?
- The *hardness* reveals how resistant the surface is to abuse. How hard can you pound when taking your frustrations out on your workbench?

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 US 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.*

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 5000 years of craftsmanship. And at the heart of this craft is a surprising material that has yet to reveal all of its mysteries.

Wood Properties

This chart shows some important properties for 18 common species of wood. Tangential and radial movements are given as a percentage (%) of a board's measurement across the grain as it dries. To find compressive strength, engineers load a block of wood 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, and is measured in 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	12,40	1.95	710
Mahogany, 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