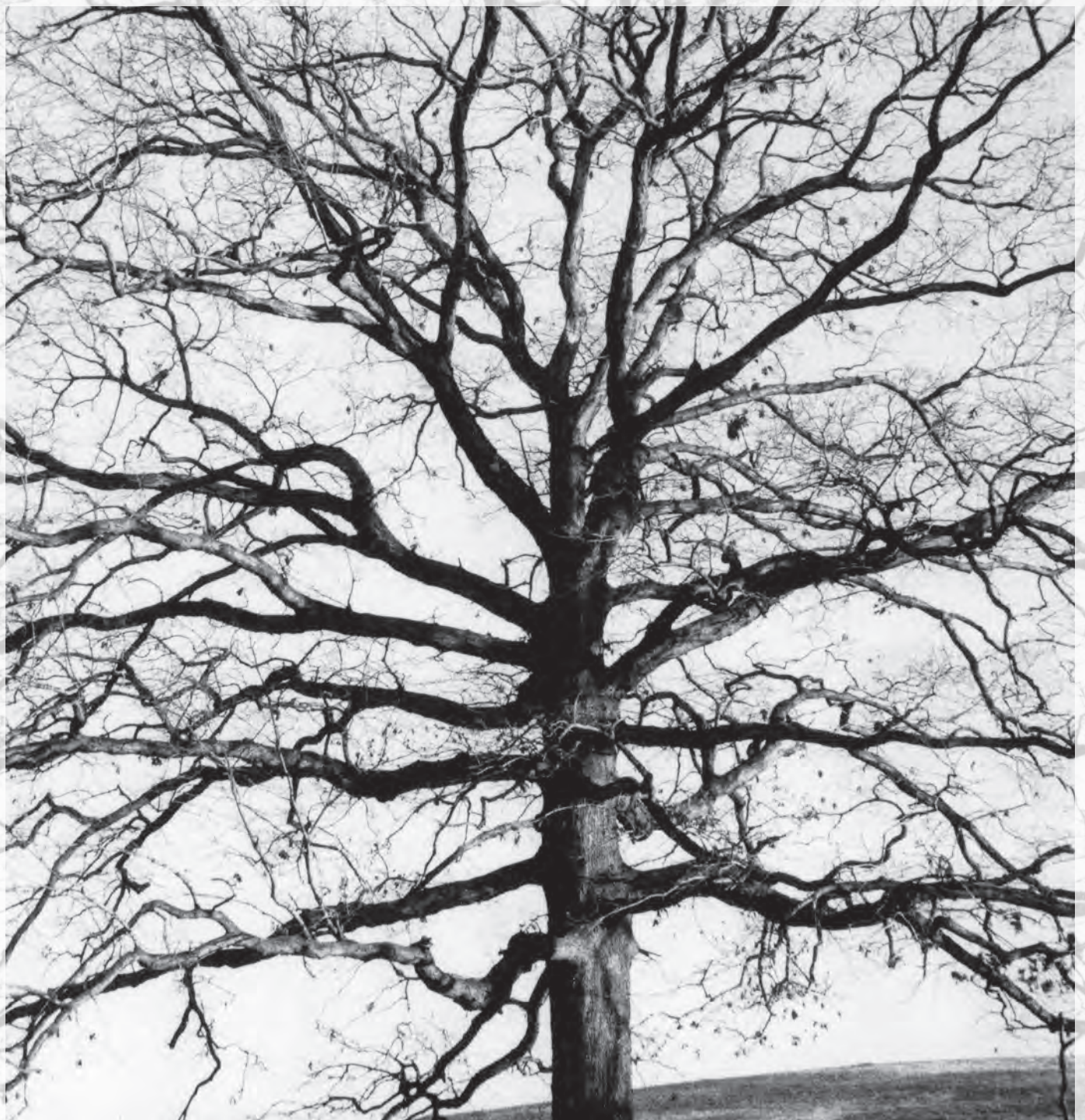


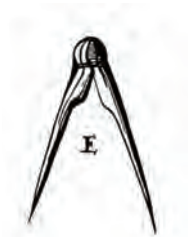
WITH THE GRAIN



WITH THE GRAIN

A Craftsman's Guide to
Understanding Wood

CHRISTIAN BECKSVOORT



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This book is written in memory of Max Cook of Luray, Va.



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PREFACE

The key to working harmoniously with wood is understanding. Understanding comes from years of experience and familiarity with a few species.

This book is intended for the woodworker and cabinet maker. The first four chapters deal with subjects not often covered in woodworking texts. They serve as an introduction to wood structure, tree identification, woodlot management, harvesting and drying of wood.

The final chapter more closely examines solid wood construction. Not specific joints or design, but rather ways of dealing with the movement of wood through the seasons. Shrinkage and expansion are inevitable and must be taken into account when planning, gluing, cutting joints and assembling the finished piece. Because there are usually several ways of achieving the same end, the actual construction process, the method, is subjective and drawn not only from my decades of building, but also from the Shaker pieces I was privileged to restore and learn from, and from the time-tested methods of traditional joinery.

The difference between an antique and landfill fodder is that antiques were built to last, following sound rules of wood technology and joinery. The worth of a finished object is not necessarily in the wood used, but how well and intelligently it is used. Wood is becoming too precious a material to be wasted through incompetence.

My thanks to all those who directly or indirectly helped with this project.

CHAPTER I

TREES AND WOOD STRUCTURE

Trees have always held a fascination. These, the largest organisms on the planet, are symbols of strength, hope and renewal. They combine graceful beauty and utility, providing mankind with sustenance and warmth that is both physical and psychological. More than the basic necessities of life, trees provide us with a link to the natural world. In no way is this natural mystique better personified than in the wood itself, in the infinite combinations of color and grain. This variety, so pleasing to the eye, is all the more appreciated in today's world of plastic and electronics. Yet the average person has less knowledge of the characteristics of solid wood than our less educated ancestors.

WOOD ANATOMY

A basic knowledge of wood anatomy and structure is vital to anyone seriously working with wood. A familiarity with the cellular structure of the tree leads to a better understanding of wood properties and behavior. What causes color, taste and odor, and how does it affect the wood's intended use? What is the difference between density and specific gravity, and how does this relate to the weight and hardness of wood? What are the causes of some of the more common defects, and how can one avoid them, or work with them? An in-depth understanding leads to a more intelligent use of this versatile material.

ROOTS

The root system serves four major functions: absorption, conduction, storage and anchorage. Roots absorb water and inorganic salts. Water is vital for respiration and photosynthesis, and is also an essential element of protoplasm. It is used in the transportation of raw materials including oxygen and carbon dioxide. Water is taken in directly through the root hairs, the smallest, yet most active portion of the root system. Because inorganic salts can be absorbed only when in solution, water is necessary for this function as well. Once inside the roots, the solution can be transported to the rest of the tree as needed.

Roots also act as storage areas. Excess sugar manufactured in the leaves is stored in the roots (and sapwood) over the winter, until needed for growth and leaf development the following spring.

Roots are well adapted to holding the tree in place. The root hairs, rootlets and branch roots form a network that firmly grips rocks and soil particles. A few roots are programmed by hormones to grow more or less straight down (positive geotropism), whereas most roots grow away from the vertical (plagiotropism). Small roots will grow into rock crevices and exert tremendous pressure, eventually splitting the rock apart.

Trees have a large (invisible to the eye), fibrous root system, the majority of which is in the top 2-3 feet (.6-.9 m) of soil. The root system extends well beyond the edges of the branches of the tree.

Visualize a tree like a champagne flute: canopy on top, long trunk and a very wide, relatively flat base, corresponding to the roots. The combined length of the roots often reaches hundreds of miles, a much larger network than the branches. In some cases, roots can act as regenerative organs. Black locust and beech, for example, will sprout from root buds to form suckers around the trunk.

A few trees, such as walnut, hickories, oaks and some conifers, have a large central taproot (or sinker) when grown in deep, fertile and sandy soil. Nonetheless, they still have the horizontal fibrous root system to absorb moisture and nutrients.

From a woodworker's utilitarian point of view, the value of roots as a material is limited. Very little research has been done on root properties and potential uses. Occasionally, the root ball just below the trunk can be salvaged and used for sculpting, carving or even veneer. Root burls of the *Erica* species are fashioned into pipe briars, and some root cross-sections can be used as inlays. Wooden boat builders often use the root knees (also known as crook, or compass timbers) of tamarack and spruce as angular braces or supports.

BRANCHES

Although twigs and branches account for roughly 10 percent to 20 percent of a tree's total volume, they are usually the first noticed, and appear to be most important. From a tree's point of view, however, they are merely a superstructure for holding leaves. Branches expose leaves as evenly as possible to all available sunlight. Each species has a distinct pattern and spacing.

Twigs are extremely useful in tree identification. They can be very slender as in cherry or maple, or thick and stubby as in ash and walnut. Bud shapes can also be used in identification. The location of the buds determines the location of the new twigs. Therefore, buds opposite each other grow into opposite twigs, as in ash and maple trees, while alternate buds will form alternate twigs and leaves, as in beech, birch and oaks. Occasionally, buds will be whorled, growing in groups of three, like catalpa.

Vertical growth that gives trees and branches height and length originates from the leader buds at the end of twigs. The area of growth inside the leader bud is called the apical meristem.

Twigs and branches form knots in the wood. Starting as a bud on the young trunk, the new

twig grows laterally. As the tree grows, new wood is formed around the trunk and around the branch, one layer or ring each year. Thus, the branch becomes an integral part of the wood. When that portion of the trunk is cut into boards, the branch appears as a tight knot. On the other hand, if the branch is killed, either by insects, shade or pruning, the trunk will continue to grow around the branch, while the dead stub remains the same size. Eventually wood grows completely around and over the dead branch. A dead knot in a board is loose and black in color. Branch stubs will often decay before they are completely covered by new growth. When these decayed black knots appear in boards, they usually fall out, leaving a hole or slash. Because black and red knots are often present in the same board, and because knots are usually denser than the surrounding wood and have grain that runs contrary to the grain of the board, they are considered defects by all lumber-grading systems.

On the whole, branches, like roots, are of no great value to the woodworker. Because branches seldom grow perfectly upright, they consist mainly of reaction wood, which shrinks and warps excessively. This makes the wood less than ideal for most work, although branch wood is sometimes used for carving, turning, plaques and other small objects. Boat builders often use branch wood for structural knees or braces. In hardwoods such as oak, apple, ash and elm, the crooks are cut from the underside of the branch/trunk intersection to avoid tension wood on the upper side while conifer crooks are cut from the upper side, to avoid the compression wood on the underside. Unless branches are the only source of wood available, the effort of cutting, sawing and drying is rarely worth the resulting product. For firewood, however, branches contain the same number of British thermal units (BTUs) as the rest of the trunk, and often do not even need to be split.

LEAVES

Leaves and needles are the food-manufacturing organs of the tree. Leaf cells contain chloroplasts, which in turn contain chlorophyll. Plants are the only living organisms that can convert sunlight into sugar. Carbon dioxide is absorbed through openings in the undersides (and in some cases the upper side as well) of the leaves. Water from the roots is transported to the leaves and is converted

with carbon dioxide in the chloroplasts. In the presence of sunlight, this reaction produces sugar and oxygen. By means of this simple yet vital process, green plants absorb carbon dioxide, restore oxygen to the atmosphere, feed themselves and in turn feed all other forms of life.

With the approach of autumn, as the amount of daylight shortens, an abscission layer forms at the base of the leaves. This is where the leaf separates from the twig. At the same time, chlorophyll is no longer being produced, possibly because the abscission layer cuts off nutrients to the leaves. As the chlorophyll begins to break down, the leaves turn yellow, red and orange as a result of xanthophylls and carotenes present in the leaves that were previously masked by the chlorophyll. When all nutrients to the leaves are cut off, the abscission layer separates and the leaves fall. A leaf scar appears just below the bud formed during the summer. That bud becomes next year's leaf.

WOOD STRUCTURE

Wood, or xylem, is the cellular material that makes up the bulk of the tree. It consists mainly of dead, hollow cells. Chemically, wood is composed of 40-50 percent cellulose, 20-35 percent hemicellulose, and 15-30 percent lignin. Cellulose is a very long, complex molecular chain, which, when broken down, yields the simple sugar glucose. Hemicellulose, closely associated with cellulose, is composed of shorter molecular chains of several types of sugar. Lignin is an intercellular material that bonds the wood fibers together. Aside from these three major components, various extractives are also present in the wood. Although not part of the wood structure, the extractives are usually found mostly in the cell walls, and contribute to the wood's characteristic color, odor, taste, decay resistance and flammability. These secondary ingredients include oils, tannins, waxes, gums, starches, alkaloids, color materials and about 1-2 percent ash-forming minerals such as calcium and silica.

Figure 1-1 shows a typical cross section of a hardwood stem. (A) is the cambium layer, only a few cell layers thick, which produces the bark (phloem) toward the outside of the tree, and wood (xylem) toward the inside of the tree. Cambium extends in a continuous layer between the wood and bark, and gives rise to the tree's lateral growth. In the temperate zones, during the course of one

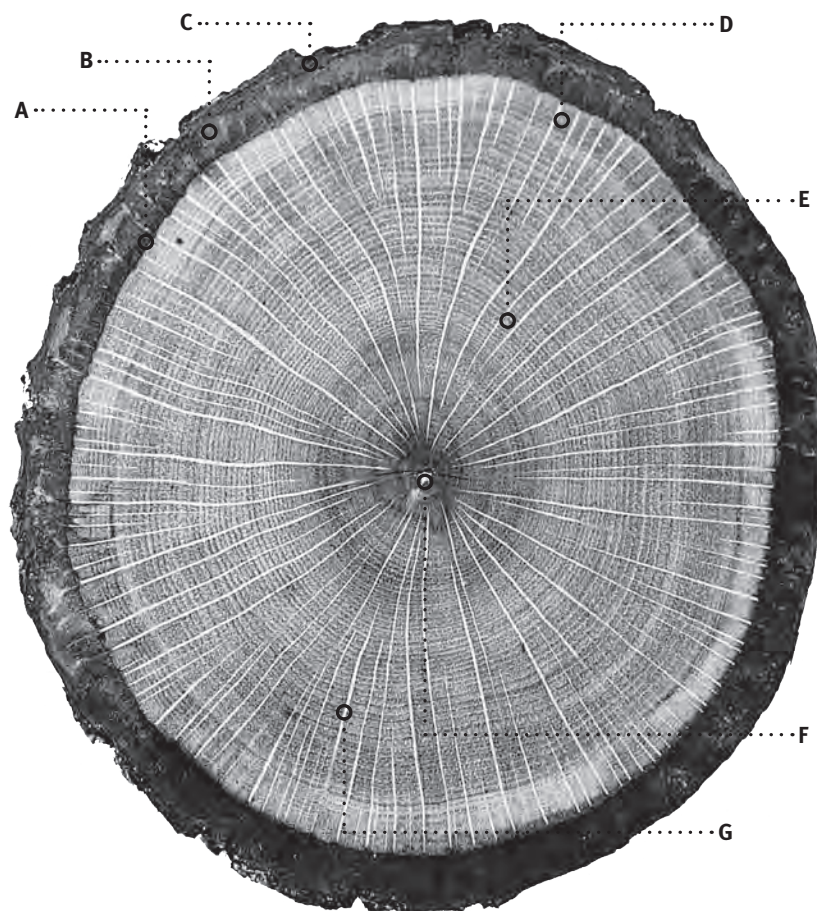


Fig 1-1. Oak trunk in cross section: (A) cambium, (B) inner bark, (C) outer bark, (D) sapwood, (E) heartwood, (F) pith, (G) rays.

growing season, one new ring of wood is added to the trunk, roots and branches. Wood formed the previous year does not continue to grow. The width of the growth rings is not necessarily consistent in size, even within a species. Ash, for example, when grown in an area of little rainfall and poor soil, may have up to 40 rings per inch (2.5 cm), slow growth, while the same species grown in an area of abundant moisture and nutrients may have only 4 or 5 rings per inch, or fast growth. Slow versus fast growth also depends on competition from neighboring trees. (B) is the newly formed inner bark, a soft, fibrous material that carries food down from the leaves to all parts of the tree. During the growing season, the cambium layer and the inner bark are very soft and fragile. This means that logs cut during the spring and summer will have easily peeled bark, whereas those cut during the late fall and winter will usually retain their bark. (C) is the dead, corky, outer bark. As the diameter of the tree increases year by year, the bark becomes thicker and begins to crack. With age it usually becomes quite

NUMBER OF ANNUAL RINGS IN THE SAPWOOD OF COMMON HARDWOODS

Catalpa	<i>Catalpa speciosa</i>	1-2
Black locust	<i>Robinia pseudoacacia</i>	2-3
Chestnut	<i>Castanea dentata</i>	3-4
Butternut	<i>Juglans cinerea</i>	5-6
Osage orange	<i>Maclura pomifera</i>	5-10
Sassafras	<i>Sassafras albidum</i>	7-8
Black cherry	<i>Prunus serotina</i>	10-12
Black walnut	<i>Juglans nigra</i>	10-20
Apple	<i>Malus pumila</i>	12-30
Beech	<i>Fagus grandifolia</i>	20-30
Sugar maple	<i>Acer saccharum</i>	30-40
Dogwood	<i>Cornus florida</i>	30-40
Basswood	<i>Tilia americana</i>	55-65
Sweet birch	<i>Betula lenta</i>	60-80
Sweet gum	<i>Liquidambar styraciflua</i>	65-75
Persimmon	<i>Diospyros virginiana</i>	100+

SOURCE: Charles Sprague Sargent, *Manual of the Trees of North America*.

Fig. 1-2.



Fig. 1-3. Pith in black walnut.

thick and furrowed (except in trees like beech and birch), and begins to slough off from the action of wind and weather.

The newly formed wood is the sapwood (D). It constitutes from one or two to more than 200 years growth (in some conifers), depending on the species (Fig. 1-2). Sapwood functions primarily to conduct water and minerals from the roots to the leaves. Most of the newly formed cells die in a short time. A few, the parenchyma cells, retain their protoplasm in the cell cavity and act as living food-storage cells. After a number of years, the sapwood loses its function and turns to heartwood (Fig. 1-1 E). The last of the parenchyma cells die, leaving only the cell walls that give the tree structural support. Extractives are deposited in the heartwood cells, giving the wood its distinctive color and other properties. Sapwood, having no extractives (some of which are toxic to fungi), is not as decay-resistant as heartwood, and should not be used under conditions conducive to decay. The extractives present in the heartwood of some

species add to the mass of the cells, and increase the density of the wood somewhat.

The pith is located in the center of the tree (Fig. 1-1 F). This is a soft, sometimes spongy material formed behind the apical meristem. In most species it is only slightly visible as a darker tube. In some trees such as black walnut (Fig. 1-3), butternut and sumac, the pith is quite pronounced. Surrounding the pith is an indistinct area known as juvenile, or pith wood, characterized by wide growth rings (especially in conifers), low density and strength, and greater longitudinal shrinkage.

Radiating from the pith outward are the rays (Fig. 1-1 G). They extend to the cambium and are used in lateral transport of nutrients through the sapwood. Rays tend to bind the wood, thereby reducing the radial dimensional change.

Trees grown in temperate climates have a cycle of growth and dormancy that results in the appearance of annual rings. Typically, each spring as growth resumes, the cambial layer produces an abundance of large, thin-walled cells. Spring is a time of mild temperatures, maximum daylight and ample rainfall. Consequently, cell growth is quick and profuse. This initial growth is known as early-wood, or spring-wood. As the season progresses and day length decreases, the weather gets hotter and drier and growth slows. Cell formations become smaller and thicker-walled. These are the late-wood cells. Finally, during autumn growth stops for the season. Because the late-wood cells have thicker walls that portion of the growth ring is more dense. This is most apparent in old, weathered wood, which takes on a ridged appearance as the early-wood erodes faster than the dense late-wood.

Some tropical woods have no apparent growth rings. In areas where the weather is constant year-round, growth continues uninterrupted.

CLASSIFICATION OF TREES

Botanically, trees are divided into two classes: gymnosperms and angiosperms. Commercially, woods are divided into softwoods and hardwoods, softwoods referring to the gymnosperms and hardwoods referring to the angiosperms. These terms should not be taken literally, because not all softwoods are soft (yellow pine is about as hard as black walnut), nor are all hardwoods hard (basswood, and cottonwood are quite soft). Because

these terms will continue to be used in the trade, the knowledgeable woodworker should recognize that they are used merely to distinguish the two groups, not define them.

Gymnosperms, characterized by exposed seeds, are the older of the two groups, and include all the conifers and even ginkgo (commonly thought of as a hardwood because of its broad, deciduous leaves). Conifers are characterized by their single, straight trunk and needle-shaped leaves, which are retained all year (except for cypresses and larches). Needles, usually smaller than leaves, have a wax-like coating that prevents water loss during long periods of dormancy. Thus adapted, the conifers are the dominant trees in the northern forest.

Coniferous wood is fairly simple (primitive) in structure. It is composed predominantly (roughly 90 percent) of all-purpose tracheid cells, which are long, thin and hollow. Although the cells are closed at both ends, liquids pass from one cell to the next through “pits” in the cell walls. Conifers also contain medullary rays. Some of the conifers also contain resin canals, which are large (visible), tubular passages that exude resin, or pitch. These canals occur in the species of pine (*Pinus*), larch (*Larix*), spruce (*Picea*) and Douglas fir (*Pseudotsuga*). Conifers lack specialized vessels or pores. The entire group is classified as having nonporous wood.

On a cellular level, the angiosperms are more specialized than the gymnosperms. They contain more ray cells (from 6 percent to 31 percent by volume), and only about 25 percent of the wood consists of fibers. These, like the tracheids in conifers, are long, thin cells with thick walls that give the tree support. From 6 percent to 55 percent of the wood is composed of vessels, or tubular open-ended cells. They have thin walls and large diameters, specifically made for the conduction of sap. When the vessels are exposed by cutting, they are called pores. Wood with large vessels such as oak, ash or chestnut are said to be open-pored, or open-grained. When exposed on any surface, these vessels are readily visible by eye or with a hand lens, and can be felt by a fingernail across what appears to be a smooth surface. Because vessel sizes vary widely among species, designation such as open- or close-grain are relative. What is more important is the arrangement of the vessels in the growth rings.

When large vessels (pores) are formed primarily in the early-wood, the wood is called

ring-porous. The vessels form a distinct band in the early-wood (Fig. 1-4). Vessels, although present in the late-wood, are much smaller and fewer. Ring-porous woods include ash, hickory, oaks, chestnut, elm, sassafras and locust.

At the other extreme are the woods that are diffuse porous (Fig. 1-5), those with pores scattered evenly throughout the year's growth. The pores are all about equal in size, so the early-wood and late-wood are therefore indistinct. Maple, birch, dogwood, beech, holly, poplar, magnolia, hornbeam, sycamore, willow and basswood are all diffuse-porous.

Between these two distinct groups are the semi-ring porous (or semi-diffuse porous) woods (Fig. 1-6). The main characteristic of these woods is a gradual change from large vessels in the early-wood to smaller vessels in the late-wood. Species that have semi-ring porous wood include catalpa, persimmon and plum. Certain species of hickory, walnut, oak and willow are sometimes included in this group.

Fig. 1-4. Ring-porous wood cross section, white ash (25x).

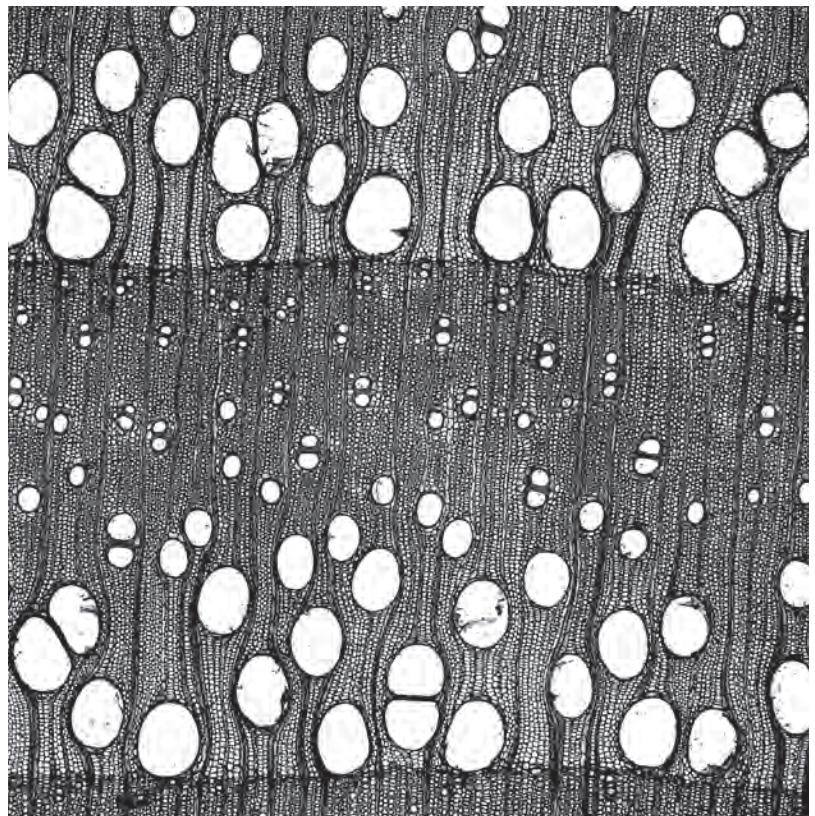


Fig. 1-5. Diffuse-porous wood cross section, birch (25x).

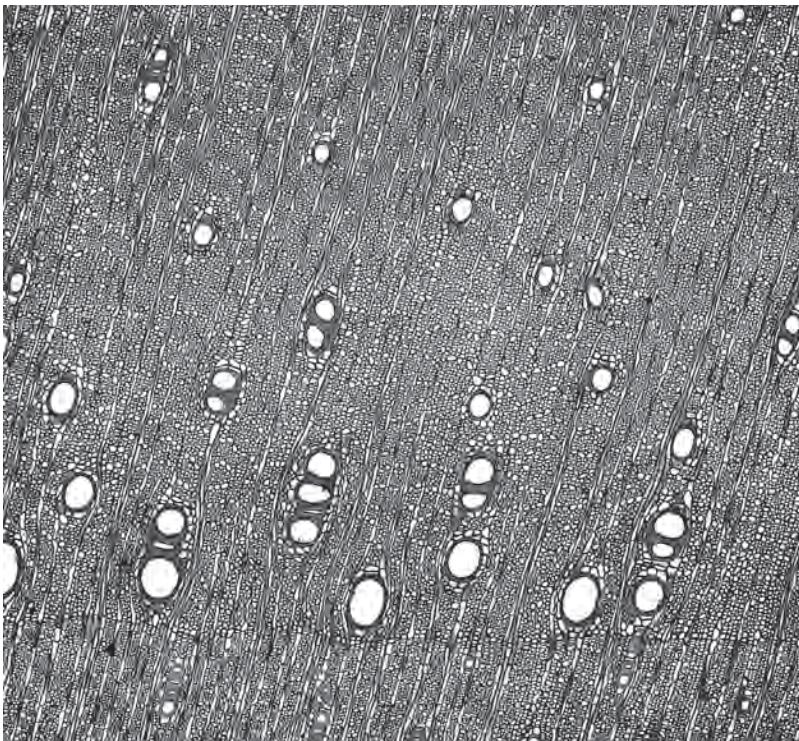
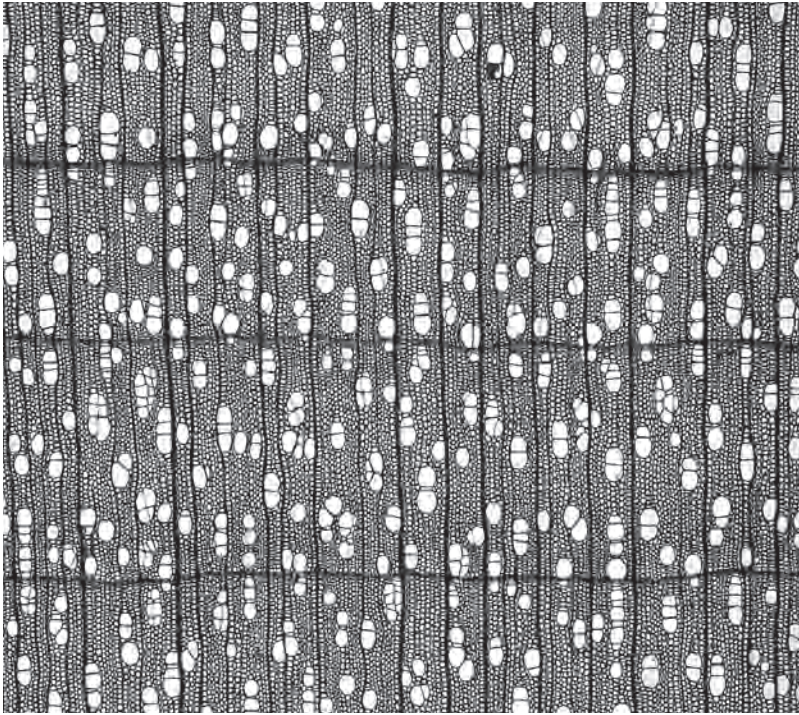


Fig. 1-6. Semi-ring-porous wood cross section, persimmon (25x).

The pores of exposed end-grain heartwood will sometimes appear clogged with a frothy, film-like substance called tyloses. Tyloses is formed in some species when the sapwood turns to heartwood. In woods such as red oak, cherry, maple, dogwood and honeylocust tyloses is insignificant or totally absent. In others such as white oak, tyloses development is quite extensive, while in Osage orange and black locust, the vessels are tightly filled.

WOOD PROPERTIES

Figure 1-7 shows the three faces, or planes, of wood. Cutting the wood parallel to the ground and perpendicular to the pith exposes the cross section, or transverse face. Such a cut is in the transverse direction and reveals the growth rings, pores, rays and pith.

Cutting in a plane parallel to and through the pith reveals the radial face and is in the radial direction. This cut shows the parallel edges of the growth rings and best shows the widest portion of the rays.

Again cutting vertically through the trunk, but parallel to the pith, reveals the tangential face, or plane, which displays the ends of the rays and the wide figure of the growth rings.

Wood is an anisotropic material: It has different and distinct properties in each of its directions. In the longitudinal direction, with the length of the wood fibers, wood has its greatest shock resistance and compression strength. Hence the use of longitudinal lumber in posts, legs and other weight-bearing members. In addition, wood shrinks an insignificant amount in this direction. Yet with all its compression strength, it splits in the radial and tangential direction. In the transverse direction (cross section) wood refuses to split, yet compresses perpendicular to the grain. In ring-porous woods such as oak and ash, the concentration of large, thin-walled vessels in the early-wood forms rings of weakness. Utilizing this property, basket makers beat ash logs to separate the growth rings, lifting them off in sheets.

COLOR AND LUSTER

Color in heartwood is caused by extractives. In most species the sapwood is a light, creamy tan color. Heartwood color varies tremendously among species, and even within a species, color is variable. One theory states that shading is influenced

by the soil in which the tree grew. Because of the variables, color should only be used secondarily as an aid to identification. Other factors also influence color: exposure to sunlight, which hastens the development of the patina; and finishes, which alter the natural darkening or bleaching of the wood. Although color is an unreliable factor in wood identification, it is this variability, in conjunction with the figure of the grain, that makes each piece unique and adds to its aesthetic value.

Luster is the natural ability of the wood to reflect light. It has nothing to do with color or finish. Luster is most evident when the wood is planed with a sharp tool. This produces a more reflective surface with more sheen than sanding, which abrades the wood and clogs the pores. Occasionally luster can be used to identify wood. White ash, for example, is noticeably more lustrous than black ash.

TASTE AND ODOR

Extractives are also the cause of taste and odor in wood. Some odors are so distinctive they can be used in identification. Aromatic extractives are most noticeable in red and white cedar, black walnut, sugar pine and sassafras. A few woods such as catalpa and tulip poplar have a rather disagreeable odor. Because most of the odor-causing extractives are volatile, they can be detected only in green or freshly sawn wood. Taste is usually not pronounced in wood. Rather, woods are often chosen for their lack of taste and odor. Butter tubs, cutting boards and kitchen utensils are made of fir, spruce, maple, beech and basswood for this reason.

DENSITY AND SPECIFIC GRAVITY

Specific gravity measures the relative amount of cell wall material, and is an excellent index for predicting the strength of wood. It is expressed as the ratio of the density of a material compared to the density of water at 39°F (4°C), or:

$$\text{specific gravity} = \frac{\text{density of wood in g/cc}}{\text{density of water at 39° F (4°C)}}$$

The moisture content of the wood must always be specified, because the wetter the wood, the larger its volume and the more water it will displace. Figure 1-8 lists the specific gravity of common native woods at 12 percent moisture content (air dry).

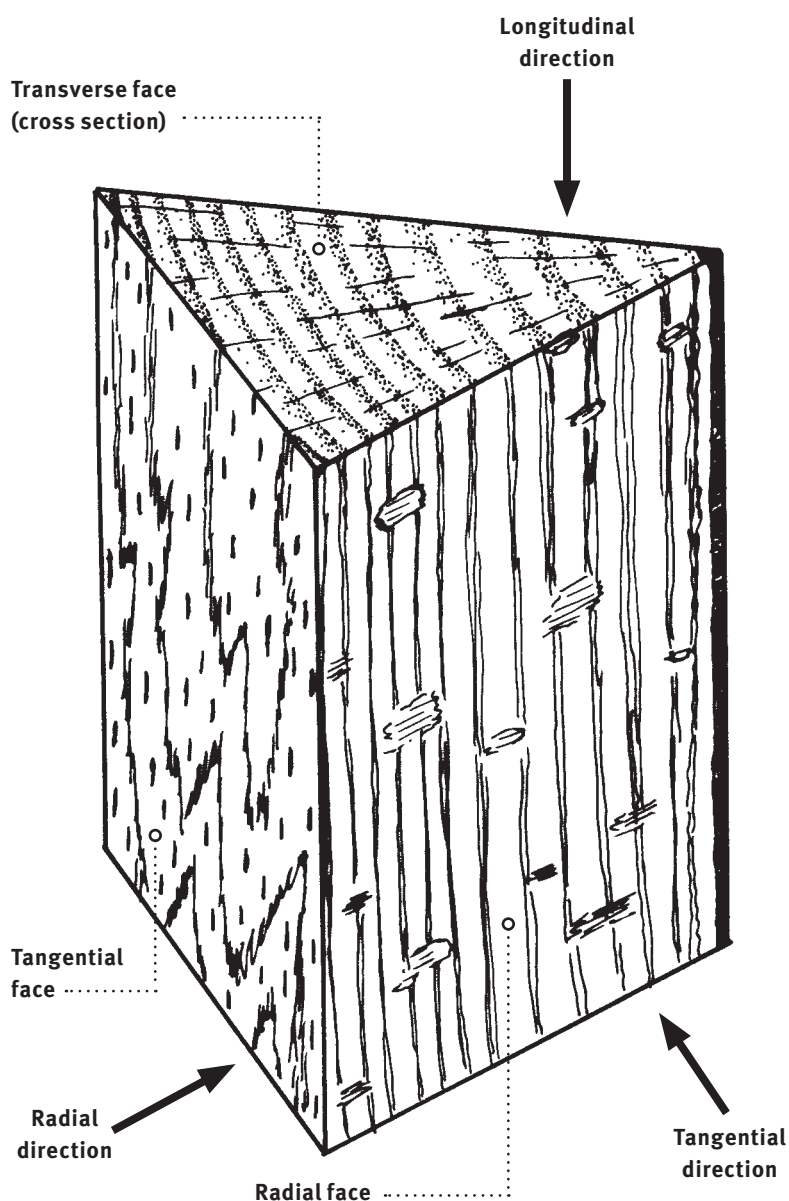


Fig. 1-7. Three planes of wood section: transverse, radial and tangential.

Water has a specific gravity of 1.0, whereas pure wood material (with no cell cavities) would have a specific gravity of 1.54, about 50 percent higher than water. All wood has cell cavities filled with air, water or extractives. Live oak has the highest specific gravity (.88, at 12 percent moisture content) of any North American wood, while Northern white cedar has the lowest at about .31.

Density is defined as mass per unit volume, and is usually expressed as pounds/cubic foot (lb/ft³), or grams per cubic centimeter (g/cc). Density

SPECIFIC GRAVITY AND DENSITY

SPECIES	SPECIFIC GRAVITY AT 12% M.C.	GREEN	DENSITY AT 12% M.C. (G/CC) (LBS/FT ³)
Alder, red	.41	.37	.46 28
Ash, black	.49	.45	.55 34
Ash, white	.60	.55	.67 42
Bald cypress	.46	.42	.52 32
Basswood	.37	.32	.41 26
Beech	.64	.56	.71 45
Birch, paper	.55	.48	.61 38
Birch, yellow	.62	.55	.69 43
Butternut	.38	.36	.42 27
Catalpa	.41	.36	.46 29
Cedar, N. white	.31	.29	.34 22
Cedar, red	.47	.44	.52 33
Cherry, black	.50	.42	.56 35
Chestnut, American	.43	.40	.48 30
Dogwood	.73	.64	.81 51
Elm, American	.50	.46	.56 35
Hickory, shagbark	.72	.64	.80 50
Holly, American	.57	.50	.63 40
Honeylocust	.67	.60	.75 44
Hornbeam, American	.70	.58	.78 49
Locust, black	.69	.66	.77 48
Maple, red	.54	.49	.60 38
Maple, sugar	.63	.56	.70 44
Oak, N. red	.63	.56	.70 43
Oak, white	.68	.60	.76 45
Osage orange	.80	.76	.84 56
Pecan	.66	.60	.73 46
Persimmon	.74	.64	.78 52
Pine, sugar	.36	.34	.40 25
Pine, E. white	.35	.34	.39 25
Redwood	.40	.38	.43 20
Sassafras	.46	.42	.52 32
Sweet gum	.52	.46	.56 35
Sycamore	.49	.46	.54 34
Tulip poplar	.42	.40	.47 30
Walnut, black	.55	.51	.61 38

SOURCE: U.S. Forest Products Laboratory, *Wood Handbook: Wood as an Engineering Material*, U.S.D.A. Handbook No. 72.

Fig. 1-8.

also varies with the moisture content of wood. Water weighs 62.4 lb/ft³ or 1g/cc. Wood with a specific gravity of .50 would have a density of 31.2 lb/ft³, or .5g/cc. A cubic foot of solid wood material (with no cell cavities) at 0% moisture content, having a specific gravity of 1.54 would weigh 96.1 lb/ft³, or 1.54 g/cc. Density is a good general indicator of hardness and the amount of shrinkage and swelling to be expected for a given species. As a rule of thumb, the denser the wood, the more movement can be expected.

Density is easy to approximate by floating a long, thin piece of wood upright in water. The ratio of the length below water to the total length, times the weight of water per cubic foot equals the density at that specific moisture content. For example a 14" (35.5 cm) is floated upright, and 8.5" (21.6 cm) is below the waterline, then

$$\frac{8.5}{14} \times 62.4 \text{ lb/ft}^3 = 37.9 \text{ lb/ft}^3$$

or

$$\frac{21.5}{35.5} \times 1 \text{ g/cc} = .61 \text{ g/cc}$$

GRAIN AND FIGURE

A knowledge of the basic makeup of wood helps in the understanding of grain structure. Grain is simply the alignment of the wood cells. The term is used in describing the arrangement, direction, size and appearance of the fibers, vessels and rays. Strictly speaking, figure is the appearance of the grain as it is exposed on the surface of a board. In the lumber industry figured wood refers to certain types of irregular grain patterns. By simply splitting a piece of wood, one can determine whether the grain is straight or wavy. Grain around branches, roots and crotches will be wild, wavy and extremely unpredictable and difficult to work.

In some trees the grain does not grow perfectly up and down, but tends to spiral around the trunk. Spiral growth is present to some extent in both hard and softwoods, but unless the spiral is severe, it is considered normal. In some species the spiral reverses itself every few years, growing first clockwise, then counterclockwise. This interlocked grain is very difficult to split, chisel and plane. The grain goes in opposite directions and appears as fuzzy stripes (Fig. 1-9). Interlocking grain is found in elm, sycamore and black tupelo. Finished, it is sometimes known as ribbon grain.

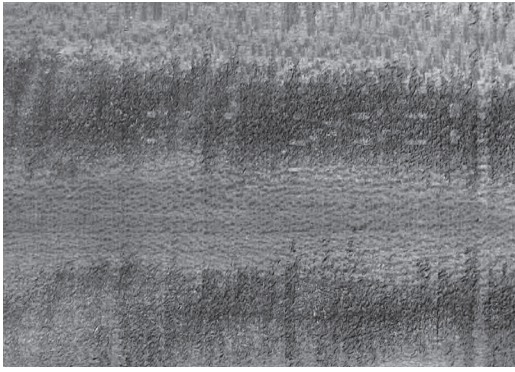


Fig. 1-9. (top left)
Interlocking grain
looks fuzzy on sawn
sycamore.

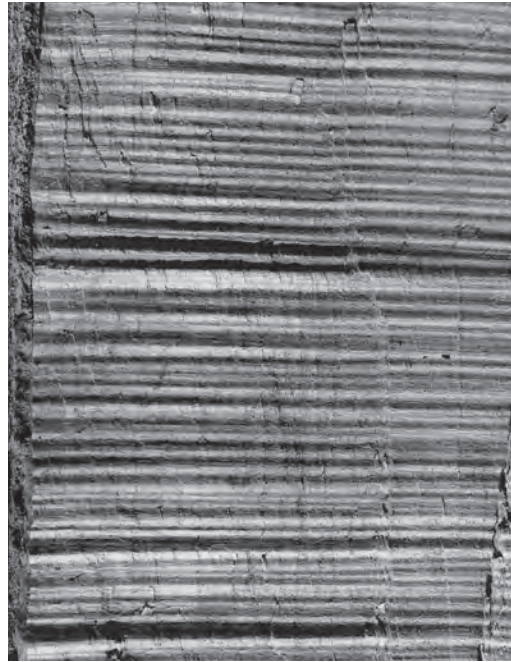


Fig 1-10. (top right)
Split tiger-stripe
maple shows the
undulating grain.



Fig, 1-11. (bottom
left) Bird's-eye maple.

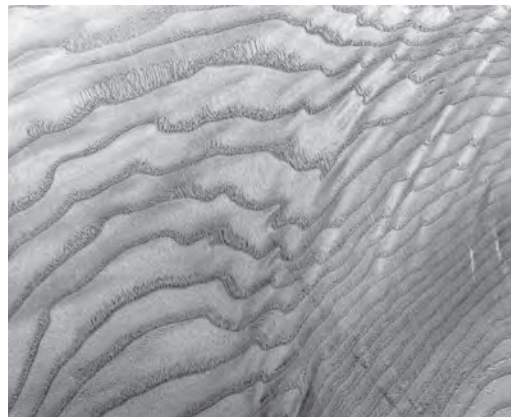


Fig. 1-12. (bottom
right) Feather or
crotch figure in white
ash.

Wavy grain patterns are the result of longitudinal cell growth in waves, which gives a wash-board appearance when the wood is split (Fig 1-10). This occurs most often in maples, birches, and, to some extent, in ash and cherry. In maple, when the waves are small and tightly spaced, the grain is called tiger-stripe or fiddleback. This abrupt oscillation of the grain is known as chatoyance, (from the French *chatoyer*, meaning to shimmer) and results in dark and light areas, depending on the direction of view. Chatoyance is not limited to figured wood. Even straight-grained door frames made from the same piece of wood will exhibit differences in color when the rails are turned 90° to the stiles.

Very rarely, areas of interconnected ovals and grooves will result in blister, or quilted grain in maple. A more common figure is bird's-eye (Fig. 1-11). This is the result of small indentations in the grain, more or less like dimples, usually evident under the inner bark. Because the cambium layer is the source of new growth, the bird's-eye figure continues as each new ring is formed. Bird's-eye varies in size and distribution. This figure is most common in rock, or sugar maple, but is sometimes found in ash and birch.

There is as of yet no satisfactory explanation as to what causes blister, tiger-stripe or bird's-eye figure. Suggestions such as climate, soil, stress, viruses or genetics have so far been discounted.

Crotch grain, or feathering around root and branch crotches, is caused by distortion of the grain and crowding and twisting of the annual growth. Crotch grain (Fig. 1-12) is one of the most common figures encountered. It occurs frequently in walnut, ash, oak, birch, cherry and to some extent in all hardwoods.

Another specialized pattern is pigment figure. Actually, it is not a grain pattern, but rather streaks of color independent of the growth rings. Pigment figure is caused by uneven distribution of extractive deposits in the heartwood. An excess of dark deposits is most dramatic, but occasionally a lack of extractives may cause a lighter area in the heartwood known as false or included sapwood (see Fig. 2-6 F). Pigment figure is common in black walnut, Eastern red cedar and sweet gum, and is sometimes present in cherry and even pine.

DEFECTS AND ABNORMALITIES

Wood is an organic material, which varies in character and properties. These variations can be either a detriment or a benefit to those working with wood.

WARP

Warped wood is by far the most common complaint (Fig. 1-13). Warps are categorized as cups (curvature of the sides of the board curling up or down), bows (curvature resulting from both ends of the board curling up or down), crooks (curvature of both edges of the board, with the board remaining flat) and twists (curvature of one end

tilting up, the opposite end tilting down). These dimensional changes are usually the result of uneven shrinkage, or inner stresses. Cupping, for example, is caused by either the faces of the board drying at different rates, or by differences in the radial and tangential shrinkage. On a plain-sawn board this usually results in cupping away from the pith. It is most pronounced in flat-sawn lumber.

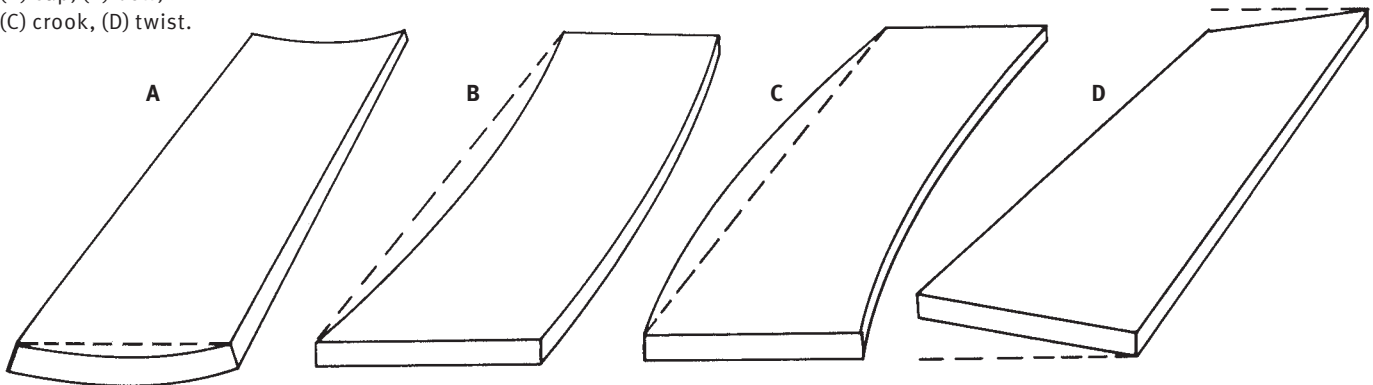
Case hardening is another cause of warping. It occurs most often in kiln-dried lumber when the wood is dried too fast or is not “conditioned” prior to removal from the kiln. Drying wood too fast creates stresses. The outside and ends dry and begin to shrink while the core is still wet. The surfaced wood is stretched and under tension while the core is compressed. If not conditioned, the outer fibers dry under tension and the inner fibers eventually dry too, but under compression. This condition is not apparent until the board is worked, either planed or re-sawn. Then the internal stresses can result in severe cupping. Intense cupping can also be caused by reaction wood (see Reaction Wood section on page 12).

In some cases, warps can be used to the woodworker’s advantage. For example, when a curve is needed for a high post bed canopy, a severely bowed board cut into strips is ideal. These will form a gentle crown, as opposed to flat stock, which has a tendency to sag.

STAIN

Staining in wood can be caused by one of several factors. Blue stain, probably the most prevalent, is caused by a fungus and is the direct result of poor air circulation. Freshly sawn wood is most

Fig. 1-13. Warps:
(A) cup, (B) bow,
(C) crook, (D) twist.



susceptible and must be stickered right away. Small strips or stickers are placed between the boards to allow air circulation (see *Sawing and Drying Wood*, chapter 4). Brown stain is the result of a chemical reaction (oxidation) that often occurs in the sapwood. Water-soluble chemicals are brought to the surface as moisture evaporates.

Sticker stain results from the use of damp stickers. The stain is caused by fungal growth between the freshly cut board and the wet sticker.

Woods containing tannins, such as oak and chestnut, will stain in the presence of iron. Not only are buried fence nails a headache for sawyers, they also leave long stains in the wood above and below the nail. Sometimes the nail will have been totally dissolved by the tannins, leaving only a long, bluish-black streak in the wood.

SPALTING

Spalting, or incipient decay, is an early step in the decay process. Associated with white rot, spalting forms distinct zones of white, tan, pink and brown, outlined in black (Fig. 1-14). These zones are actually areas that have been invaded by fungi, with different fungi producing different colors. Spalting occurs in wood left in contact with soil or water, but not submerged. It is most often found in maple, birch, beech and other non-decay resistant woods. To some woodworkers it is a desirable visual asset, even though the wood may be spongy, making it difficult to work. Dust masks should be worn when working spalted wood to avoid inhalation of the fungal spores.

DECAY

After staining and spalting, decay sets in as fungi break down the wood fiber. The wood becomes soft and punky, loses its structure and begins to crumble. Decay fungi require four basic ingredients to break down wood, the lack of any one of which can prevent its growth. Food is first. Fungi usually attack the sapwood first because the sapwood contains sugars and carbohydrates, but no extractives, which are decay inhibitors in some species of wood. Water is also necessary for fungal growth to occur. Perfectly dry wood will not decay. Dry-rot is a misnomer. Wooden objects found in Egyptian tombs are still solid after thousands of years. Wood does not have to be in contact with water to decay; damp air and poor circulation will suffice. Temperature is another requirement. Fungal activity



Fig. 1-14. Spalted wood, or incipient decay.

ceases below 40° F (5° C) and above 105° F (41° C). Therefore, decay or even staining is not a problem during the winter. Finally, oxygen is required for the decay process to occur. Wood kept totally submerged in water does not rot.

BARK, PITCH AND GUM POCKETS

Injuries to a tree take several years to heal, depending on their severity. If the cambium layer is injured or removed in spots, it will cause a localized interruption of growth in that spot. Every year the cambium on both sides will advance in order to cover the injury. Bark is also produced. As the years progress, the growth begins to cover the injury all around, often trapping the bark. Within a few years the cambium will fuse and form a continuous growth ring, leaving a small pocket of enclosed bark.

In softwoods with resin canals, injuries will cause resin (or pitch) to collect at the site in

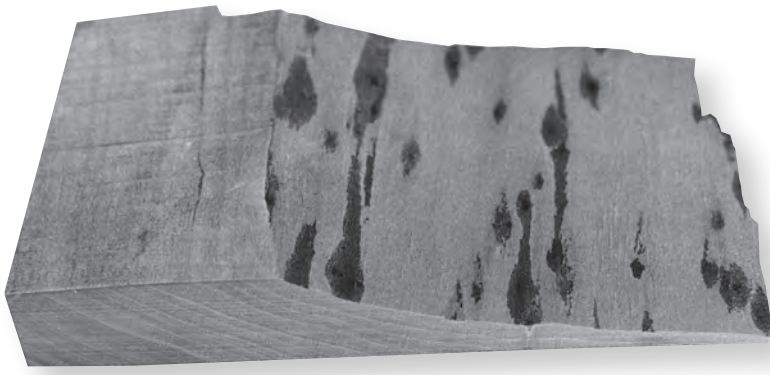


Fig. 1-15. Gum pockets in black cherry, usually located between the growth rings.

pockets. These pocket form under the cambium layer, and are then covered with new growth. When the wood is machined, the pockets exude pitch, which can stay in liquid form for years. In old wood, the pitch crystallizes.

In some hardwoods, gums and extractives will sometimes collect in pockets between the growth rings. These result in dark patches on the surface of the board (Fig. 1-15). These gum pockets are a result of cell separations (gummosis). This is most prevalent in black cherry and sweet gum.

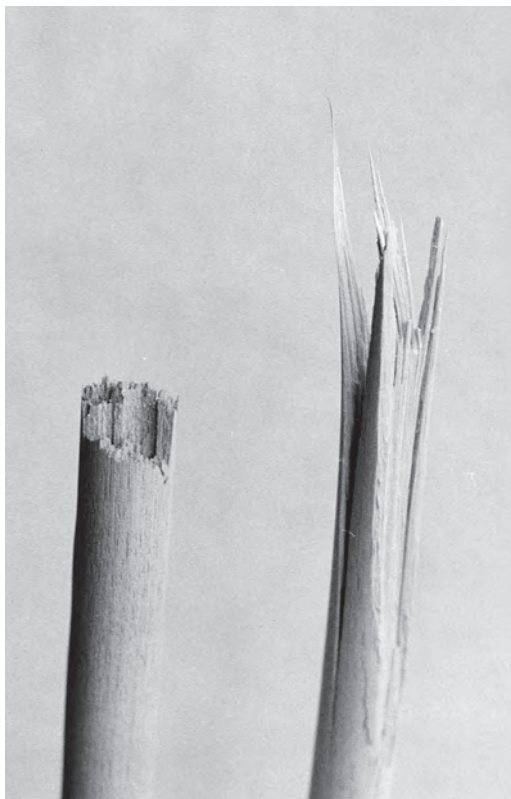


Fig. 1-16. Brashness in white ash spindle (left), normal break (right).

BRASHNESS

Certain pieces of wood will break with no warning, under lighter than expected loads. Brashness is the cause. Brash wood will break cleanly across the grain, with none of the usual long splinters or cracks (Fig. 1-16). It is usually much lighter in weight, up to 15 percent less than normal wood of the same species (although in some instances brashness occurs in wood of normal or higher density). The light weight is the result of much thinner cell walls. The weakness may also stem from not only thin cell walls, but in some cases a decrease in the cellulose content of the walls. The basic cause can be one of several factors: compression wood, excessive heat or decay. When working with structural part such as table legs or chair parts, take care to avoid brash wood. This can be done by comparing relative weights or flexing the individual pieces.

BURLS

Burls are abnormal, cancer-like growths on trunks or branches. They may be caused by viruses or gall-forming insects. The grain in burls twists and turns in all directions (Fig. 1-17). Often it contains heartwood and sapwood mixtures, bark and gum pockets, and pin-knot formations. Structurally it is quite unpredictable and is used for veneer and inlay work. Large burls are often used for bowl turnings because the wood is not only highly interesting, but also shrinks more or less equally in all directions, unlike straight-grained wood that turns round objects oval when dry.

REACTION WOOD

Reaction wood is truly abnormal in its properties. It occurs in the timbers of leaning trees and in branches. The reaction wood is located in the area of greater growth. It is a result of a growth response to restore a leaning tree to an upright position, or to maintain branch angles. It is believed that there is an asymmetrical response to growth hormones in those parts of the tree containing reaction wood.

In conifers, reaction wood is classified as compression wood, and occurs on the lower side of the leaning stem. This may be due to gravity creating compression on the lower (leaning) side. It is readily apparent in cross section, identifiable by the large eccentric growth rings, and an inordinate amount of late wood (Fig. 1-18). The specific gravity is higher because the cell walls are thicker, and

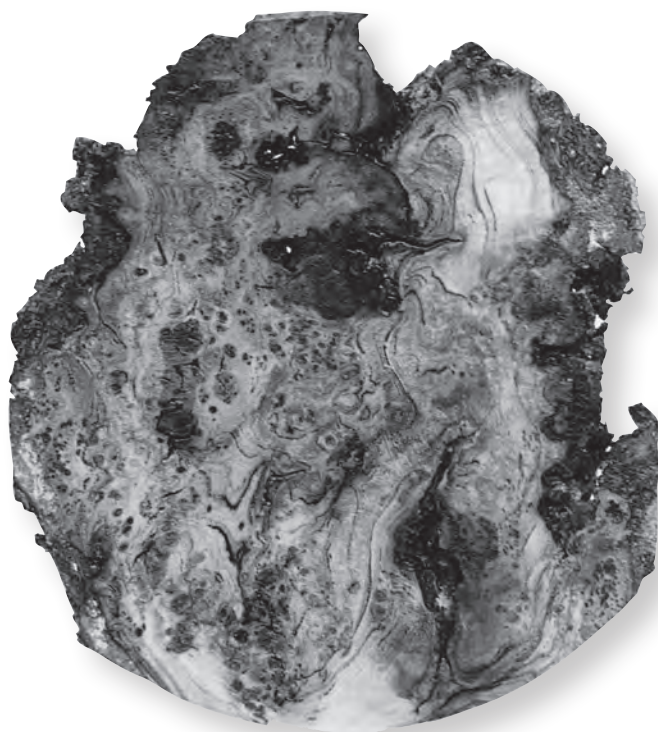


Fig. 1-17. (left)
Cross section of burl
in black cherry.

Fig. 1-18. (right)
Reaction wood in
white pine. The
darker, wider rings
at the bottom are
compression wood.

the whole area appears darker. This is sometimes known by its German name, *rotholz*, or red wood. Even though the wood is denser and harder, it is also more brittle, because of the decreased amount of cellulose and increased amount of lignin. Longitudinal shrinkage is up to 10 times as much as in normal wood. Across the grain, shrinkage is somewhat less than normal. This causes severe warping problems.

Reaction wood in hardwoods is known as tension wood, and usually forms on the upper side of the leaning tree. Tension wood occurs more commonly than is generally realized, and is more

difficult to detect than compression wood. The pith is not always located off-center. One property of tension wood is that it is very fuzzy when sawn. A certain amount of fuzziness remains after drying, and even after careful sanding, which makes finishing, especially staining, very difficult. Like compression wood, it has greater longitudinal shrinkage, making it prone to warping. Tension wood has more cellulose and less lignin, making it weaker and more difficult to work. Wood that binds or curves away from the blade when ripping, is usually tension wood.

