PROPERTIES OF PULPWOODS

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INTRODUCTION

A large number of tree species are pulped in the United States and Canada. Much information is available on the properties of certain of these but, unfortunately, such data are scattered in various publications. They have been collected for the use of students and member mills of the Institute. It is hoped that any errors or omissions will be brought to the attention of the compiler and also that additional information will be forthcoming, so that the usefulness of the work will be enhanced. In the future it is planned that a revised edition, including photomicrographs, will be issued.

The compiler wishes to thank Dr. L. E. Wise of the Institute staff for his aid in assembling the chemical data.

Further information concerning these fibrous raw materials, or any others, will be furnished on request, if available.

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EXPLANATION OF TERMS

Common Name. This appears at the head of each species description. In ost cases, it is the name favored by the U. S. Forest Service.

Scientific Name. The technical name for the tree is given in italics (i.e., underscored), followed by the name of the person who first used the name in this combination and wrote the plant description. Sometimes another person's name is given in parentheses. If so, it means that person first applied the second or specific part of the name, but put it in a different combination, later found to be incorrect. Scientific names were originated because of the great confusion in common names, and their use is governed by a botanical code of nomenclature.

Synonyms. Some of the common names which are not so widely known or well chosen as the one used in the title are listed as synonyms. According to the U. S. Forest Service Check List (U. S. Dept. Agr., Misc. Circ. 92. 1927), a few species have as many as 30 common names.

Family Name. A family is a group of closely related genera just as a genus is composed of closely related species. The family name is given because experience has shown that it is convenient to think of woods in terms of Plant Families.

Range. This indicates the district or region where the species is indigenous. Certain localities within the range may not contain the tree because of environmental conditions, natural enemies, or removal by man.

Dimensions. Average measurements on mature trees are given.

Bark. A description of the appearance of the bark is given. Occasionally, in addition, data are available on the percentage of the total volume of the trunk occupied by the bark.

Silvics. This includes a general description of the tree, its environment, its associates, and other pertinent facts connected with its growth.

Gross Features of the Wood. This is a statement of the general characteristics and properties of the typical wood from the merchantable part of the tree. A hand lens (10X) is the greatest magnification used to obtain these data. In referring to the planes of section, x signifies cross, r signifies radial, and t signifies tangential.

Microscopic Structure. The minute anatomy of the wood is described by considering dimensions and characteristics of the wood elements normally present in the species. In the future, it is planned to illustrate this section with photomicrographs of the cross, radial, and tangential sections made from authentic wood samples.

Nonmechanical Physical Properties. These are the several common values which do not have to be determined by stress. The specific gravity is based on the oven-dry weight and the volume of the test piece when it was in a green, air-dry, or oven-dry condition. The density is given in pounds per cubic foot for various conditions of moisture. The moisture content is the average for green wood. It is the custom in wood industries to relate the loss in moisture from the original to the oven-dry condition to the weight of the oven-dry piece, whereas in the pulp and paper industry moisture is expressed as a percentage of the original weight as it is with chemicals. Both values are given. Most woods have their cell walls saturated and the cell cavities free from water (fiber-saturation point) at a moisture content of 25 to 30% (based on the oven-dry weight). When the moisture content decreases below the fiber-saturation point, shrinkage takes place. The shrinkage values for volume, radial direction, and tangential direction are figured on the loss in size to the oven-dry condition based on the dimension when green; the shrinkage to the air-dry condition will be less. The value for thermal expansion is a coefficient per degree Fahrenheit at ordinary temperatures. The coefficients along the grain and across the grain are given customarily. The thermal conductivity is expressed as B.t.u. per hour per square foot of material when the temperature gradient is one degree Fahrenheit per inch of thickness. The electrical resistance is expressed in megohms. The value is given at moisture contents of 7 and 12% (on the oven-dry basis), corresponding closely to the kiln-dry and air-dry moisture contents. This small difference in moisture content causes a several-fold difference in resistance.

Mechanical Properties. These values are included because it is felt that the pulp and paper engineer encounters considerable structural work and in many places wood might be a desirable constructional material. It must be remembered that wood is heterogeneous, unidirectional, and variable with moisture contents below the fiber-saturation point. Since the various properties listed are familiar to one versed in the testing of materials, they will not be expanded here. Toughness is given as the drop in inches of a 50-lb. hammer at complete failure, hardness as the load in pounds required to embed a 0.444-inch sphere to half of its diameter, and splitting strength or cleavability as the pounds necessary per inch of width when splitting; all other stress values are expressed as pounds per square inch. More complete information is available in publications of the U. S. Forest Products Laboratory or the Canadian Forest Products Laboratory.

Chemical Properties. The data on proximate analysis of many of the pulpwoods are surprisingly meager. All the information available has been given in the following pages. In general, the methods of the U. S. Forest Products Laboratory have been used by the various investigators, although modifications have been made. Specific references are given when feasible, and any unusual methods have been noted.

Pathology. A knowledge of the durability of wood and its susceptibility to various diseases and insects should be helpful to woodyard and woodroom operators. Much of this information concerns the forest trees and far

less the logs. Unfortunately, there is no direct relationship between the pathological resistance of a growing tree and the durability of the wood cut from it. Certain types of diseases do not interfere with the use of wood for chemical pulping; others cause so much decay that it is undesirable to take the log as far as the landing deck.

Utilization. All phases of utilization have been considered in this compilation. It is important to know the properties of wood and its uses other than as pulpwood because of the competition for raw material in certain localities. Usually an integrated or multiple-use program can be worked out with other utilizers, especially if all concerned are interested in keeping their industries going. The production figures are the latest and most reliable obtainable.

Supply. This information has been obtained from estimates of the U. S. Forest Service and the Canadian Forest Service. The data for certain species and regions are much more complete and detailed than for others.

BLACK SPRUCE

Scientific Name. Picea mariana (Miller) Britton, Sterns, and Poggenberg.

Synonyms. Swamp spruce, bog spruce, water spruce.

Family Name. Pinaceae.

Range. Newfoundland; northern limit of tree growth in Canada from Labrador to west coast of Alaska; south within 100 miles of the coast to central British Columbia; east through south central Alberta and Saskatchewan, southern Manitoba, northeastern Minnesota, central Wisconsin, southern Michigan and Ontario, western New York, central Pennsylvania, northern West Virginia, western Maryland to central New Jersey.

Dimensions. 30 to 40 feet tall and 6 to 12 inches in diameter.

Bark. 0.25 to 0.5 inch thick, broken into thin, flaky, grayish-brown to reddish-brown scales with freshly exposed inner layers somewhat olive green in color.

Silvics. The tree has a long, straight, tapering bole, a pyramidal crown, and a shallow, spreading root system. In the southern part of its range, this species is usually restricted to cool sphagnum bogs; in the far north, it is also found on dry slopes and makes its best growth on moist, well-drained alluvial bottoms. It occurs in dense pure stands, or in mixture with such species as tamarack, balsam fir, white cedar, black ash, aspen, and white birch.

Gross Features of the Wood. The wood of black spruce is soft, lustrous fine- to medium-grained, fine-textured, nonresinous, without characteristic color or taste. The sapwood is not distinguishable from the heartwood; it is nearly white to pale yellow in color. The springwood zone is several times wider than the summerwood; the summerwood zone is distinct with the naked eye but not pronounced, so that flat grain boards show only a faint growth ring figure. In x-section the rays are very fine and are not distinct with the naked eye unless they include a horizontal resin canal, and in r-section they form a fine, close, inconspicuous fleck. Both longitudinal and horizontal resin canals are normally present. The longitudinal canals, which are not usually visible with the naked eye but appear as white flecks with a hand lens, are solitary or 2 or more contiguous in a tangential row and irregularly distributed. The horizontal canals are smaller than the longitudinal ones but are visible with a hand lens on the transverse surface. Parenchyma are absent.

Microscopic Structure

Tracheids. 18 to 44 mu (Average, 33 mu) in diameter and 3.3 mm in length; bordered pits in one row or rarely paired on the radial walls; tangential pitting present in last few rows of summerwood tracheids; pits

leading to ray parenchyma small, uniform in size, oval to angular (piciform), with distinct border, 1 to 6 (generally 2 to 4) per ray crossing; many tracheid pits present.

Resin canals. Longitudinal, 30 to 85 mu in diameter; horizontal, less than 30 mu; thick-walled epithelial cells, tylosoids.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous, 1 to 17 cells (303 mu) high; the fusiform rays are scattered, with one or rarely two horizontal resin canals, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 40 cells (681 mu) high; ray tracheids are present in all types of rays, usually restricted to one row on the upper and lower margins, with nondentate inner walls. Five rays per mm. tangentially on x-section and 28 rays per sq. mm. on t-section.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.40
	oven-dry volume	0.45
Density, lb./cu. ft.	green	37
	air-dry	30
	oven-dry	28

Moisture content, when green: 38% based on oven-dry weight (27.5% on green basis).

Shrinkage, from green condition: v, 11.6%; r, 4.1%; t, 6.8%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	104	--
Compressive stress at p.l. //, lb./sq. in.	1900	4070
Compressive stress at p.l. /, lb./sq. in.	290	620
Shear, maximum stress //, lb./sq. in.	810	1180
Static bending FSPL, lb./sq. in.	3100	5700
Static bending E, lb./sq. in.	1.29×10^6	1.52×10^6
Static bending R, lb./sq. in.	5800	10,300
Toughness, in.	25	26
Hardness //, lb.	410	680
Hardness /, lb.	355	515
Cleavability, lb./in. width	185	265

Chemical Properties

Calorific value: 19.1×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	I.P.C.	I.P.C.
Hot-water soly., %	2.1	2.2
Ether soly., %		0.6
Alcohol-benzene soly., %	2.2	
Ash, %		
Lignin, %	27.3	27.7*
Methoxyl, %	4.68	4.6*
Methoxyl in lignin, %	15.7	15.5*
Pentosans, %	12.5	
Polyuronides (as CO_2), %	0.86	

* Based on alcohol-benzene-extracted wood.

Ash (oven-dry wood), %	0.34	Ind. Eng. Chem. 30:1408(1938)
Pentosans (Bailey's method), %	7.5	
Lignin, %	27.1	
C. & B. cellulose (Sieber-Walter method), %	62.0	
Alpha-cellulose (Gortner-McNair method), %	44.8	
"Total extractives," %	2.7	

Pathology

Resistance to decay: low +.

Red ring rot, also called ring scale, red heart, or pecky rot, is caused by Fomes pini and is severe on spruces. Butt rot in living trees is caused by Polyporus circinatus. Red-brown butt rot (Polyporus schweinitzii) occurs in heartwood of living trees. Brown cubical rot in heartwood of living trees is caused by the sulfur fungus (Polyporus sulfureus). Feather rot of heartwood is caused by the white root conk (Poria subacida). Sap rot of dead trees is caused by Fomes pinicola and Polystictus abietinus.

Eastern dwarf mistletoe is common on black spruce. Spruce stands in northern New England and eastern Canada are often killed by the spruce budworm, sawfly, or bark beetle. The spruce budworm is probably the most destructive enemy of spruce in America. The European spruce sawfly attacks spruce. The eastern spruce beetle has caused an enormous loss of mature spruce timber in the United States and Canada. The hemlock budworm and hemlock spanworm attack spruce. Severe defoliation of the lower crowns of black spruce by needle cast (Lophodermium filiforme) is not unusual.

Utilization

Use properties. Light, good strength for weight; does not impart odor or color; somewhat heavier, stronger, harder, and more durable than white spruce; on account of its size it is not so important a lumber species as red and white spruce, but it is a very valuable pulpwood and is also used for mine timbers and similar applications. Like other softwoods, spruce is apt to contain compression wood.

Lumber. The wood of the various eastern species of spruce is not separated in the lumber trade; hence, some black spruce probably finds its way into boxes and crates, tanks and silos, sounding boards, boat building, car construction, ladder stock, dimension, woodenware, scaffolding, light and medium construction. Spruce is the standard construction material in New England. As sawn lumber in Canada, spruce is second only to Douglas fir in volume of output.

Pulping. This species is a very valuable pulpwood and, although satisfactory for any of the standard processes, is especially useful for mechanical and sulfite pulps. Statistics are not available for this one species. In 1940, however, 2,045,519 cords of domestic and 963,195 cords of imported spruce (all species) pulpwood were consumed in the United States. This is about 21.9% of the pulpwood used.

Sulfite process. Reduces readily; unbleached pulp is strong, of fine texture and excellent color, yield, 48%; bleaches easily to excellent white; used for news, wrapping, book, high-grade printing, and bond paper.

Sulfate process. Reduces readily; unbleached pulp is strong, of fine texture, yield, 48%; used for high-grade kraft wrapping and fiberboard.

Soda process. Yield of unbleached pulp, 43%.

Mechanical process. Reduces readily; excellent color and standard strength; 60 to 80 horsepower-days per ton; any use requiring groundwood.

Other uses. In New England an oil is prepared by the steam distillation of the needles and twigs of black spruce. These oils are used as perfumes in greases and shoe blackings, and in liniments and other medicinal preparations.

Spruce gum is collected from trees after 3 years of aging and used in chewing gum and in medicinal preparations.

Supply. No information available on black spruce alone.

65 billion cu. ft. of all spruces in Canada (1935).
Forest Service estimate in 1932: 431,242,000 cords of spruce and fir in the United States.
Forest Survey estimate in 1935: 4,348,000 cords of spruce in Upper Michigan.

WHITE SPRUCE

Scientific Name. Picea glauca (Moench) Voss.

Synonyms. Canadian spruce, cat spruce, skunk spruce.

Family Name. Pinaceae.

Range. Newfoundland; northern limit of tree growth in Canada from Labrador to west coast of Alaska; south through northern British Columbia along the east slopes of the Rockies to northwestern Montana; from central Alberta through central Saskatchewan, southern Manitoba, northern Minnesota, central Wisconsin, central Michigan, southern Ontario, northern New York, southern Vermont and New Hampshire to southern Maine.

Dimensions. 60 to 70 feet tall and 18 to 24 inches in diameter.

Bark. 0.25 to 0.5 inch thick, flaky or scaly, ashy brown with freshly exposed layers somewhat silvery; volume, 12.4%.

Silvics. White spruce forms extensive pure stands but also occurs in mixture with aspen, white birch, balsam poplar, tamarack, balsam fir, black spruce, and red spruce. The best growth is made on moist sandy loam or alluvial soils; although found on many different sites, this species is especially typical of stream banks, lake shores, and adjacent slopes.

Gross Features of the Wood. The wood of white spruce is soft, lustrous, fine- to medium-grained, fine-textured, nonresinous, without characteristic odor or taste. The sapwood is not distinguishable from the heartwood; it is nearly white to pale yellow in color. The springwood zone is several times wider than the summerwood; the summerwood zone is distinct with the naked eye but not pronounced, so that flat grain boards show only a faint growth ring figure. In x-section the rays are very fine and are not distinct with the naked eye unless they include a horizontal resin canal; in r-section they form a fine, close, inconspicuous fleck. Both longitudinal and horizontal resin canals are normally present. The longitudinal canals, which are not usually visible with the naked eye but appear as white flecks with a hand lens (10X), are solitary or 2 or more contiguous in a tangential row and irregularly distributed. The horizontal canals are smaller than the longitudinal ones but are visible with a hand lens on the transverse surface. Parenchyma are absent.

Microscopic Structure

Tracheids. 15 to 47 mu (average, 24 to 34 mu) in diameter and 3.2 mm. in length; bordered pits in one row or rarely paired on the radial walls; tangential pitting present in last few rows of summerwood tracheids; pits leading to ray parenchyma small, uniform in size, oval to angular (piciform), with distinct border, 1 to 6 (generally 2 to 4) per ray crossing; ray tracheid pits present.

Resin canals. Longitudinal, 25 to 102 mu (average, 54 to 61 mu) in diameter; horizontal, less than 25 mu; thick-walled epithelial cells, tylosoids.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous, 1 to 20 cells (410 mu) high; the fusiform rays are scattered, with one or rarely two horizontal resin canals, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 30 cells (548 mu) high; ray tracheids are present in all types of rays, usually restricted to one row on the upper margins, with nondentate inner walls. Five rays per mm. tangentially on x-section and 30 rays per sq. mm. on t-section.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.35
	oven-dry volume	0.38
Density, lb./cu.ft.	green	38
	air-dry	26
	oven-dry	24

Moisture content, when green: 50% based on oven-dry weight (33% on green basis).

Shrinkage, from green condition: v, 13.7%; r, 4.7%; t, 8.2%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1840	3380
Compressive stress at p.l. ⊥, lb./sq. in.	250	490
Shear, maximum stress //, lb./sq. in.	710	960
Static bending FSPL, lb./sq. in.	2800	5300
Static bending E, lb./sq. in.	1.15×10^6	1.40×10^6
Static bending R, lb./sq. in.	5100	8600
Toughness, in.	22	22
Hardness //, lb.	340	540
Hardness ⊥, lb.	280	420
Cleavability, lb./in. width	155	220

Chemical Properties

Calorific value: 16.2×10^6 B.t.u. per air-dry cord.

Mannans: 7.12% [Ind. Eng. Chem. 9:748(1917)].

Proximate analysis (oven-dry wood):

	Chidester and Billington (1)		F.P.L.(2)		
Hot-water soly., %	3.2	2.1	2.14	2.9	2.6
Ether soly., %	0.8	1.1	1.36	1.2	0.4
Alcohol-benzene soly., %	1.8	2.3			
Pentosans, %	11.5	12.1	12.5		
Lignin, %	30.9	27.8		29.0	
C. & B. cellulose, %	61.1	60.6	61.85	60.4	
Pentosans, %			10.4		
Alpha-cellulose, %	43.0	42.1			
Acetic acid, %			1.59		
Methoxyl, %			5.30		
1% NaOH soly., %	12.2	10.7	11.6		

Special data on holocellulose and C. and B. cellulose (3):

Lignin (based on extractive-free dried wood), %	26.6
Holocellulose (based on extractive-free dried wood), %	73.3
Alpha-cellulose, %	67.5*
Pentosans, %	12.2*
Acetyl, %	3.19*
Methoxyl, %	0.96*
Uronic anhydride, %	3.64*
C. & B. cellulose (based on extractive-free dried wood), %	61.2
Alpha-cellulose, %	72.9**
Pentosans, %	6.2**
Uronic anhydride, %	1.92**
Methoxyl, %	0.43**
Acetyl, %	1.61**

1. Tech. Assoc. Papers 20:251(1937).
2. Forest Products Lab., Tech. Note 235 (July, 1931).
3. Tech. Assoc. Papers 25:596(1942).

* Based on holocellulose.
** Based on C. and B. cellulose.

Pathology. See same section under black spruce.

Resistance to decay: low +.

White spruce is very susceptible to spruce budworm. European spruce sawfly especially attacks white spruce.

Utilization

Use properties. Light, good strength for weight; does not impart odor or color; soft, easily worked, takes a smooth silky finish, paints well; nails without splitting and holds nails well; seasons fairly easily; noted for resiliency; not very durable; good resonance properties.

Lumber. Mixed with other eastern spruces.

Pulping. Similar to black spruce. Consumption included with black spruce.

Other uses. In New England an oil is prepared by the steam distillation of the needles and twigs of white spruce. These oils are employed as perfumes in greases and shoe blackings, and in liniments and other medicinal preparations.

Spruce gum is collected from trees after 3 years of aging and used in medicinal preparations and in chewing gum.

The pliable roots are employed by the Indians for lacing birch bark canoes and for making woven baskets.

Supply. See data under black spruce.

RED SPRUCE

Scientific Name. Picea rubra Link.

Synonym. Yellow spruce.

Family Name. Pinaceae.

Range. Prince Edward Island; Nova Scotia and New Brunswick south along the coast to Massachusetts and inland to northeastern Pennsylvania; south in the Appalachians to North Carolina; north through central New York and the Adirondacks; Quebec in the region just north of the St. Lawrence River to the Saguenay River. It is especially characteristic of the mountainous regions in northern New York and northern New England.

Dimensions. 60 to 70 feet tall and 12 to 24 inches in diameter.

Bark. 0.25 to 0.5 inch thick, separating into close, irregular, grayish to reddish-brown scales with reddish-brown inner layers.

Silvics. The tree has a long, cylindrical bole, a broad, short crown, and a shallow, widespreading root system. Red spruce occurs in pure stands or in groups, and also in mixture. It is found in swamps or bogs with black spruce, tamarack, balsam fir, and red maple, but grows much faster on better drained flats associated with balsam fir, hemlock, white pine, and yellow birch. Pure groups are found on upper slopes where the soil is very thin and rocky. The best growth, however, takes place in scattered trees which occur throughout the northern hardwood mixture on higher ground. In general, sandy loam soils with a great deal of moisture support the best spruce.

Gross Features of the Wood. The wood of red spruce is soft, lustrous, fine- to medium-grained, fine-textured, nonresinous, without characteristic odor or taste. The sapwood is not distinguishable from the heartwood; it is nearly white to pale yellow in color. The springwood zone is several times wider than the summerwood; the summerwood zone is distinct with the naked eye and is inclined to a more clearly defined figure than white spruce when flat sawn. In x-section the rays are very fine and are not distinct with the naked eye unless they include a horizontal resin canal; in r-section they form a fine, close, inconspicuous fleck. Both longitudinal and horizontal resin canals are normally present. The longitudinal canals, which are not usually visible with the naked eye but appear as white flecks with a hand lens, are solitary or 2 or more contiguous in a tangential row and irregularly distributed. The horizontal canals are smaller than the longitudinal ones but are visible with a hand lens on the transverse surface. Parenchyma are absent.

Microscopic Structure

Tracheids. 15 to 40 mu (average, 26 to 32 mu) in diameter and 3.1 mm. in length; bordered pits in one row or rarely paired on the radial walls;

tangential pitting present in last few rows of summerwood tracheids; pits leading to ray parenchyma small, uniform in size, oval to angular (piciform), with distinct border, 1 to 6 (generally 2 to 4) per ray crossing; ray tracheid pits present. Volume occupied, 94.8%.

Resin canals. Longitudinal, 22 to 123 mu (average, 45 to 61 mu) in diameter; horizontal, less than 30 mu; thick-walled epithelial cells, tylosoids. Volume occupied, 0.2%.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous, 1 to 30 cells (563 mu) high; the fusiform rays are scattered, with one or rarely two horizontal resin canals, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 39 cells (733 mu) high; ray tracheids are present in all types of rays, usually restricted to one row on the upper and lower margins, with nondentate inner walls. Six rays per mm. tangentially on x-section and 32 rays per sq. mm. on t-section. Volume occupied, 5.0%.

Longitudinal parenchyma. Absent.

Nonmechanical, Physical Properties

Specific gravity	green volume	0.38
	oven-dry volume	0.43
Density, lb./cu. ft.	green	35
	air-dry	28
	oven-dry	27

Moisture content, when green: 43% based on oven-dry weight (30% on green basis).

Shrinkage, from green condition: v, 11.8%; r, 3.8%; t, 7.8%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1950	3110
Compressive stress at p.l. ⊥, lb./sq. in.	280	500
Shear, maximum stress //, lb./sq. in.	800	1235
Static bending FSPL, lb./sq. in.	3000	5500
Static bending E, lb./sq. in.	1.32×10^6	1.45×10^6
Static bending R, lb./sq. in.	5900	8900
Toughness, in.	23	22
Hardness //, lb.	440	660
Hardness ⊥, lb.	365	460
Cleavability, lb./in. width	180	275

Chemical Properties

Calorific value: 18.1×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	Richter (1) Sap	Richter (1) Heart	Jahn and Wise (2)	Hajny and Ritter (3)
Ash, %	0.25	0.93		
Hot-water soly., %	2.52	3.39		
Ether soly., %	0.72	0.87		
Benzene soly., %			0.61	
Alcohol soly., %	1.11	1.06	1.25	
Methoxyl, %			4.56	
Pentosans, %	9.1	10.5	11.5	
Lignin, %	28.4	29.8	30.0	26.6
C. & B. cellulose, %			57.3*	60.3
Pentosans (4), %			7.1	6.7
Alpha-cellulose (4), %			78.0	72.0
Uronic anhydride (4), %				2.04
Methoxyl (4), %				0.42
Acetyl (4), %				1.51
Holocellulose, %				72.9
Pentosans (5), %				13.0
Acetyl (5), %				3.21
Methoxyl (5), %				1.25
Uronic anhydride (5), %				4.36
Mannans			4.7	

(1) Ind. Eng. Chem. 33:78(1941); based on oven-dry wood.
(2) Paper Ind. 10:250(1928); based on oven-dry wood.
(3) Tech. Assoc. Papers 25:596(1942); based on extractive-free wood.
(4) Based on cellulose.
(5) Based on holocellulose.

* Dore's procedure [J. Ind. Eng. Chem. 11:556(1919)].

Pathology. See same section under black spruce.

Resistance to decay: low +.

Severe defoliation of lower crowns of red spruce by needle cast is not unusual.

Utilization

Use properties: Similar to white spruce; although slightly harder, heavier, and stronger, the difference is so small that no attempt is made to separate them in marketing.

Lumber: Uses similar to those of white spruce. Red spruce is the most important eastern spruce in the United States.

Pulping: Similar to white and black spruce.

Supply. See data under black spruce.

SITKA SPRUCE

Scientific Name. Picea sitchensis (Bongard) Carriere.

Synonym. Tidewater spruce.

Family Name. Pinaceae.

Range. A narrow (50 miles) belt from Cook's Inlet, Alaska, south along the coast and on nearby islands to Mendocino County, California. Commercial operations are confined from sea level to 1200 feet, although the tree is found at elevations as great as 3000 feet.

Dimensions. 180 to 200 feet tall and 3.5 to 4.5 feet in diameter.

Bark. Thin and rarely 1 inch thick, broken into thin, elliptical, concave, loosely appressed, silvery-gray to purplish-gray scales.

Silvics. Sitka spruce trees have a long, cylindrical bole, a short, rather open crown, and a very shallow, widespreading root system. This species forms extensive pure forests in certain sections and in others occurs in mixture with both hardwoods and softwoods. In Alaska its chief associate is western hemlock, whereas in British Columbia, Washington, and northwestern Oregon it often mingles with Douglas fir, western red cedar, silver fir, lowland white fir, red alder, bigleaf maple, and northern black cottonwood; in southwestern Oregon and northwestern California it is occasionally found with Port Orford cedar and redwood.

Gross Features of the Wood. The wood of Sitka spruce can be separated from that of other spruces because of the color of the heartwood. The sapwood is creamy white to light yellow, whereas the heartwood is light pinkish yellow to pale brown with a purplish cast, darkening on exposure to silvery brown with a faint tinge of red. The wood is soft, somewhat lustrous, even- and generally straight-grained, medium-textured, non-resinous, without characteristic taste or odor. Flat grain boards exhibit a distinct but not conspicuous growth ring. The springwood zone is usually one to two times the width of the summerwood. In x-section the rays are very fine and are not visible with the naked eye except where they include a horizontal resin canal. In r-section they are darker than the background and form a fine, rather conspicuous fleck. Both longitudinal and horizontal resin canals are normally present. The longitudinal canals are fairly large, appearing as white flecks in the dark heartwood with the naked eye, sparse to fairly numerous, solitary or 2 or more contiguous tangentially and irregularly distributed. The horizontal canals are smaller than the longitudinal but are visible against the dark background of heartwood as whitish rays. Parenchyma are absent.

Microscopic Structure

Tracheids. 18 to 62 mu (average, 36 mu) in diameter and 5.7 mm. in length; bordered pits are in 1 to 2 rows on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading

to ray parenchyma small, uniform in size, oval to angular (piciform) with distinct border, 1 to 4 (generally 2 to 3) per ray crossing; ray tracheid pits present. Volume occupied, 92.5%.

Resin canals. Longitudinal, 58 to 120 mu (average, 87 mu) in diameter; horizontal, less than 35 mu; thick-walled epithelial cells, tylosoids. Volume occupied, 0.3%.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous, 1 to 53 cells (944 mu) high; the fusiform rays are scattered, with a horizontal resin canal, 3 to 5 seriate in the central portion, tapering to uniseriate margins, up to 60 cells (1060 mu) high; ray tracheids are present in both types of rays, usually restricted to one row on the upper and lower margins, with nondentate inner walls. Ray parenchyma in the heartwood generally with gummy infiltration. Five rays per mm. tangentially on x-section and 20 rays per sq. mm. on t-section. Volume occupied, 7.2%.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.37
	oven-dry volume	0.42
Density, lb./cu. ft.	green	33
	air-dry	26
	oven-dry	26

Moisture content, when green: 42% based on oven-dry weight (30% on green basis).

Shrinkage, from green condition: v, 11.5%; r, 4.3%; t, 7.5%.

Thermal conductivity: 0.68 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 22,400 megohms at 7% moisture content.
165 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile strength ⊥, lb./sq. in.	—	370
Compressive stress at p.l. //, lb./sq. in.	2240	4780
Compressive stress at p.l. ⊥, lb./sq. in.	340	710
Shear, maximum stress //, lb./sq. in.	760	1150
Static bending FSPL, lb./sq. in.	3300	6700
Static bending E, lb./sq. in.	1.23×10^6	1.57×10^6
Static bending R, lb./sq. in.	5700	10,200
Toughness, in.	24	25
Hardness //, lb.	430	760
Hardness ⊥, lb.	350	510
Cleavability, lb./in. width	165	220

Chemical Properties

Calorific value: 15.9×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	F.P.L.	Bloom, Jahn, and Wise (1)
Hot-water soly., %	5.0	2.8
Ether soly., %	0.8	0.31
Alcohol-benzene soly., %	4.5	2.3
1% NaOH soly., %	14.9	
Pentosans, %	9.0	8.1
Lignin, %	29.6	27.4
C. & B. cellulose, %	60.5	63.3
Alpha-cellulose, %	44.8	

1. Paper Trade J. 115, no. 10:33-40(Sept. 3, 1942); this article also includes data on ethanolamine cellulose and the correlation between the number of chlorinations and lignin content in C. & B. cellulose.

Pathology

Resistance to decay: low +.

Red ring rot, red heart (Fomes pini) in heartwood. Red root rot (Polyporus circinatus) in living heartwood. Red stain discoloration occurring on rough lumber. Red-brown butt rot in heartwood of living trees caused by Polyporus schweinitzii. White mottled rot caused in dead timber by Fomes applanatus.

Asemum atrum - spruce borer common in Northwest; Buprestis aurulenta - the golden buprestid; Dendroctonus obesus - Sitka spruce beetle; Dryocoetes affaber - bark beetle; Gnathotrichus sulcatus - ambrosia, wood stainer of sapwood; Ips concinnus - engraver beetle in bark kills tree; Melanophila drummondi - cambium miner; Peronea variana - hemlock budworm, partial defoliator; Pissodes sitchensis - weevil, greatly injurious at times; Xylotrechus undulatus - beetle.

Utilization

Use properties. Works easily and takes a smooth silvery finish; nails without splitting and holds nails well; takes paints and enamels well; excellent gluing properties; large clear timber available; resilient.

Lumber. Washington, Oregon, and California. Airplane construction (2%), millwork (20%), sounding boards (2%), ladder sides, boats, boxes and crates (50%), woodenware, and novelties. Average annual production for 1928-1937 period was 179 million bd. ft.

Pulping. Similar to white spruce although slightly coarser in texture; mechanical pulp slightly grayish in color. Yields: sulfite, 49%; sulfate, 48%; soda, 42%; mechanical, 95%. Average annual consumption for 1926-1935

period was 85,000 cords in United States.

Supply. In 1930, the volume of saw timber was estimated at 11.6 billion bd. ft. for United States, 16.1 billion bd. ft. for British Columbia, and 18.5 billion bd. ft. for Alaska. More recently the United States stand has been estimated at 2.6 billion cu. ft.

JACK PINE

Scientific Name. Pinus banksiana Lambert.

Synonyms. Scrub pine, gray pine, Banks pine.

Family Name. Pinaceae.

Range. Essentially a Canadian and Lake States species. From the St. Lawrence River just below Anticosti Island northwest to within 100 miles of the east side of James Bay, around James Bay and Hudson Bay to west central Mackenzie and extreme southeastern Yukon and northeastern British Columbia, east through central Alberta and Saskatchewan, south central Manitoba, central Minnesota, southern Wisconsin, central Michigan, southeastern Ontario, northern New York, Vermont and New Hampshire, to Maine and New Brunswick.

Dimensions. 60 to 70 feet tall and 10 to 20 inches in diameter.

Bark. Thin and brown, slightly tinged with red or dark gray, and irregularly divided into scaly ridges; volume, 9.8%.

Silvics. The tree has a scraggly appearance and prunes very poorly; the root system is widespreading and moderately deep. Jack pine is a pioneer tree and occurs in pure stands, or in open mixtures with aspen and white birch on dry, sandy soils.

Gross Features of the Wood. The sapwood of jack pine is white with a yellow tinge, and the heartwood has a reddish tinge. The wood is medium hard. It has a resinous, noncharacteristic odor and no characteristic taste. The springwood zone is usually much wider than the darker colored summerwood; the transition is more or less abrupt. Flat sawn boards exhibit a distinct but not conspicuous growth ring. In x-section the rays are very fine, not visible with the naked eye, and form a fine, close, inconspicuous flock on the quarter surface. Both longitudinal and horizontal resin canals are present and relatively inconspicuous with the naked eye. Parenchyma are absent.

Microscopic Structure

Tracheids. Average, 28 to 40 mu in diameter and 3.4 mm. in length; bordered pits in one row, rarely two on the radial walls; tangential pitting absent; pits leading to ray parenchyma variable in shape and size, 1 to 7 per ray crossing (generally 2 to 4); ray tracheid pits small and regular in form, with distinct border.

Resin canals. Longitudinal, 59 to 126 mu (average, 80 to 95 mu) in diameter; horizontal canals smaller; thin-walled epithelial cells.

Rays. Two types, uniseriate and fusiform; uniseriate rays numerous, up to 27 cells (562 mu) high; fusiform rays scattered, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 29 cells (575 mu) high. Ray tracheids both marginal and interspersed, the inter-

opposed usually being found in the higher rays; dentate inner walls. Five rays per mm. tangentially on the x-section and 27 per sq. mm. on the t-section.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.39
	oven-dry volume	0.46
Density, lb./cu. ft.	green	50
	oven-dry	29

Moisture content, when green: 105% based on oven-dry weight (51% on green basis).

Shrinkage, from green condition: v, 10.4%; r, 3.4%; t, 6.5%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2180	5400
Compressive stress at p.l. ⊥, lb./sq. in.	380	820
Shear, maximum stress //, lb./sq. in.	760	1120
Static bending FSPL, lb./sq. in.	3000	5000
Static bending E, lb./sq. in.	0.92×10^6	1.22×10^6
Static bending R, lb./sq. in.	5400	7900
Toughness, in.	30	35
Hardness //, lb.	380	660
Hardness ⊥, lb.	370	580
Cleavability, lb./in. width	180	200

Chemical Properties

Calorific value, 21.6×10^6 B.t.u. per air-dry cord.

Ether soly., 2.70, 3.24, 2.37, 1.91%.

Alcohol soly., 0.99, 1.71, 0.77%.

Hot-water soly., 5.98%.

Proximate analysis:

	F.P.L.	F.P.L.	F.P.L.	Chidester, et al.(1) Top	Middle	Butt	Chidester and McGovern (2) Sap	Heart
Hot-water soly., %	4.3	3.1	3.7	3.1	3.0	3.6	1.9	4.3
Ether soly., %	2.1	2.4	2.2	3.4	2.9	4.1	1.6	5.2
Alcohol-benzene soly., %	3.8	4.2		3.9	4.0	5.6	6.5	7.5
Pentosans, %		14.0		14.0	14.0	12.6	12.2	13.2
Lignin, %	27.0	29.9	28.5	27.5	27.0	26.3	27.0	25.5
C. & B. cellulose, %	59.1	58.3	58.7	56.8	58.0	57.4	59.2	55.2
Pentosans, %				11.3	11.2	10.8	8.7	11.1
Alpha-cellulose, %		42.8		42.0	42.2	41.4	44.0	39.3
1% NaOH soly., %	13.4	13.9		13.2	12.9	14.8	12.9	16.7

Data on holocellulose and C. & B. cellulose (3):

Holocellulose (based on extractive-free oven-dry wood), %	72.5
Alpha-cellulose, %	68.3*
Pentosans, %	15.0*
Acetyl, %	2.68*
Methoxyl, %	1.04*
Uronic anhydride, %	4.00*
C. & B. cellulose (based on extractive-free oven-dry wood), %	58.3
Pentosans, %	6.8**
Acetyl, %	1.76**
Methoxyl, %	0.73**
Uronic anhydride, %	1.88**

1. Paper Trade J. 109, no. 13:36-42(Sept. 28, 1939).
2. Paper Trade J. 110, no. 10:39-42(March 7, 1940).
3. Hajny and Ritter, Tech. Assoc. Papers 25:596(1942).

* Based on holocellulose.
** Based on C. and B. cellulose.

Pathology

Resistance to decay: moderately durable.

Red heart rot is caused by Fomes pini; brown sap stain; "red stain" caused by an unknown fungus.

Spruce budworm is a serious pest on open-grown stands, especially working in conjunction with jack pine sawfly; jack pine tip moth.

Utilization

Use properties. Works well; finishes well; holds nails well; seasons without difficulty; low, uniform shrinkage.

Lumber. Boxes and crates, ties.

Other uses. Ties, poles, posts, and piles.

Pulping. Sulfate reduces readily; unbleached pulp very strong and of fine structure; yield, 47%.

Yields: sulfite, 46%; soda, 42%; mechanical, 95%.

Supply. Total stand of white, red, and jack pine in New England and the Lake States was 50 million cords (1932); 46 million cu. ft. in Upper Michigan (1935); 15.6 billion cu. ft. of jack and lodgepole pines in Canada (1935).

LONGLEAF PINE

Scientific Name. Pinus palustris Miller.

Synonyms. Southern yellow pine, southern pine, yellow pine, hard pine.

Family Name. Pinaceae.

Range. Southern coastal plain from southeastern Virginia to eastern Louisiana, with the exception of southern Florida, and inland to central Georgia, north central Alabama, and central and southern Mississippi. Also in western Louisiana and extreme eastern Texas.

Dimensions. 80 to 120 feet tall and 2 to 2.5 feet in diameter.

Bark. Coarsely scaly, with rough plates on older trees; volume, 11.6%.

Silvics. Longleaf pine is a medium-sized to large tree with a long, clear bole, a small, open crown, and a very deep taproot with many wide-spreading, well-developed laterals. Best growth is made on well-drained sandy soils. In the southern part of its range this species often occupies low ridges or knolls, whereas slash pine is found in the more moist places. Pure open stands are typical with a small accumulation of needles or short grasses on the ground.

Gross Features of the Wood. The wood of longleaf pine cannot be separated from that of the other southern yellow pines; hence, the following description and the data under microscopic structure will suffice for all.

The sapwood is nearly white to yellowish, orange white or pale yellow, and the heartwood ranges through shades of yellow and orange to reddish brown or light brown. The wood is hard and moderately heavy to heavy, with a distinct resinous, noncharacteristic odor, and without a characteristic taste. The transition from springwood to summerwood is very abrupt, but the widths of each vary within wide limits. A distinct growth ring figure is present. Rays are very fine and are not visible with the naked eye except where they include a horizontal resin canal, forming a fine, close, inconspicuous fleck on the quarter surface. Both longitudinal and horizontal resin canals are present. The longitudinal ones appear as whitish or brownish flecks which are conspicuous or relatively conspicuous with the naked eye, plainly distinct with a hand lens, numerous, confined largely to the central and outer portions of the ring, solitary or rarely 2 to 3 contiguous in a tangential line, generally visible as relatively inconspicuous streaks along the grain. Horizontal rays are less conspicuous and appear as whitish, relatively inconspicuous wood rays spaced at irregular intervals on the transverse surface. Longitudinal parenchyma are absent.

Microscopic Structure

Tracheids. Average, 35 to 45 mu in diameter and 3.7 mm. in length; bordered pits in one row or not infrequently paired on the radial walls; tangential pitting absent; pits leading to ray parenchyma variable in size and shape, 1 to 6 (generally 2 to 5) per ray crossing; ray tracheid pits small and uniform in size, marginal and interspersed. Volume occupied, 90.8%.

Resin canals. Longitudinal, 90 to 150 mu in diameter; horizontal, less than 70 mu; thin-walled epithelial cells; tylosoids common in the heartwood. Volume occupied, 0.8%.

Rays. Two types, uniseriate and fusiform. The uniseriate rays are numerous and 1 to 8+ cells high. The fusiform rays are scattered, with a horizontal resin canal, 2 to 4 seriate in the central portion, tapering to uniseriate margins, up to 12+ cells high. Ray tracheids occur in both types of rays, marginal and interspersed; dentate inner walls; marginal and interspersed tracheids often in several rows; low rays frequently consisting entirely of ray tracheids; ray parenchyma thin-walled. Volume occupied, 8.4%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.54
	oven-dry volume	0.62
Density, lb./cu. ft.	green	55
	oven-dry	39

Moisture content, when green: 63% based on oven-dry weight (39% on green basis).

Shrinkage from green condition: v, 12.2%; r, 5.1%; t, 7.5%.

Thermal conductivity: 0.96 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 25,000 megohms at 7% moisture content.
270 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	330	470
Compressive stress at p.l. //, lb./sq. in.	3430	6150
Compressive stress at p.l. ⊥, lb./sq. in.	590	1190
Shear, maximum stress //, lb./sq. in.	1040	1500
Static bending FSPL, lb./sq. in.	5200	9300
Static bending E, lb./sq. in.	1.60×10^6	1.99×10^6
Static bending R, lb./sq. in.	8700	14,700
Toughness, in.	35	34
Hardness //, lb.	550	920
Hardness ⊥, lb.	590	870
Cleavability, lb./in. width	210	270

Chemical Properties

Composition of ash: K_2O, 10.3; Na_2O, 2.3; CaO, 37.2; MgO, 4.2; P_2O_5, 2.7; SO_3, 4.3; Cl, 0.2; SiO_3, 3.4; Fe_2O_3, 2.8; C, 1.1; CO_2, 31.5%.

Calorific value: 22.0×10^6 B.t.u. per air-dry cord.

Destructive distillation: 35 gallons of crude tars and oils and 345 pounds of charcoal per ton.

Ethanol production: 25 gallons per ton.

Proximate analysis:

	Chidester, et al. (1)	F.P.L.	F.P.L.
Ash, %		0.37	
Hot-water soly., %	2.4	7.15	3.1
Cold-water soly., %		6.20	
1% NaOH soly., %	11.1	22.4	
Ether soly., %	2.9	6.32	2.1
Alcohol-benzene soly., %	4.3		
Acetic acid, %		0.76	
Methoxyl, %		5.05	
Pentosans, %	12.4	11.1	
C. & B. cellulose, %	58.8	58.5	58.6
Pentosans, %	10.2	8.87	
Alpha-cellulose, %	44.3		
Lignin, %	27.9		30.8
Mannan, %		4.75	

1. Paper Trade J. 107, no. 4:37(July 28, 1938).

Pathology

Resistance to decay: intermediate.

Blue stain caused by Ceratostomella is very common in logs and lumber.

Buprestis apricans beetle attacks injured, dying and dead pines; Chalcophora beetles mine wood; black turpentine beetle (Dendroctonus terebrans); engraver beetles (Ips calligraphus and I. grandicollis).

Utilization

Use properties. Hard, heavy, durable, stiff, strong, tough; the less dense type holds nails well; does not split easily, takes paint well.

Lumber. Planing mill products (framing, sheathing, trip, sash, doors, etc.), heavy construction, bridges, poles, piles, ties, posts, boxes and crates, flooring, props, tanks, silos, furniture, paving blocks, ships, vehicles.

Pulping. Yields: sulfite, 48%; sulfate, 48%; soda, 40%; mechanical, 95%.

Other uses. Turpentine and rosin (gum and wood). Steam solvent: 6.5 gallons of turpentine, 6.2 gallons of pine oil, and 350 pounds of rosin per ton of stumpwood.

Supply

625 million cords of all species of southern yellow pine in 1933.
3.3 million cords in eastern Texas (1935).
270 million cu. ft. in eastern Texas (1935).
1 billion bd. ft. in northeastern Florida (1934).
1.5 billion bd. ft. in southern Georgia (1934).

SLASH PINE

Scientific Name. Pinus caribaea Morelet.

Synonym. Swamp pine.

Family Name. Pinaceae.

Range. Southern tip of South Carolina through central Georgia, south central Alabama, southern Mississippi to eastern tip of Louisiana. Also in the Bahamas, Isle of Pines, Cuba, Honduras, and eastern Guatemala.

Dimensions. 80 to 90 feet tall and 2 feet in diameter.

Bark. Deeply furrowed on young trees, later becoming plated and 0.75 to 1.5 inches thick, with thin papery, orange or silvery scales; volume, 15.6%.

Silvics. Slash pine has a long, cylindrical bole, a dense rounded crown, and a deep root system. In old stands this species occupies the moist depressions, but on cutover lands it is very aggressive and quickly takes over abandoned land which is at all moist.

Gross Features of the Wood. The wood cannot be separated from that of the other southern yellow pines. See description under longleaf pine.

Microscopic Structure. See longleaf pine except for the following data:

Tracheids. 28 to 58 mu (average, 43 mu) in diameter.

Resin canals. 185 to 296 mu (average, 185 to 220 mu) in diameter.

Rays. Uniseriate, up to 16 cells (385 mu) high; fusiform, up to 27 cells (666 mu) high; 20 rays per sq. mm. on tangential surface.

Nonmechanical Physical Properties

Specific gravity	green volume	0.56
	oven-dry volume	0.66
Density, lb./cu. ft.	green	58
	oven-dry	41

Moisture content, when green: 66% based on oven-dry weight (40% on green basis).

Shrinkage, from green condition: v, 12.2%; r, 5.5%; t, 7.8%.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	400	570
Compressive stress at p.l. //, lb./sq. in.	3040	6280
Compressive stress at p.l. ⊥, lb./sq. in.	680	1390
Shear, maximum stress //, lb./sq. in.	1000	1730
Static bending FSPL, lb./sq. in.	5100	9800
Static bending E, lb./sq. in.	1.58×10^6	2.06×10^6
Static bending R, lb./sq. in.	8900	15,900
Toughness, in.	36	36
Hardness //, lb.	600	1080
Hardness ⊥, lb.	630	1010
Cleavability, lb./in. width	230	290

Chemical Properties

Destructive distillation: Tar, oil, charcoal.

Proximate analysis:

	Schwartz and Bray (1)	Chidester, et al.(2)	F.P.L.	Max (3)
Hot-water soly., %	3.9	1.9	3.6	2.27
Ether soly., %	5.1	1.4	3.3	2.99
Alcohol-benzene soly., %	6.4	2.7		12.6
Pentosans, %	9.1	12.3		28.2
Lignin, %	24.9	27.3	27.6	0.55
Uronic acids, %				54.5
C. & B. cellulose, %	58.7	60.5	59.8	
Pentosans, %	7.5	8.5		
Alpha-cellulose, %	47.6	45.7		
1% NaOH soly., %	14.7	11.2		
Mannan, %			7.50	

Lower one row

Composition of ether extractives (based on original wood) (3):

	Green Wood	Seasoned Wood
Unsaponifiables, %	0.26	0.19
Rosin acids, %	0.97	0.64
Saturated fatty acids, %	0.05	0.03
Unsaturated fatty acids, %	0.82	0.44

1. Paper Trade J. 113, no. 10:33(Sept. 4, 1941).
2. Paper Trade J. 107, no. 4:37(July 28, 1938).
3. Ph. D. thesis, The Institute of Paper Chemistry, 1943.

Pathology

Resistance to decay: intermediate.

Twig and branch girdling canker (Atropellis tingens).

Utilization. Similar to longleaf pine, including turpentine and rosin.

Supply

625 million cords of all species of southern yellow pine in 1933.
1.6 billion bd. ft. in northeastern Florida (1934).
2.7 billion bd. ft. in southern Georgia (1934).

LOBLOLLY PINE

Scientific Name. Pinus taeda Linnaeus.

Synonym. Oldfield pine.

Family Name. Pinaceae.

Range. Central Delaware south to central Florida and west to southeastern Texas; thence north to southeastern Oklahoma, central Arkansas, along the southern boundary of Tennessee to central North Carolina, and north on the coastal plain. Not found in the bottomlands of the Mississippi River.

Dimensions. 90 to 110 feet tall, and 2 to 2.5 feet in diameter.

Bark. Variable, on young trees scaly and nearly black; later 0.75 to 2.0 inches thick, with irregular brownish blocks; on very old trees with reddish-brown scaly plates similar to those on shortleaf pine or red pine; volume, 10.5%.

Silvics. The tree is medium-sized to large, with a long, cylindrical bole, an open crown, and an extensive lateral root system. In virgin stands loblolly pine was found typically with hardwoods along streams, or in the bottoms. On drier soils nearly pure stands occurred, and throughout its range various mixtures were found with the other southern pines. On cutover lands this species has spread remarkably and is especially aggressive in forming pure stands on old fields.

Gross Features of the Wood. Similar to longleaf pine.

Microscopic Structure. See longleaf pine, except for the following data:

Tracheids. 28 to 53 mu (average, 38 mu) in diameter.

Rays. Uniseriate, up to 19 cells (496 mu) high; fusiform, up to 25 cells (651 mu) high.

Nonmechanical Physical Properties

Specific gravity	green volume	0.47
	oven-dry volume	0.54
Density, lb./cu. ft.	green	53
	oven-dry	34

Moisture content, when green: 81% based on oven-dry weight (45% on green basis).

Shrinkage, from green condition: v, 12.3%; r, 4.8%; t, 7.4%.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	260	470
Compressive stress at p.l. //, lb./sq. in.	2550	4820
Compressive stress at p.l. ⊥, lb./sq. in.	480	980
Shear, maximum stress //, lb./sq. in.	850	1370
Static bending FSPL, lb./sq. in.	4100	7800
Static bending E, lb./sq. in.	1.41×10^6	1.80×10^6
Static bending R, lb./sq. in.	7300	12,800
Toughness, in.	30	30
Hardness //, lb.	420	750
Hardness ⊥, lb.	450	690
Cleavability, lb./in. width	180	270

Chemical Properties

See following page.

Pathology

Resistance to decay: intermediate.

Nantucket tip moth attacks young trees; southern pine bark beetle.

Eastern gall rust and southern fusiform rust prevalent in stands containing scrub oak, the alternate host.

Utilization

Use properties, lumber, and pulping similar to longleaf pine.

Supply

625 million cords of all species of southern yellow pine in 1933.
717 million bd. ft. in northeastern Florida (1934).
4.5 billion bd. ft. in eastern Texas (1935).
2 billion bd. ft. in southern Georgia (1934).

Chemical Properties

Proximate analysis:

	F.P.L.	Chidester, et al. (1)	Seasoned Heartwood (2)	Max (3)	Ritter and Fleck (4) Sapwood Spring	Sapwood Summer	Heartwood Spring	Heartwood Summer
Hot-water soly., %	1.8	3.1	4.6		3.49	2.97	7.16	6.44
Cold-water soly., %					3.28	2.18	7.5	7.64
Ether soly., %	1.9	2.5	2.6	1.83				
Alcohol-benzene soly., %	2.7	3.8	4.9	2.76				
1% NaOH soly., %	9.9	13.4	13.6		11.1	11.0	18.1	21.2
Acetic acid, %					1.28	1.41	1.00	1.11
Methoxyl, %					4.05	4.18	6.17	6.88
Pentosans, %	12.4	12.6	11.3	8.8	11.6	11.1	12.8	12.1
Lignin, %	28.3	28.1	28.2	27.1	28.1	26.8	26.8	24.2
Uronic acids, %				0.79				
C. & B. cellulose, %	58.7	59.3	57.8	59.0	58.1	61.2	53.4	52.9
Pentosans, %		9.3	10.0		8.78	8.69	11.5	11.2
Alpha-cellulose, %	45.7	43.3	43.0					
Mannan, %	5.10							

1. Paper Trade J. 107, no. 4:37(July 28, 1938).
2. Tech. Assoc. Papers 25:679(1942).
3. Ph. D. thesis, The Institute of Paper Chemistry, 1943.
4. Ind. Eng. Chem. 18:608(1926).

SHORTLEAF PINE

Scientific Name. Pinus echinata Miller.

Synonym. Yellow pine.

Family Name. Pinaceae.

Range. Staten Island west through central Pennsylvania, southern Ohio, central Kentucky, southern Missouri, eastern Oklahoma, and eastern Texas. It does not grow near the Gulf Coast, in the higher Appalachians, or in the immediate vicinity of the Mississippi River.

Dimensions. 80 to 100 feet tall and 2 to 3 feet in diameter.

Bark. Nearly black, roughly scaly, with small surface pockets or holes on small trees; later reddish brown and broken into irregular flat plates, scaly on the surface; volume, 11.9%.

Silvics. The tree is medium-sized to large with a clear well-formed bole, a small narrowly pyramidal crown, and a very deep taproot. This species is most common in pure or mixed stands on dry upland soils. On more moist soils, it is frequently associated with red gum and bitternut hickory.

Gross Features of the Wood. See longleaf pine.

Microscopic Structure. See longleaf pine.

Nonmechanical Physical Properties

Specific gravity	green volume	0.46
	oven-dry volume	0.54
Density, lb./cu. ft.	green	52
	oven-dry	34

Moisture content, when green: 81% based on oven-dry weight (45% on green basis).

Shrinkage, from green condition: v, 12.3%; r, 4.4%; t, 7.7%.

Thermal conductivity: 0.98 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 43,600 megohms at 7% moisture content.
255 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	320	470
Compressive stress at p.l. //, lb./sq. in.	2500	5090
Compressive stress at p.l. ⊥, lb./sq. in.	440	1000
Shear, maximum stress //, lb./sq. in.	850	1310
Static bending FSPL, lb./sq. in.	3900	7700
Static bending E, lb./sq. in.	1.39×10^6	1.76×10^6
Static bending R, lb./sq. in.	7300	12,800
Toughness, in.	30	33
Hardness //, lb.	410	750
Hardness ⊥, lb.	440	690
Cleavability, lb./in. width	200	270

Chemical Properties

Proximate analysis:

	Chidester, et al. (1)	F.P.L.
Hot-water soly., %	2.1	2.6
Ether soly., %	2.3	2.0
Alcohol-benzene soly., %	3.0	
Pentosans, %	12.1	
Lignin, %	26.4	29.0
C. & B. cellulose, %	62.2	58.8
Pentosans, %	9.5	
Alpha-cellulose, %	47.2	
1% NaOH soly., %	11.2	

1. Paper Trade J. 107, no. 4:37(July 28, 1938).

Pathology

Resistance to decay: intermediate.

Nantucket tip moth attacks young trees.

Utilization

Use properties, lumber, and pulping similar to longleaf pine.

Supply

625 million cords of all species of southern yellow pine (1933).
1.9 billion bd. ft. in eastern Texas (1935).

VIRGINIA PINE

Scientific Name. Pinus virginiana Miller.

Synonyms. Scrub pine, Jersey pine.

Family Name. Pinaceae.

Range. Long Island through north central Pennsylvania and southern Ohio to southern Indiana; south to central Alabama and east to Savannah.

Dimensions. 30 to 40 feet tall and 12 to 15 inches in diameter.

Bark. Bark thin and smooth, eventually scaly-plated.

Silvics. This species is chiefly characterized by its ability to grow on the poorest of dry soils; abandoned farm lands in many localities support pure stands. Seed is produced in abundance and shows a high percentage of germination. The tree has a shallow root system at maturity.

Physical Properties

Density, lb./cu. ft.	oven-dry	26

Utilization

Pulping. Sulfate process reduces rapidly; yield, 45 to 50% strong pulp; 38 to 43% for bleaching.

Lumber. Little used except perhaps locally.

SPRUCE PINE

Scientific Name. Pinus glabra Walter.

Synonym. White pine.

Family Name. Pinaceae.

Range. Coast region from South Carolina (Santee River) to northern Florida to northeastern Louisiana.

Dimensions. 80 to 90 feet tall and 2 to 2-1/2 feet in diameter.

Bark. Bark is gray, on old trees closely furrowed, with narrow ridges.

Silvics. It occurs as a scattered tree, or occasionally in pure groups, on moist, fresh, sandy loam soils intermediate between the dry sandy soils of the pine lands and those of alluvial origin in the bottoms. Commonly associated with cucumber magnolia, red gum, beech, hickory, shortleaf and loblolly pines.

RED PINE

Scientific Name. Pinus resinosa Aiton.

Synonym. Norway pine.

Family Name. Pinaceae.

Range. Central Nova Scotia through all New Brunswick, southern Quebec, central Ontario to southeastern Manitoba; south and east through southeastern Minnesota, central Wisconsin and Michigan, southern Ontario, northeastern Ohio, south central Pennsylvania, and northeast to the vicinity of Boston.

Dimensions. 50 to 80 feet tall and 2 to 3 feet in diameter.

Bark. Flaky and orange red on young trees, eventually breaking up into large, flat, reddish-brown, superficially scaly plates irregularly diamond-shaped in outline.

Silvics. The tree has a symmetrical oval crown, a well-formed, long, cylindrical bole, and a spreading root system. Formerly magnificent pure and mixed stands grew in the Lake States. Now on cutover lands red pine appears to be following jack pine and is often found in mixture with it.

Gross Features of the Wood. The sapwood is white to yellowish, and the heartwood is light red to orange brown or reddish brown. The wood is moderately hard and moderately heavy, and has a fairly strong, resinous, noncharacteristic odor, without a characteristic taste. The springwood zone is generally wide; the transition from springwood to summerwood is more or less abrupt; the summerwood zone is narrow to fairly wide, darker and appreciably denser than the springwood zone. Flat grain boards exhibit a distinct, inconspicuous growth ring. In the x-section the rays are very fine, not visible with the naked eye, appearing whitish with a lens where they contain a horizontal resin canal, and forming a fine, close, inconspicuous fleck on the radial surface. Both longitudinal and horizontal resin canals are present. The longitudinal canals are relatively inconspicuous with the naked eye, appearing as minute, brownish flecks, relatively conspicuous with a hand lens, numerous, confined largely to the central and outer parts of the ring, solitary or rarely 2 to 3 contiguous in a tangential line, not visible or forming relatively inconspicuous streaks along the grain. The horizontal canals are less conspicuous than the longitudinal canals, appearing as whitish, radial lines spaced at irregular intervals on the transverse surface. Longitudinal parenchyma are absent.

Microscopic Structure

Tracheids. 22 to 40 mu (average, 27 to 32 mu) in diameter and 3.4 mm. in length; bordered pits in one or two rows on the radial walls; tangential pitting absent or very sporadic in the last few rows of summerwood tracheids; pits leading to ray parenchyma large, windowlike, 1 to 2

(mostly 1) per ray crossing; ray tracheid pits small and uniform in size.

Resin canals. 67 to 104 mu (average, 89 mu) in diameter; horizontal, usually less than 50 mu; thin-walled epithelial cells; frequently occluded with tylosoids in the heartwood.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous and 1 to 15 cells (333 mu) in height; the fusiform rays are scattered and contain a transverse resin canal, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 23 cells (422 mu) in height. Ray tracheids are present in both types of rays; marginal and interspersed; dentate inner walls. 4 rays per mm. tangentially on the x-section; 21 to 25 rays per sq. mm. on the tangential surface.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.44
	oven-dry volume	0.51
Density, lb./cu. ft.	green	42
	oven-dry	32

Moisture content, when green: 54% based on oven-dry weight (35% on green basis).

Shrinkage, from green condition: v, 11.5%; r, 4.6%; t, 7.2%.

Thermal conductivity: 0.84 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	190	490
Compressive stress at p.l. //, lb./sq. in.	2410	5330
Compressive stress at p.l. ⊥, lb./sq. in.	360	830
Shear, maximum stress //, lb./sq. in.	780	1230
Static bending FSPL, lb./sq. in.	3700	9400
Static bending E, lb./sq. in.	1.38×10^6	1.80×10^6
Static bending R, lb./sq. in.	6400	12,500
Toughness, in.	28	25
Hardness //, lb.	360	670
Hardness ⊥, lb.	340	580
Cleavability, lb./in. width	160	200

Chemical Properties

Calorific value: 19.7×10^6 B.t.u. per air-dry cord.

Alcohol production: 23 gallons of ethanol per ton.

Proximate analysis:

	McMillen, et al. (1)
Ash, %	0.23
Pentosans (Bailey's method), %	3.2
Lignin, %	25.1
C. & B. cellulose, %	62.4
Alpha-cellulose, %	46.1
"Total extractives," %	4.4

1. Ind. Eng. Chem. 30:1408(1938).

Pathology

Resistance to decay: moderately durable.

Red heart rot (Fomes pini); red-brown butt rot (Polyporus schweinitzii); brown sap stain.

European tip moth (Rhyacionia frustrana) shows evidence of becoming a serious pest.

Utilization

Use properties. Easy to work, takes a good finish, holds nails and screws well, easily treated with preservatives, seasons easily, medium shrinkage.

Lumber. Structural timber, poles, piles, tanks, car construction, boxes and crates, general millwork; lower grades mixed with white pine and sold as eastern white pine.

Pulping. Sulfate process. Reduces readily; unbleached pulps very strong; yield about 50%. Newsprint has been made from young red pine (23 years old) at the New York State College of Forestry.

Supply

4 billion bd. ft. saw timber in the United States (1939).
84 million bd. ft. saw timber in Upper Michigan (1935).
0.9 billion cu. ft. in Canada (1935).
White, red, and jack pines totaled 66 million cords in the United States (1933).

WHITE PINE

Scientific Name. Pinus strobus Linnaeus.

Synonyms. Northern white pine, eastern white pine.

Family Name. Pinaceae.

Range. From Newfoundland west to southeastern Manitoba; south to central Iowa; east to northeastern Ohio; south in the Appalachians to northern Georgia; on the coast from central New Jersey northward.

Dimensions. 80 to 100 feet tall and 2 to 3.5 feet in diameter.

Bark. On young stems thin and smooth, dark green, soon furrowed; on old trees 1 to 2 inches thick, deeply and closely fissured into narrow, roughly rectangular blocks, minutely scaly on the surface; volume, 12.5%.

Silvics. The forest tree has a tall, clear, cylindrical bole, a crown composed of several nearly horizontal or ascending branches, and a moderately deep root system without a taproot. Best development is made on moist sandy loam soils, or those with a small proportion of clay. In Canada, pure stands or mixtures with red pine and spruce frequently occur, whereas in the Northeast, in addition to limited pure groups, white pine occurs on sandy loams with the northern hardwoods, red spruce, and hemlock. Relatively little now grows in the Lake States where once magnificent stands flourished.

Gross Features of the Wood. The sapwood is white to pale yellowish white and the heartwood is cream colored to light brown or reddish brown, turning much darker on exposure. The wood is soft, light, even-textured, and has a slightly resinous noncharacteristic odor and no taste. Flat grain boards show a faint growth ring. The springwood is usually wide and the transition to summerwood gradual. In the x-section the rays are very fine, not visible with the naked eye except where they include a horizontal resin canal, forming a fine, close, inconspicuous fleck on the r-surface. Both horizontal and longitudinal resin canals are present. The longitudinal canals appear as whitish flecks with the naked eye, numerous, confined largely to the central and outer portions of the ring, solitary or rarely 2 to 3 contiguous in a tangential line, forming more or less prominent streaks along the grain. The horizontal canals appear as whitish, rather prominent wood rays spaced at irregular intervals on the transverse surface. Parenchyma cells are absent.

Microscopic Structure

Tracheids. 25 to 35 mu in diameter and 3.1 mm. in length; bordered pits in one row or occasionally paired on the radial walls, tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma large, windowlike, 1 to 2 (generally 1) per ray crossing; volume occupied, 94.0%.

Resin canals. Longitudinal, 90 to 120 mu in diameter; horizontal, less than 60 mu; thin-walled epithelial cells; frequently occluded with tylosoids in the heartwood; volume occupied, 0.7%.

Rays. Two types, uniseriate and fusiform; the uniseriate rays are numerous and 1 to 8+ cells high; the fusiform rays are scattered, with a horizontal resin canal, 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 12+ cells in height. Ray tracheids are present in both types of rays, marginal and interspersed, nondontate inner walls. Volume occupied, 5.3%.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.34
	oven-dry volume	0.37
Density, lb./cu. ft.	green	36
	oven-dry	23

Moisture content, when green: 68% based on oven-dry weight (40% on green basis).

Shrinkage, from green condition: v, 8.2%; r, 2.3%; t, 6.0%.

Thermal expansion: // 0.00000365; ⊥ 0.0000636.

Thermal conductivity: 0.83 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 20,900 megohms at 7% moisture content.
200 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	240	300
Compressive stress at p.l. //, lb./sq. in.	2060	3680
Compressive stress at p.l. ⊥, lb./sq. in.	290	550
Shear, maximum stress //, lb./sq. in.	660	860
Static bending FSPL, lb./sq. in.	3100	6000
Static bending E, lb./sq. in.	1.02×10^6	1.28×10^6
Static bending R, lb./sq. in.	5000	8800
Toughness, in.	17	19
Hardness, //, lb.	310	500
Hardness ⊥, lb.	310	400
Cleavability, lb./in. width	140	160

Chemical Properties

Calorific value: 17.1×10^6 B.t.u. per air-dry cord.

Alcohol production: 22.5 gallons of ethanol per ton.

Proximate analysis:

	Martin and Bray (1)	Ritter and Fleck (2) Sap	Heart
Ash, %		0.23	0.42
Hot-water soly., %	4.6	5.15	7.68
Cold-water soly., %		3.55	5.97
Ether soly., %	3.0	5.46	3.62
1% NaOH soly., %	16.2	17.2	19.2
Acetic acid, %		1.68	1.43
Methoxyl, %		4.16	4.6
Pentosans, %	10.6	9.31	8.56
Lignin, %	27.5	26.5	26.1
C. & B. cellulose, %	60.0	54.3	50.2
Pentosans, %		6.8	7.1
Alpha-cellulose, %	44.0	29.6	28.8
Alcohol-benzene soly., %	6.9		

1. Paper Trade J. 111, no. 25:36(Dec. 19, 1940).
2. Ind. Eng. Chem. 15:1056(1923).

Pathology

White pine blister rust (Cronartium ribicola); feather rot (Poria subacida); red heart rot (Stereum sanguinolentum); red heart (Fomes pini); butt rot (Polyporus circinatus); red-brown butt rot (Polyporus schweinitzii).

White pine weevil (Pissodes strobi); engraver beetle (Ips); Chalcoplora virginiensis beetle; Monochamus confusor beetle.

Utilization

Use properties. Seasons easily and shrinks little; light, soft, fine-grained, even-textured; works easily; takes paint, etc., perfectly; polishes well, glues well, holds nails well.

Lumber. 450 million bd. ft. cut annually from 1928 - 1937; loading producers are Maine, New Hampshire, and Minnesota; planing mill products, boxes and crates, tanks, furniture, patterns, shipbuilding, general millwork, pails, cabinets.

Pulping. Sulfate process reduces readily; unbleached pulp very strong. Yields: sulfate, 47%; soda, 42%; mechanical, 95%.

Other uses. Excellent wood flour for linoleum.

Supply

White, red, and jack pines totaled 66 million cords in United States (1933).
12 billion bd. ft. of white pine saw timber in United States (1939).
813 million bd. ft. in Upper Michigan (1935).
2.6 billion cu. ft. in Canada (1935).

PITCH PINE

Scientific Name. Pinus rigida Miller.

Synonyms. Yellow pine, black pine.

Family Name. Pinaceae.

Range. Eastern Maine west to vicinity of Kingston, Ontario; south through western New York to central Kentucky and northern Georgia; north in the Appalachians and to the coast in southeastern Virginia.

Dimensions. 50 to 60 feet tall and 1 to 2 feet in diameter.

Bark. On young trees dark in color, roughened, and deeply furrowed; with age it becomes rather smooth and yellowish, and breaks in irregular plates.

Silvics. This species is quite variable in form and location. It is very intolerant. It will invade poor, sterile sandy soils but makes its best growth where moisture is adequate. It grows in fairly open, pure stands, or in mixture with such hardwoods as black, chestnut, and scarlet oaks, red maple, chestnut, and black locust. In New England it is commonly a small tree growing on sandy soils with scrub oak and gray birch. The root system is at first deep but later becomes much more shallow.

Gross Features of the Wood. Most closely resembles shortleaf pine.

Microscopic Structure. See longleaf pine.

Nonmechanical Physical Properties

Specific gravity	green volume	0.45
	air-dry volume	0.49
	oven-dry volume	0.52
Density, lb./cu. ft.	green	50
	oven-dry	34

Moisture content, when green: 79% based on oven-dry weight (44% on green basis).

Shrinkage from green condition: v, 10.9%; r, 4.0%; t, 7.1%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	280	480
Compressive stress at p.l. //, lb./sq. in.	1950	3960
Compressive stress at p.l. /, lb. sq. in.	450	1010
Shear, maximum stress //, lb./sq. in.	860	1360
Static bending FSPL, lb./sq. in.	3600	6900
Static bending E, lb./sq. in.	1.2×10^6	1.43×10^6
Toughness, in.	28	31
Hardness //, lb.	420	700
Hardness /, lb.	470	620
Cleavability, lb./in. width	190	260

Pathology

No serious diseases. Deer browse young trees.

Southern pine beetle (Dendroctonus frontalis); pitch twig moth (Evetria constockiana); pitch midge (Diplosis resinicola); Lecontes sawfly (Lophyrus lecontei).

Utilization

Use properties. Moderately strong; medium stiffness; coarse-grained; rather brittle; younger trees have large amounts of sapwood; resinous; straight-grained; easy to split; easily worked; takes a good finish; takes paint fairly well.

Lumber. Makes good common lumber but naturally open-grown trees have many knots; the close-grown trees have wood which is straight-grained, free from knots, and relatively free from resin; structural work, flooring, wharves, bridges, slack cooperage, door frames, interior finish, wagon bodies, furniture, boxes, crates, ties, mine props.

Pulping. Sulfate process reduces readily; unbleached pulp very strong; yield, 48%; high-grade wrapping, fiberboard, book stock. Turpentine from digester relief.

Other uses. Tar, pitch.

Supply. No data available.

EASTERN HEMLOCK

Scientific Name. Tsuga canadensis (Linnaeus) Carriere.

Synonym. Hemlock.

Family Name. Pinaceae.

Range. From northern New Brunswick to Lake Superior about 100 miles north of the Soo, reappearing at Duluth; then south to south central Wisconsin, southern Michigan, eastern Ohio, and down the Appalachians to northern Alabama; in the East, south along the coast to New Jersey.

Dimensions. 60 to 70 feet tall and 2 to 3 feet in diameter.

Bark. On young trees flaky or scaly, soon with wide, flat ridges, and on old trees heavily and deeply furrowed.

Silvics. The tree is medium-sized with a tapered bole, a ragged crown, and a superficial, widespreading root system. Hemlock is found on many types of soil but it reaches its best development in cool, moist situations. In the north, the common associates include white pine, red spruce, sugar maple, beech and yellow birch; farther south, shagbark hickory, yellow poplar, basswood, and white and red oaks are common.

Gross Features of the Wood. The sapwood is buff to light brown and not distinct from the heartwood. The summerwood frequently has a roseate or reddish-brown tinge. The wood is soft to medium hard, medium weight, coarse and uneven-grained, dry and brittle, subject to windshake, uneven-textured; odorless or sour when fresh, without characteristic taste. Flat grain boards exhibit a distinct but not conspicuous growth ring. The springwood occupies at least two thirds of the ring and there is an abrupt transition to the summerwood, which is decidedly darker and denser than the springwood and varies in thickness. Normally, resin canals are absent and traumatic canals are rare. In the x-section the rays are very fine, not distinct with the naked eye, and form a fine, close, inconspicuous fleck on the radial surface. Parenchyma are not visible.

Microscopic Structure

Tracheids. 28 to 40 mu in diameter and 3.0 mm. in length; bordered pits in 1 to 2 (mostly 1) rows on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 5 (generally 3 to 4) per ray crossing; ray tracheid pits present; volume occupied, 94.0%.

Resin canals. Absent.

Rays. Uniseriate, 1 to 12+ cells in height; ray tracheids present, usually restricted to one row on the margins of the ray; volume occupied, 6.0%.

Longitudinal parenchyma. Terminal and very sparse, or absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.38
	oven-dry volume	0.43
Density, lb./cu. ft.	green	50
	oven-dry	27

Moisture content, when green: 74% based on oven-dry weight (42% on green basis).

Shrinkage, from green condition: v, 9.7%; r, 3.0%; t, 6.8%.

Thermal conductivity: 0.80 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	204	344
Compressive stress at p.l. //, lb./sq. in.	2600	4020
Compressive stress at p.l. ⊥, lb./sq. in.	440	800
Shear, maximum stress //, lb./sq. in.	850	1060
Static bending FSPL, lb./sq. in.	3800	6100
Static bending E, lb./sq. in.	1.07×10^6	1.20×10^6
Static bending R, lb./sq. in.	6400	8900
Toughness, in.	21	21
Hardness //, lb.	500	810
Hardness ⊥, lb.	400	500
Cleavability, lb./in. width	150	150

Chemical Properties

Calorific value: 17.9×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	Forest Products Laboratory				
C. & B. cellulose, %	53.0	52.8	56.5	55.2	54.4
Alpha-cellulose, %	37.8	40.1	42.5	40.3	
Lignin, %	34.5	34.8	34.2	32.7	34.1
Pentosans, %			9.5		
1% NaOH soly., %	14.0	12.8	11.7	12,4	
Hot-water soly., %	3.9	3.2	3.1	3.8	3.7
Alcohol-benzene soly., %	4.1	4.0	3.4	4.6	
Ether soly., %	0.5	1.2	0.2	0.6	0.6

Data on holocellulose and C. & B. cellulose [Paper Trade J. 108, no. 7:27 (Feb. 16, 1939)]:

Holocellulose (based on extractive-free wood), %	68.5
Alpha-cellulose, %	70.4*
Pentosans, %	8.9*
Acetyl, %	2.7*
Methoxyl, %	1.23*
Uronic anhydride, %	4.88*
C. & B. cellulose (based on extractive-free wood), %	56.0
Alpha-cellulose, %	77.1**
Pentosans, %	4.6**
Acetyl, %	1.94**
Methoxyl, %	0.33**
Uronic acid, %	1.88**

* Based on holocellulose.
** Based on C. and B. cellulose.

Pathology

Resistance to decay: low +.

Feather rot (Poria subacida); butt rot (Polyporus circinatus); white spongy rot (Ganoderma lucidum).

Buprestis striata beetles; spruce budworm; Melanophila fulvoguttata beetle; Dicerca tuberculata; hemlock spanworm (Ellopia).

Utilization

Pulping. Average annual cut in the period from 1929-1938 was 500,000 cords; leading producers are Wisconsin, Michigan, Maine.

Sulfite process. Reduces fairly readily; very strong, as compared with spruce sulfite; darker in color and with a decided reddish-gray tone; fibers somewhat coarser and more readily hydrated in the beater; fairly easily bleached; yield, 44%.

Sulfate process. Reduces readily; very strong; yield, 45%.

Mechanical process. Reduces fairly readily; slightly reddish in color, somewhat brittle; 50 to 60% more power required than for white spruce, to obtain standard strength; yield, 95%.

Lumber. 373 million bd. ft. cut annually from 1928-1937; leading producers are Wisconsin, Michigan, Pennsylvania, West Virginia; house construction, sheathing, lath, flooring, boxes and crates, studs and joists, ship building, bridge planks.

Use properties. Inclined to be splintery and cross-grained, strength moderate, shrinkage moderate, rather difficult to season because of tendency to twist, good nail holder, resists splitting.

Other uses. Hemlock oil from the steam distillation of leaves and twigs is used as perfumes in greases and shoe blackings, etc.; tannin from bark is used extensively as a tanning material.

Supply

600 million cu. ft. in Canada.
40 million cords in the United States (1933).
22 million cords in Upper Michigan (1935).

WESTERN HEMLOCK

Scientific Name. Tsuga heterophylla (Rafinesque) Sargent.

Synonyms. West Coast hemlock, hemlock.

Family Name. Pinaceae.

Range. Cook's Inlet, Alaska south along the coast to San Francisco Bay, extending east through northern Washington and northern Idaho to western Montana.

Dimensions. 125 to 175 feet tall and 2 to 4 feet in diameter.

Bark. The bark is thin, even on the largest trees, and is separated by deep narrow fissures into broad, flat, russet-brown ridges.

Silvics. The tree has a long, clear, symmetrical bole, a short, open, pyramidal crown, and a shallow widespreading root system. An abundance of soil and atmospheric moisture are necessary for the best growth. Western hemlock occurs in pure, dense, even-aged forests or as an occasional tree in mixed hardwood and coniferous stands. Nearly pure, extensive forests of hemlock occur in southeastern Alaska, coastal British Columbia, and western Washington. In the south they are largely restricted to the middle-upper western slopes of the Cascade and Olympic Mts. above the Douglas fir belt. This species often pre-empts cutover and burned-over areas formerly occupied by other species when moisture is not a limiting factor, because it is a constant and prolific seed producer.

Gross Features of the Wood. The sapwood, which is colored a light yellowish brown, is usually not distinct from the heartwood. Frequently the summerwood shows a faint roseate or reddish-brown tinge. The texture is fine and uniform, and the grain usually straight. There is a distinct but not conspicuous growth ring. The wood is medium hard, medium light, dry and brittle, odorless or sour when green, without characteristic taste. The springwood usually occupies at least two thirds of the annual ring and is lighter and less dense than the summerwood. The transition from springwood to summerwood is more or less gradual. In the x-section the rays are very fine, not distinct with the naked eye, and form a fine, close, inconspicuous fleck on the radial surface. Although resin canals are normally absent, longitudinal strands of traumatic resin cells or wound canals sometimes occur sporadically in tangential lines in widely separated annual rings. Longitudinal parenchyma are not visible.

Microscopic Structure

Tracheids. 35 to 45 mu in diameter and 4.2 mm. in length; bordered pits in 1 to 2 (mostly 1) rows on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 4 (generally 2 to 3) per ray crossing; ray tracheid pits present; volume

occupied, 91.2%.

Resin canals. Normally absent.

Rays. Uniseriate or very rarely biseriate, 1 to 16+ cells in height; ray tracheids present, usually restricted to one row on the margins of the ray; volume occupied, 8.8%.

Longitudinal parenchyma. Very sparse and terminal, or absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.38
	oven-dry volume	0.44
Density, lb./cu. ft.	green	41
	oven-dry	27

Moisture content, when green: 74% based on oven-dry weight (42% on green basis).

Shrinkage, from green condition: v, 11.9%; r, 4.3%; t, 7.9%.

Thermal conductivity: 0.76 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 22,900 megohms at 7% moisture content.
185 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	310	310
Compressive stress at p.l. //, lb./sq. in.	2480	5340
Compressive stress at p.l. ⊥, lb./sq. in.	390	680
Shear, maximum stress //, lb./sq. in.	810	1170
Static bending FSPL, lb./sq. in.	3400	6800
Static bending E, lb./sq. in.	1.22×10^6	1.49×10^6
Static bending R, lb./sq. in.	6100	10,100
Toughness, in.	22	26
Hardness //, lb.	520	940
Hardness ⊥, lb.	430	580
Cleavability, lb./in. width	190	200

Chemical Properties

Calorific value: 19.3×10^6 B.t.u. per air-dry cord.

Alcohol production: 23 gallons of ethanol per ton.

Proximate analysis:

	Forest Products Laboratory							McGovern and Chidester (1)			
								Sap	Heart	Sap	Heart
H. & B. cellulose, %	59.3	58.6	58.3	59.5	62.3	58.5	59.6	58.9	57.8	59.8	56.9
Pentosans, %										6.3	6.3
Alpha-cellulose, %	42.3	42.7	43.7	41.1	46.6	41.9		41.7	43.4	43.7	43.1
Lignin, %	30.5	30.3	31.2	28.9	29.8	30.2	30.2	30.1	31.8	28.8	29.5
Pentosans, %	9.6	9.1	8.7	9.3	10.2	9.4		8.4	8.3	8.6	8.3
1% NaOH soly., %	13.1	13.0	14.0	11.9	10.5	12.7		12.1	14.4	12.2	15.6
Hot-water soly., %	2.8	3.3	4.0	2.7	2.0	2.9	3.0	2.2	3.5	2.6	5.1
Ether soly., %	0.5	0.3	0.8	1.3	0.8	0.7	0.7	0.2	0.2	0.5	1.0
Alcohol-benzene soly., %	2.8	1.9	4.1	3.1	2.3	2.5		2.1	4.5	2.1	5.8

1. Paper Trade J. 107, no. 14:32(Oct. 6, 1938); average growth of all types; data also on slow, rapid, and very rapid growth classes in old and young trees.

Pathology

Resistance to decay: low +.

Butt rot prevalent in overmature trees or suppressed forest stands; brown stringy rot (Echinodontium tinctorium) severe; butt rot (Polyporus circinatus); white spongy rot (Ganoderma oregonense).

Dark streak in wood from hemlock maggot (Chilosia alaskensis); spruce budworm; hemlock spanworm; western hemlock wood stainer (Gnathotrichus sulcatus) mines sapwood; green hemlock looper (Nepytia phantasmaria); hemlock budworm (Peronea variana).

Utilization

Total cut estimated as equivalent to 1.25 billion bd. ft.

Use properties. Normally free from resin, light color, takes a beautiful finish, holds nails and screws well, high strength, high shrinkage, seasons well with care, pronounced silky sheen when dry.

Pulping. 1.7 million cords annually from 1936-1940; leading producers are Washington and Oregon.

Sulfite process. Reduces readily (more like spruce than eastern hemlock); unbleached pulp tough and strong (much lighter in color and finer in texture than eastern hemlock); yield, 46%.

Sulfate process. Reduces readily; unbleached pulp very strong and tough; yield, 47%.

Mechanical process. Reduces readily; good color and standard strength; power requirement 10 to 15% more than that for spruce.

Lumber. 333 million bd. ft. cut annually from 1931-1940 in Washington and Oregon; general construction, sheathing, lath, flooring, car construction, slack cooperage, boxes and crates, furniture, ladder rails, siding, studs, sash and doors, interior trim, veneers, ties (logging railroads chiefly).

Other uses. Bark suitable for tannin but not used because of cheaper competitors.

Supply

9 billion cu. ft. in Canada.
23 billion cu. ft. in the United States (1939).
274 million cu. ft. in the ponderosa pine region (1936).
124 billion bd. ft. in the United States (1940).

TAMARACK

Scientific Name. Larix laricina (Du Roi) Koch.

Synonyms. Larch, eastern larch, hackmatack.

Family Name. Pinaceae.

Range. Newfoundland; northern limit of tree growth from Labrador to Hudson Bay and northwestward to northern Yukon; south along eastern base of the Rockies to central Alberta; east to southeastern Manitoba, southeastern Minnesota, northern Illinois, and approximately on the latitude of New York City to the coast. Also in the Yukon River valley in Alaska.

Dimensions. 40 to 80 feet tall and 1 to 2 feet in diameter.

Bark. Thin and smooth on young stems, later becoming 0.5 to 0.75 inch thick; gray to reddish brown, scaly.

Silvics. The tree is small to medium-sized with a long, clear, cylindrical bole, an open pyramidal crown, and a shallow, widespreading root system. In the southern part of its range it is usually restricted to cool swamps or sphagnum bogs, but farther north it grows best on beaches and better drained uplands. In bogs black spruce is its chief associate; on drier land it occurs with black spruce, balsam fir, aspen, white birch, and jack pine. Unlike most coniferous trees, tamarack sheds its needles every autumn.

Gross Features of the Wood. The color of the sapwood is whitish and that of the heartwood is yellowish brown. The wood is moderately hard and heavy and has no characteristic taste or odor. The springwood usually occupies at least three quarters of the annual ring, and the transition to summerwood is abrupt. Flat grain boards exhibit a distinct growth ring figure because of the conspicuous summerwood. In the x-section the rays are very fine, not distinct with the naked eye, and form a fine, close, inconspicuous fleck on the radial surface. Both longitudinal and horizontal resin canals are present. The longitudinal canals are small, inconspicuous, not visible with the naked eye or appearing as whitish or dark flecks, sparse, confined largely to the central and outer portions of the ring, solitary or 2 or more contiguous tangentially. The horizontal canals are smaller than the longitudinal ones and appear with a hand lens as somewhat broader, whitish rays spaced irregularly on the transverse surface. Longitudinal parenchyma are not visible.

Microscopic Structure

Tracheids. Average, 25 to 35 mu in diameter and 3.6 mm. in length. Those in the summerwood occasionally have spiral thickening. Bordered pits in 1 to 2 rows on radial rows; tangential pits present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 12 (generally 4 to 6) per ray crossing; ray tracheid pits present; volume occupied, 89.0%.

Resin canals. Longitudinal, average 60 to 90 mu in diameter; horizontal, less than 25 mu. Thick-walled epithelial cells and no tyloses. Volume occupied, 0.1%.

Rays. Two types, uniseriate or rarely in part biseriate, and fusiform. The uniseriate rays are numerous and 1 to 16+ cells in height; the biseriate rays are very sparse and scattered, or absent. The scattered fusiform rays, which include a horizontal resin canal, are 2 to 3 seriate in the central portion, tapering to uniseriate margins, up to 16+ cells in height. Ray tracheids are present in both types of rays, marginal and very rarely interspersed, nondentate inner walls; marginal usually in one row. Volume occupied, 10.0%.

Longitudinal parenchyma. Terminal and very sparse, or absent. Volume occupied, 0.9%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.49
	oven-dry volume	0.56
Density, lb./cu. ft.	green	47
	air-dry	38
	oven-dry	35

Moisture content, when green: 52% based on oven-dry weight (34% on green basis).

Shrinkage, from green condition: v, 13.6%; r, 3.7%; t, 7.4%.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	260	400
Compressive stress at p.l. //, lb./sq. in.	2930	4780
Compressive stress at p.l. ⊥, lb./sq. in.	480	990
Shear, maximum stress //, lb./sq. in.	860	1280
Static bending FSPL, lb./sq. in.	4200	8000
Static bending E, lb./sq. in.	1.24×10^6	1.64×10^6
Static bending R, lb./sq. in.	7200	11,600
Toughness, in.	28	23
Hardness //, lb.	400	670
Hardness ⊥, lb.	380	590
Cleavability, lb./in. width	160	230

Chemical Properties

Calorific value: 24.0×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	McMillen et al. (1)
Ash, %	0.89
Pentosans (Bailey's method), %	5.0
Lignin, %	25.2
C. & B. cellulose, %	54.5
Alpha-cellulose, %	39.5
"Total extractives," %	10.9

1. Ind. Eng. Chem. 30:1408(1938).

Pathology

Resistance to decay: intermediate.

Red ring rot (Fomes pini) is severe.

Larch sawfly (Nematus erichsonii) has caused widespread damage by repeated defoliation in certain localities.

Utilization

Use properties. Heavy, hard, very strong, and stiff. Extreme variations in strength. Somewhat coarse-grained and brittle; inclined to warp.

Lumber. 3 million bd. ft. cut annually in the United States from 1928-1937; leading producers are Wisconsin, Minnesota, Michigan, Maine; boxes and crates, rough construction.

Other uses. Ties, poles, posts.

Pulping. Average annual cut from 1928-1937 was 25,500 cords. Sulfate process reduces readily; unbleached pulp very strong and tough; yield, 45%; high-grade kraft wrapping papers and fiberboard.

Supply

2 million cords in the United States (1933).
0.5 million cords in Upper Michigan (1935).

Scientific Name. Pseudotsuga taxifolia (La Marck) Britton.

Synonyms. Red fir, yellow fir, Oregon pine.

Family Name. Pinaceae.

Range. From central British Columbia southwestward to the coast, and southeastward to the Rockies; south along the east slopes of the Rockies to northern Mexico; then through central Arizona, eastern Nevada, southwestern Idaho, northeastern Oregon, and south in the Sierra Nevada to south central California. Along the coast from British Columbia to 200 miles south of San Francisco Bay. Along the coast it occurs from sea level to 5000 feet, but inland it is usually at an elevation of 4000 to 6000 feet.

Dimensions. 180 to 250 feet tall and 4 to 6 feet in diameter.

Bark. On young stems the bark is smooth except for resin blisters; on old trees it becomes 6 to 24 inches thick and divides into thick reddish-brown ridges separated by deep, irregular fissures; volume, 10.6%.

Silvics. There are two forms of this species, the coast form and the inland form, but only the coast form is used for pulping. Douglas fir is the largest tree in the Pacific Northwest. The old virgin trees have an exceptionally clear, long, cylindrical bole, either a rounded or an irregularly flat-topped crown, and a strong, well-developed, widespreading lateral root system. The best growth is made on deep, rich, well-drained, porous loams in regions where there is an abundance of both soil and atmospheric moisture. In its early growth Douglas fir forms extensive, pure, even-aged stands, but these are later invaded by other species. In the Pacific Northwest its principal associates include western red cedar, western hemlock, Sitka spruce, and lowland white, silver, and noble firs.

Gross Features of the Wood. The sapwood is whitish to pale yellowish or reddish, and the heartwood ranges from yellowish or pale reddish yellow to orange red or deep red. The wood varies considerably in hardness and weight and has a characteristic resinous odor when fresh, which is different from that of pine, but no characteristic taste. The springwood is usually several times wider than the summerwood; the transition is abrupt. The summerwood is pronounced, very narrow in slow grown stock to very wide and dense in wide rings. The growth ring is conspicuous. Yellow fir is narrow-ringed, fine-grained, uniform-textured, moderately soft, and easily worked, whereas red fir is wide-ringed, coarser grained, and more uneven-textured. In the x-section the rays are very fine, not visible with the naked eye, and form a fine, close, inconspicuous fleck on the radial surface. Both longitudinal and horizontal resin canals are present. The longitudinal canals are small, barely visible or indistinct with the naked eye, but plainly visible with a hand lens as dark spots or openings which are confined largely to the outer half of the growth ring. They may be sparse and scattered, or numerous and exhibit more or less of a tendency toward tangential rows of 2 to 30+. The

transverse canals are smaller and appear with a hand lens as somewhat broader rays spaced at irregular intervals on the transverse surface. Longitudinal parenchyma are not visible.

Microscopic Structure

Tracheids. Average, 40 to 48 mu in diameter and 3.9 mm. in length. Spiral thickening is present on all tracheids; bordered pits in one row or occasionally paired on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 6 (generally 4) per ray crossing; ray tracheid pits present; volume occupied, 92.5%.

Resin canals. Longitudinal, 60 to 90 mu in diameter; horizontal, usually less than 25 mu in diameter; thick-walled epithelial cells; volume occupied, 0.2%.

Rays. Two types, uniseriate or rarely in part biseriate, and fusiform. The uniseriate rays are numerous and 1 to 8+ cells high. Biseriate rays, if present, are very sparse and scattered. The fusiform rays are scattered, with one or very rarely two horizontal resin canals, 3 to 5 seriate in the central portion, tapering to uniseriate margins. Ray tracheids are present in both types, marginal and very rarely interspersed, nondentate inner walls, occasionally with spiral thickening; marginal usually in one row. Volume occupied, 7.3%.

Longitudinal parenchyma. Terminal and very sparse, or absent.

Nonmechanical Physical Properties (coast form)

Specific gravity,	green volume	0.45
	oven-dry volume	0.51
Density, lb./cu. ft.	green	38
	oven-dry	32

Moisture content, when green: 36% based on oven-dry weight (26% on green basis).

Shrinkage, from green condition: v, 11.8%; r, 5.0%; t, 7.8%.

Thermal conductivity: 0.77 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 22,400 megohms at 7% moisture content.
120 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	240	300
Compressive stress at p.l. //, lb./sq. in.	3410	6450
Compressive stress at p.l. /, lb./sq. in.	510	910
Shear, maximum stress //, lb./sq. in.	930	1140
Static bending FSPL, lb./sq. in.	4800	8100
Static bending E, lb./sq. in.	1.55×10^6	1.92×10^6
Static bending R, lb./sq. in.	7600	11,700
Toughness, in.	24	30
Hardness //, lb.	510	760
Hardness /, lb.	480	670
Cleavability, lb./in. width	160	180

Chemical Properties

See following page.

Pathology

Resistance to decay: moderately durable.

Brown cubical rot of heartwood of living tree by Polyporus sulfureus; brown top rot of heartwood of living tree by Fomes roseus; brown trunk rot of heartwood of living tree by Fomes laricis; red ring rot (Fomes pini) particularly severe; red root and butt rot by Polyporus circinatus; red-brown butt rot by Polyporus schweinitzii; string and ray rot by Polyporus berkeleyi; white mottled rot on dead timber by Fomes applanatus; white pocket rot on dead timber by Fomes nigrolimitatus.

Buprestis aurulenta in damaged trees and sawn lumber; spruce budworm; wood borer (Ergates spiculatus) in main trunk; western pine wood stainer (Gnathotrichus retusus) mines in sapwood; fir tussock moth (Hemerocampa pseudotsugata) has killed large areas; cambium borer (Melanophila drummondi); wood borer (Monochamus scutellatus); weevil (Pissodes fasciatus) widespread on coast; Pseudohylesimus nebulosus beetle attacks recently felled trees; Douglas fir pitch moth (Synanthedon novaroensis) is the primary cause of a very large percentage of pitch seams, pitch pockets, and gum checks; two-striped timber beetle (Trypodendron divittatum) is often a serious pest in recently felled timber and injured trees.

Utilization

Use properties. Hard, strong, easily seasoned, high shrinkage.

Lumber. Eight billion bd. ft. produced chiefly in Washington, Oregon, and California; heavy structural timbers, piles, ties, flooring, construction, general millwork, tanks and silos, veneer, plywood, ship building, boxes and crates, ladder rails.

Chemical Properties

Calorific value: 24.3×10^6 B.t.u. per air-dry cord.

Alcohol production: 20.6 gallons of ethanol per ton.

Proximate analysis:

	F.P.L.	F.P.L.	F.P.L.	F.P.L.	F.P.L.(1)	Chidester and McGovern (2) Sap	Chidester and McGovern (2) Heart	Bray, Schwartz, and Martin (3) Range of 18 Samples
Ash, %					0.38			
Hot-water soly., %	5.7	5.0	5.7	6.1	6.5	5.0	4.2	2.0-6.6
Ether soly., %	0.4	0.7	1.3	1.2	1.0	0.4	1.0	0.3-2.6
Alcohol-benzene soly., %	3.7	3.9	4.3	3.9		1.6	3.3	1.5-5.7
Acetic acid, %					1.04			
Methoxyl, %					4.95			
Pentosans, %	10.0	8.6	9.1	7.2	8.6	8.7	8.8	7.5-10.6
Lignin, %	30.0	30.2	31.1	29.9		25.4	27.3	25.3-29.6
C. & B. cellulose, %	59.6	60.2	57.8	61.0	61.5	63.2	61.5	54.0-66.0
Alpha-cellulose, %	42.6	44.6	42.3	44.5		46.2	43.7	38.4-46.5
1% NaOH soly., %	12.5	11.9	17.7	15.2	16.1	12.7	12.6	10.9-18.3
Mannan, %					6.65			

1. Forest Products Laboratory, Tech. Note 235; Hawley & Wise. Chemistry of Wood, 1926, p. 176-177.
2. Tech. Assoc. Papers 23:324(1940).
3. Tech. Assoc. Papers 23:234(1940); 24:227(1941).

Pulping.

Sulfate process. Reduces readily; unbleached pulp fairly strong; yield, 48%.

Sulfite process. Various studies; sapwood suitable [Pac. Pulp Paper Ind. 12, no. 11:17-26(Nov., 1938)].

Other uses. Oleoresin from resin canals (especially in the sapwood) for varnish and porous plasters.

Supply

80 billion cu. ft. in Washington and Oregon (1939).
8.4 billion cu. ft. in Canada (1935).
415 billion bd. ft. estimated for the United States with 380 billion bd. ft. in the Pacific Coast states.
5 billion cu. ft. in the ponderosa pine region (1936).

BALSAM FIR

Scientific Name. Abies balsamea (Linnaeus) Miller.

Synonyms. Balsam, eastern fir.

Family Name. Pinaceae.

Range. Newfoundland; from southern Labrador west to James Bay, through north central Manitoba and Saskatchewan, northeastern Alberta, and southwestern Mackenzie to the headwaters of the Yukon River; then south along the Rockies to south central Alberta and east through central Saskatchewan, southeastern Manitoba, central Minnesota, central Wisconsin, central Michigan, and southern Ontario, to the coast in New Hampshire; extending from New York down the Appalachians to southwestern Virginia.

Dimensions. 40 to 60 feet tall and 12 to 18 inches in diameter.

Bark. The bark is about 0.5 inch thick, dull green, later with grayish patches, smooth except for numerous raised resin blisters, eventually breaking up into small, reddish-brown, irregular, scaly plates.

Silvics. The tree is small to medium-sized. The moderately tapering bole and narrow pyramidal crown, terminating in a slender, rigid, spirelike tip, are supported by a shallow, widespreading root system. Balsam fir is a typical cold climate tree and requires abundant moisture for the best development. In swamps it often forms pure stands but does best in association with spruce on the adjacent flats which are better drained. On higher ground it occurs scattered in mixture with spruce, hemlock, yellow birch, beech, and maple.

Gross Features of the Wood. The wood of this species cannot be distinguished from that of the other true firs. The sapwood is whitish to creamy white or pale brown (especially the springwood), the summerwood frequently has a lavender tinge, and the heartwood is not distinct. The wood is soft, weak, dull, light, without characteristic odor or taste. It is fine-textured and straight-grained. Flat grain boards exhibit a distinct but not conspicuous growth ring figure. The springwood usually occupies two thirds or more of the annual ring; the transition from springwood to summerwood is very gradual, but the summerwood zone is distinct with the naked eye. In the x-section the rays are very fine and are not distinct with the naked eye. A fine, close, inconspicuous fleck is formed by the rays on the r-section. Normal resin canals are absent, but traumatic (wound) canals are sometimes present; if so, they are sporadic and arranged in a tangential row which frequently extends for some distance along the growth ring, appearing as dark streaks along the grain. Longitudinal parenchyma are absent.

Microscopic Structure

Tracheids. Average, 35 to 42 mu in diameter and 3.5 mm. in length; bordered pits in one row or very rarely paired on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 3 (generally 2 to 3) per ray crossing; ray tracheid pits sometimes present; volume occupied, 94.3%.

Rays. Uniseriate, very variable in height from 1 to 30+ cells, and made up wholly of ray parenchyma or rarely with a row of ray tracheids on both margins. Volume occupied, 5.7%.

Longitudinal parenchyma. Absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.34
	oven-dry	0.37
Density, lb./cu. ft.	green	45
	air-dry	24
	oven-dry	23

Moisture content, when green: 117% based on oven-dry weight (54% on green basis).

Shrinkage, from green condition: v, 10.8%; r, 2.8%; t, 6.6%.

Thermal conductivity: 0.65 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1690	3030
Compressive stress at p.l. ⊥, lb./sq. in.	240	440
Shear, maximum stress //, lb./sq. in.	665	900
Static bending FSPL, lb./sq. in.	2800	4400
Static bending E, lb./sq. in.	1.14×10^6	1.42×10^6
Static bending R, lb./sq. in.	5300	8600
Toughness, in.	17	20
Hardness //, lb.	320	680
Hardness ⊥, lb.	290	395
Cleavability, lb./in. width	150	170

Chemical Properties

Calorific value: 15.5×10^6 B.t.u. per air-dry cord.

Proximate analysis: Sapwood and heartwood analyses from two trees by Richter [Ind. Eng. Chem. 33:78(1941)].

	July Felled		February Felled	
	Sap	Heart	Sap	Heart
Ash, %	0.25	0.93	0.33	0.53
Hot-water soly., %	1.65	3.8	2.9	3.0
Ether soly., %	0.95	1.18	0.93	0.74
Alcohol soly., %	1.75	4.3	3.3	3.7
Pentosans, %	9.7	10.6	7.0	7.6
Lignin, %	28.7	30.7	28.9	31.5

Data on holocellulose and C. & B. cellulose by Hajny and Ritter [Tech. Assoc. Papers 25:596(1942)].

Lignin (based on extractive-free wood), %	30.1
Holocellulose (based on extractive-free wood), %	69.9
Alpha-cellulose, %	63.0*
Pentosans, %	10.3*
Acetyl, %	3.18*
Methoxyl, %	0.58*
Uronic anhydride, %	4.28*
C. & B. cellulose (based on extractive-free wood), %	56.4
Pentosans, %	6.0**
Alpha-cellulose, %	70.7**
Acetyl, %	1.4**
Methoxyl, %	0.54**
Uronic anhydride, %	1.92**

* Based on holocellulose.
** Based on C. & B. cellulose.

Pathology

Resistance to decay: low.

Balsam butt rot (Polyporus balsameus) is an important factor in rapid deterioration of dead timber; feather rot (Poria subacida) is the most common butt and root rot of balsam, causing considerable loss and predisposing infected trees to windthrow; also very important is heart rot caused by Stereum sanguinolentum in the living tree; pitted sap rot (Polystictus abietinus) in dead sapwood.

Spruce budworm (Cacoeci fumiferana) very destructive; Pityokteines sparsus beetles frequently destructive; Buprestis maculativentrus wood borer; Dicerca tenebrosa beetle mines dead wood; Melanophila drummondi cambium beetle; Monochamus marmoratus beetles attack felled trees; the spruce sawfly attacks this species.

Utilization

Use properties. Soft, light color; finishes well; holds nails well; no taste or odor when seasoned. In properties, fir is closely similar to spruce, though inclined to be more open in texture and more brittle.

Lumber. Boxes and crates, excelsior, slack cooperage, rough dimension.

Pulping

Sulfite process. Reduces readily under slightly milder conditions than are required for spruce; unbleached pulp has good color and excellent strength, but is usually slightly softer than spruce sulfite; yield, 45%; fairly easily bleached; news, wrapping, book, and high-grade printing papers.

Sulfate process. Reduces readily; unbleached pulp very strong; yield, 43%; high-grade kraft wrapping and fiberboard.

Soda process. Yield, 42%.

Mechanical process. Reduces readily; excellent color and standard strength; power requirement is 15 to 25% ~~of that for~~ more than white spruce; yield, 95%; practically all uses requiring groundwood.

Other uses. Canada balsam, widely used for medicinal purposes and as a glass cement, is made from the resin of the bark blisters.

Supply

21.2 billion cu. ft. in Canada (1935).
431 million cords of spruce and balsam in the United States (1933).
4.5 million cords of balsam fir in Upper Michigan (1935).

LOWLAND WHITE FIR

Scientific Name. Abies grandis Lindley.

Synonyms. Grand fir, white fir.

Family Name. Pinaceae.

Range. Occurs along the Pacific Coast from the northern end of Vancouver Island south to San Francisco Bay; it ranges inland just north of the international boundary to western Montana and occurs in north central Idaho and northeastern Oregon.

Dimensions. 140 to 160 feet in height and 2 to 4 feet in diameter; usually smaller in the Rockies.

Bark. The bark is smooth, gray brown, with resin blisters and chalky white blotches on young stems. On old trunks it becomes reddish brown, plated or more commonly deeply furrowed or divided into flat ridges.

Silvics. The tree has a long, clear, columnar bole, a domelike crown, and a deep, spreading root system. It is found most frequently on deep, moist, alluvial soils in gulches, along streams, and on gentle mountain slopes in mixed hardwood and softwood forests; it occasionally occurs in limited pure stands. In the region where it is usually cut for pulpwood (at low elevations in western Washington and Oregon), this species mingles with Sitka spruce, silver fir, western red cedar, western hemlock, Douglas fir, Oregon ash, red alder, bigleaf maple, and northern black cottonwood.

Gross Features of the Wood. The wood of lowland white fir cannot be distinguished from that of the other true firs. The sapwood is whitish to light buff to yellowish brown or light brown, the summerwood frequently with a roseate, reddish-brown, or lavender tinge. The wood is soft, light, generally straight-grained, without characteristic taste or odor if dry, medium and fairly uniformly textured. Flat grain boards exhibit a conspicuous growth ring figure. The springwood occupies at least one half of the annual ring; the transition to summerwood is gradual, but the summerwood is very distinct to the naked eye. In the x-section the rays are very fine and are not distinct to the naked eye. In the r-section they form a fine, close, inconspicuous fleck. Normal resin canals are absent, but traumatic (wound) canals are sometimes present; if so, they are sporadic and arranged in a tangential row which frequently extends for some distance along the ring, appearing as dark streaks along the grain. Longitudinal parenchyma are not visible.

Microscopic Structure

Tracheids. Average, 32-52 mu in diameter and 3.2 mm. in length; bordered pits in one row or occasionally biseriate on the radial walls; tangential pitting present in the last few rows of summerwood tracheids;

pits leading to ray parenchyma small, quite uniform in size, with distinct border, 1 to 4 (generally 2 to 4) per ray crossing; ray tracheid pits absent.

Rays. Uniseriate, very variable in height ranging from 1 to 30+ cells, consisting entirely of ray parenchyma.

Longitudinal parenchyma. Terminal and very sparse, or absent.

Nonmechanical Physical Properties

Specific gravity	green volume	0.37
	oven-dry volume	0.42
Density, lb./cu. ft.	green	45
	oven-dry	26

Moisture content, when green: 94% based on oven-dry weight (48% on green basis).

Shrinkage, from green condition: v, 10.6%; r, 3.2%; t, 7.2%.

Thermal conductivity: 0.65 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 57,600 megohms at 7% moisture content.
180 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2640	4420
Compressive stress at p.l. ⊥, lb./sq. in.	340	620
Shear, maximum stress //, lb./sq. in.	760	930
Static bending FSPL, lb./sq. in.	3600	5800
Static bending E, lb./sq. in.	1.30×10^6	1.63×10^6
Static bending R, lb./sq. in.	6100	9300
Toughness, in.	22	28
Hardness //, lb.	420	660
Hardness ⊥, lb.	360	490
Cleavability, lb./in. width	150	190

Chemical Properties

Calorific value: 17.4×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	Forest Products Laboratory			
			Sap	Heart
Hot-water soly., %	2.3			
Ether soly., %	0.9		1.2	0.3
Alcohol-benzene soly., %	2.6		4.1	1.5
1% NaOH soly., %	10.3			
Pentosans, %	8.9			
Lignin, %	27.2	27.0		
C. & B. cellulose, %	62.8	63.0		
Alpha-cellulose, %	45.9			

Pathology

Resistance to decay: low.

Overmature trees are frequent hosts of stringy brown rot (Echinodontium tinctorium); red ring rot (Fomes pini) kills sapwood and inner bark; white pocket rot caused by fir hydnum in heart of living tree.

Young trees are commonly attacked by the eastern spruce budworm (Cacoecia fumiferana); dark streaks along the grain are from the attack of the fir bark beetle (Melanophila drummondi); Dicerca beetle mines dead wood; Molasis rufipennis beetle prefers this species; Trypodendron timber beetle often a serious pest; Monochamus beetles; ambrosia beetles on dead and dying trees; Tetropium abietis beetles.

Utilization

Use properties. No taste or odor when seasoned; takes a good finish and holds nails well; glues easily; seasons satisfactorily with care; both sapwood and heartwood resist penetration of preservatives.

Lumber. Average annual cut of all species of western "white fir" from 1931-1940 was 98 million bd. ft.; leading producers are California and Idaho; boxes and crates, light and medium construction.

Pulping. Average annual consumption of all "white fir" pulpwood for the 10-year period from 1931-1940 was 133,000 cords.

Sulfite process. Reduces readily; unbleached pulp of excellent color and strength; fibers somewhat coarser than spruce; yield, 49%; fairly easily bleached; news, wrapping, book, and high-grade printing papers.

Sulfate process. Reduces readily; unbleached pulp very strong; yield, 48%.

Mechanical process. Reduces readily; of excellent color; power requirement is 20% ~~of that for~~ more than white spruce.

Supply. Estimated at 16 billion bd. ft.; equals about 13% of stand and about 25% of true fir cut.

SILVER FIR

Scientific Name. Abies amabilis (Loudon) Forbes.

Synonyms. Amabilis fir, white fir, "larch."

Family Name. Pinaceae.

Range. From southeastern Alaska south along the coast to northern Washington; thence along the Olympic peninsula and Cascade Mts. to northwestern Oregon. At sea level in Alaska and Canada but at an elevation of 1000 to 5000 feet in Washington and Oregon.

Dimensions. Average, 140 to 160 feet high and 2 to 4 feet in diameter in the Olympic Mts., but smaller elsewhere.

Bark. The bark is ashy gray, with large, irregular, chalky-colored blotches and resin blisters on stems less than 3 feet in diameter; superficially scaly on the largest trunks; volume, 15.9%.

Silvics. The tree has a long, clear, columnar bole, a pyramidal or spirelike crown, and a deep, spreading root system. This species is most abundant on deep moist soil covering slopes of southern and western exposures. It forms extensive pure forests in many localities and in mixed stands it is commonly associated with Sitka spruce, Douglas fir, lowland white fir, western hemlock, and western red cedar.

Gross Features of the Wood. The wood of silver fir is very similar in appearance and texture to other western balsam firs, although it is somewhat darker in color.

Microscopic Features. See lowland white fir. Tracheid length, 3.1 mm.

Nonmechanical Physical Properties

Specific gravity	green volume	0.35
	oven-dry volume	0.42
Density, lb./cu. ft.	green	36
	air-dry	27
	oven-dry	26

Moisture content, when green: 66% based on oven-dry weight (40% on green basis).

Shrinkage, from green condition: v, 14.1%; r, 4.5%; t, 10.0%.

Thermal conductivity: 0.65 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2380	4660
Compressive stress at p.l. ⊥, lb./sq. in.	290	490
Shear, maximum stress //, lb./sq. in.	670	1050
Static bending FSPL, lb./sq. in.	3500	6200
Static bending E, lb./sq. in.	1.26×10^6	1.53×10^6
Static bending R, lb./sq. in.	5700	9400
Toughness, in.	21	24
Hardness //, lb.	360	620
Hardness ⊥, lb.	310	430
Cleavability, lb./in. width	150	200

Chemical Properties

Calorific value: 16.5 x 10^6 B.t.u. per air-dry cord.

Destructive distillation: Yields from 25 kg. of wood were 10.1 liters of pyroligneous acid, 0.51% of methanol, 2.1% of acetic acid, 1.23 liters of tar, and 19% of charcoal.

Proximate analysis:

	Bray, Martin, and Schwartz (1)	F.P.L.	F.P.L.
Hot-water soly., %	2.0	4.4	3.2
Ether soly., %	0.3	1.4	0.9
Alcohol-benzene soly., %	2.0	3.1	
1% NaOH soly., %	9.1	13.7	
Pentosans, %	10.5	9.0	
Lignin, %	26.6	29.8	28.2
C. & B. cellulose, %	62.1	59.6	60.8
Alpha-cellulose, %	44.2	43.5	

1. Paper Trade J. 109, no. 18:29(Nov. 2, 1939).

Pathology

Resistance to decay: low.

String and ray rots in roots and butts (Polyporus berkeleyi); white mottled rot on dead timber (Fomes applanatus).

Utilization

Use properties. Light, soft, no taste or odor when seasoned, close-grained and weak, subject to splitting and finishes rather poorly, somewhat harder and stiffer than the other true firs.

Lumber. Small house construction, boxes and crates. Apparently only a small amount cut for lumber.

Pulping. Leading producers are Washington and Oregon. The pulps are similar to those from lowland white fir.

Supply. Most abundant of balsam firs in the Pacific Northwest.

7 billion cu. ft. in Douglas fir region (1933).
556 million cu. ft. in ponderosa pine region (1936).

WESTERN RED CEDAR

Scientific Name. Thuja plicata D. Don.

Synonyms. Red cedar, cedar.

Family Name. Cupressaceae.

Range. From southeastern Alaska south along the coast to a point about 100 miles north of San Francisco Bay; east in northern Washington and southern British Columbia to northwestern Montana; northwest along the western slopes of the Rockies about 500 miles in British Columbia. At sea level to an elevation of 4000 feet near the coast and 2000 to 7000 feet in the Rockies.

Dimensions. 150 to 200 feet in height and 4 to 8 feet in diameter.

Bark. 0.5 to 1 inch thick, fibrous, cinnamon red on young stems, gray on old trunks, and forming a closely interlacing network.

Silvics. The tree has a broadly buttressed, often fluted base and rapidly tapering bole, an irregular crown, and a shallow, widespreading root system. It generally inhabits moist flats and slopes. This species seldom occurs in pure stands but often makes up 50% of mixed forests. On the coast its important associates are Sitka spruce, western hemlock, Douglas fir, lowland white and silver firs. In the Inland Empire, western larch, western white pine, western hemlock, white fir, Douglas fir, and Engelmann spruce are its principal associates.

Gross Features of the Wood. The sapwood is nearly white, and the heartwood is reddish or pinkish brown to dull brown. The wood is straight-grained and rather coarse, but fairly even-textured with a characteristic odor and faint bitter taste. It is soft, dry, light, and weak. Flat grain boards exhibit a distinct but not conspicuous growth ring. The springwood zone occupies most of the ring. The transition to summerwood is more or less abrupt, and the summerwood is narrow and hard. Parenchyma are not visible or barely distinct with a hand lens as a narrow line in the summerwood. In the x-section the rays are fine and form a fine, close, inconspicuous fleck on the radial surface. Resin canals are absent.

Microscopic Structure

Tracheids. Average, 32 to 38 mu in diameter and 2.8 mm. in length; bordered pits in 1 to 2 rows on the radial walls; tangential pitting present in the last few rows of summerwood tracheids; pits leading to ray parenchyma small, orbicular or nearly so, quite uniform in size, with distinct border and lenticular orifice, 1 to 4 per ray crossing; ray tracheid pits absent; volume occupied, 93.1%.

Rays. Uniseriate, 1 to 12+ cells high, consisting entirely of ray parenchyma and containing a scanty gummy infiltration; volume occupied, 6.9%.

Longitudinal parenchyma. Diffuse-zonate, very variable in distribution.

Nonmechanical Physical Properties

Specific gravity	green volume	0.31
	oven-dry volume	0.34
Density, lb./cu. ft.	green	27
	air-dry	22
	oven-dry	21

Moisture content, when green: 37% based on oven-dry weight (27% on green basis).

Shrinkage, from green condition: v, 7.7%; r, 2.4%; t, 5.0%.

Thermal conductivity: 0.72 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	230	220
Compressive stress at p.l. //, lb./sq. in.	2470	4360
Compressive stress at p.l. /, lb./sq. in.	340	610
Shear, maximum stress //, lb./sq. in.	710	860
Static bending FSPL, lb./sq. in.	3200	5300
Static bending E, lb./sq. in.	0.92×10^6	1.12×10^6
Static bending R, lb./sq. in.	5100	7700
Toughness, in.	17	17
Hardness //, lb.	430	660
Hardness /, lb.	270	350
Cleavability, lb./in. width	140	130

Chemical Properties

Considerable oil.

Calorific value: 16.8×10^6 B.t.u. per air-dry cord.

Pathology

Resistance to decay: durable.

Yellow ring rot (Poria weirii) is the most serious decay; pecky heart rot (Fomes pini) is common in overmature trees, and almost all very old trees are hollow-butted; red ray rot (Polyporus anceps) also on old trees.

Western cedar borer, or powderworm (Trachykele blondeli), attacks healthy living trees and mines the main trunk; bark beetles (Phloeosinus punctatus or P. sequoiae) prefer felled or weakened trees.

Utilization

Use properties. Exceptionally good working qualities and takes a smooth satiny finish; paints well, good gluing properties, very durable, seasons readily, shrinkage low, nails well, retains size and shape exceptionally well.

Lumber. Leading producers are Washington, Oregon, Idaho; poles, shingles, posts, siding, interior trim, boat building, tanks, pencils, greenhouses.

*Pulping. Sulfate process reduces readily; unbleached pulp very strong.

Supply

50 billion bd. ft. in the United States.
24 billion bd. ft. in the Douglas fir region.
2 billion bd. ft. in Alaska.
82 million cu. ft. in the ponderosa pine region (1936).

QUAKING ASPEN

Scientific Name. Populus tremuloides Michaux.

Synonyms. Trembling aspen, aspen, poplar, popple.

Family Name. Salicaceae.

Range. Newfoundland; from southern Labrador to the mouth of James Bay, to central and northwest Mackenzie, and through Alaska north of the Yukon River to the coast; south inland in British Columbia, the higher altitudes of the Coast range and Sierra and extensively in the Rockies to Mexico; east through south central Alberta and Saskatchewan, southern Manitoba, eastern Dakotas, central Iowa, and east to New Jersey; south in the Appalachians to Kentucky (this range includes the western variety).

Dimensions. 50 to 60 feet in height and 1 to 2 feet in diameter.

Bark. The bark is smooth, greenish-white to cream colored, eventually becoming furrowed, dark brown, or gray, often roughened by numerous wart-like excrescences; volume, 18.4%.

Silvics. Under competition a long, slender bole with a small, rounded crown is developed; the root system is superficial. Although aspen occurs as a scattered tree in unbroken woods or on stream banks, it occupies logged and burned areas in almost pure stands. In the northern forest on burns its common associates are fire cherry, bigtooth aspen, gray birch, Bebb's willow, and an understory of maple, birch, and beech. In the western mountains conifers follow aspen.

Gross Features of the Wood. The sapwood is whitish, frequently merging into the heartwood which is grayish white to light grayish brown. The wood is soft, light, without characteristic taste and odor or with a characteristic disagreeable odor when moist. The texture is fine and uniform, and flat grain boards exhibit a faint growth ring figure. The wood is semi-ring to diffuse-porous with numerous small pores, the largest barely visible with the naked eye in the springwood, decreasing gradually in size through the summerwood, solitary and in short radial rows of 2 or more. Parenchyma are terminal, with the narrow, light-colored line more or less distinct. The rays are very fine, scarcely visible with a hand lens. Aspens and cottonwoods are similar and are not separated in the trade.

Microscopic Structure

Vessels. 100 per sq. mm., the largest 81 mu in diameter; perforation plates simple; intervessel pits orbicular to angular, 7 to 11 mu in diameter; volume occupied, 33.8%.

Fibers. Thin to medium thick (about 3 mu) walls, 10 to 27 mu in diameter and 1.05 mm. long; volume occupied, 55.1%.

Rays. Unstoried, uniseriate, up to 25 cells (481 mu) in height, 27 per sq. mm. on the tangential surface, 9 per mm. tangentially on the x-section, homogeneous, 3 to 13 roughly circular pits leading from ray crossing to vessel; volume occupied, 11.1%.

Longitudinal parenchyma. Terminal, forming a narrow, continuous or interrupted line; volume occupied, trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.35
	air-dry volume	0.38
	oven-dry volume	0.40
Density, lb./cu. ft.	green	43
	air-dry	26
	oven-dry	25

Moisture content, when green: 94% based on oven-dry weight (48% on green basis).

Shrinkage, from green condition: v, 11.5%; r, 3.5%; t, 6.7%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l.//, lb./sq. in.	1670	3040
Compressive stress at p.l. ⊥, lb./sq. in.	220	460
Shear, maximum stress //, lb./sq. in.	660	850
Static bending FSPL, lb./sq. in.	3200	5600
Static bending E, lb./sq. in.	0.86×10^6	1.18×10^6
Static bending R, lb./sq. in.	5100	8400
Toughness, in.	22	21
Hardness //, lb.	280	510
Hardness ⊥, lb.	300	350
Cleavability, lb./in. width	140	210

Chemical Properties

Calorific value: 17.7×10^6 B.t.u. per air-dry cord.

Proximate analysis:

		Bray and Paul (1)		
Hot-water soly., %		3.3	2.6	
Ester soly., %		1.1	1.1	
Alcohol-benzene soly., %	—	1.3	2.1	2.8
Pentosans, %	18.7	22.1	21.5	19.2
Lignin, %	23.4	23.4	23.5	18.8
C. & B. cellulose, %	62.1	64.6	66.5	66.1
Alpha-cellulose, %	43.2	49.4	54.8	48.2
1% NaOH soly., %	16.9	20.4	17.9	16.3

1. Paper Trade J. 115, no. 16:33(Oct. 15, 1942).

Data on holocellulose and C. & B. cellulose [Van Beckum & Ritter, Paper Trade J. 108, no. 7:27(1939)].

Lignin (based on extractive-free wood), %	17.3
Holocellulose (based on extractive-free wood), %	82.5
Alpha-cellulose, %	61.4*
Pentosans, %	28.2*
Acetyl, %	5.53*
Methoxyl, %	1.13*
Uronic anhydride, %	5.04*
C. & B. cellulose (based on extractive-free wood), %	64.1
Pentosans, %	19.9**
Alpha-cellulose, %	76.3**

* Based on holocellulose.
** Based on C. & B. cellulose.

Pathology

Resistance to decay: low.

Butt rot caused by Armillaria mellea; Hypoxylon poplar canker causes significant losses in aspen stands; Nectria canker; white heart rot caused by Fomes igniarius is particularly severe on aspen and, although limited to heartwood in living trees, will spread to sapwood of dead trees in forest; white mottled rot caused by Fomes fomentarius.

Bronze birch borer (Agrilus anxius) mines and kills; aspen tortrix (Archips conflictana) eats leaves; poplar borer (Saperda calcarata) bores in sapwood and heartwood; forest tent caterpillar (Malacosoma disstria) completely defoliates aspen during occasional years.

Utilization

Use properties. Light in color and weight, soft, weak; works well and takes a good finish; good painting and gluing properties; hold nails well, tough, close grain, straight grain, even texture.

Lumber. 24 million bd. ft. cut annually in the United States from 1931-1940; leading producers are Minnesota, Michigan, Wisconsin; boxes and crates, veneered containers, slack cooperage, matches, plywood, novelties.

Pulping. The average annual cut from 1931-1940 was 334,000 cords in the Lake States.

Sulfite process. Reduces readily; unbleached pulp has excellent color but usually contains small black specks which disappear on bleaching; easily bleached; yield, 49%.

Sulfate process. Yield, 50%.

Soda process. Reduces fairly readily; bleaches easily; yield, 47%. Aspen makes up large percentage of soda pulp.

Other uses. Excelsior (about 50,000 cords annually).

Supply

12 billion bd. ft. of quaking and bigtooth aspen in the United States.
0.6 billion bd. ft. of aspen in Upper Michigan (1935).
44 million cords of aspen in the Lake States (1938).
7 million cu. ft. in the ponderosa pine region (1936).

BIGTOOTH ASPEN

Scientific Name. Populus grandidentate Michaux.

Synonyms. Largetooth aspen, poplar.

Family Name. Salicaceae.

Range. From the mouth of the St. Lawrence River west to southern Manitoba, south to central Iowa, southeast to central Tennessee and western North Carolina, northeast to central New Jersey.

Dimensions. 60 to 70 feet tall and 2 feet in diameter.

Bark. Olive green but often not readily separated from that of quaking aspen, later becomes brown and furrowed.

Silvics. Very similar to quaking aspen, with which it occurs mixed or in scattered groups in the forest. It is not of such widespread distribution or of as frequent occurrence, however.

Gross Features of the Wood. Similar to quaking aspen and not separated in the trade.

Microscopic Structure. Similar to quaking aspen. Fibers average 1.1 to 1.3 mm. in length.

Nonmechanical Physical Properties

Specific gravity	green volume	0.35
	air-dry volume	0.39
	oven-dry volume	0.41
Density, lb./cu. ft.	green	43
	air-dry	27
	oven-dry	26

Moisture content, when green: 99% based on oven-dry weight (50% on green basis).

Shrinkage, from green condition: v, 11.8%; r, 3.3%; t, 7.9%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2020	4090
Compressive stress at p.l. ⊥, lb./sq. in.	250	560
Shear, maximum stress //, lb./sq. in.	730	1080
Static bending FSPL, lb./sq. in.	2900	5600
Static bending E, lb./sq. in.	1.12×10^6	1.43×10^6
Static bending R, lb./sq. in.	5400	9100
Toughness, in.	18	22
Hardness //, lb.	400	620
Hardness ⊥, lb.	370	420
Cleavability, lb./in. width	190	220

Chemical Properties

Calorific value: 18.2×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	Freeman and Peterson (1)		Bloom, Jahn, and Wise (2)
	Sap	Heart	
Ash, %	0.26	0.33	
Hot-water soly., %	3.13	0.99	2.4
Cold-water soly., %	2.70	1.36	
Ether soly., %	1.02	1.03	0.86
Alcohol-benzene soly., %	2.41	2.13	2.6
Acetyl, %	5.48	6.07	
Methoxyl, %	5.27	5.35	
Pentosans, %	23.3	23.8	19.7
Lignin, %	16.3	16.9	17.7
Holocellulose, %	78.0	80.0	
Pentosans, %	22.5	23.0	
Acetyl, %	5.17	5.05	
Methoxyl, %	0.65	0.72	
C. & B. cellulose, %	62.7	64.4	66.3
Pentosans, %	14.5	15.8	

1. Ind. Eng. Chem., Anal. Ed. 13:803(1941).
2. Paper Trade J. 115, no. 10:33-40(Sept. 3, 1942); includes also data on ethanolamine cellulose and correlation between the number of chlorinations and lignin in Cross & Bevan cellulose.

Pathology

Resistance to decay: low.

Often subject to a branch and trunk gall somewhat globose in shape and with a rough, irregular surface.

Bronze birch borer (Agrilus anxius) mines and kills.

Utilization. See quaking aspen.

Supply. See quaking aspen.

BALSAM POPLAR

Scientific Name. Populus balsamifera Linnaeus.

Synonyms. Balm-of-Gilead, balm, tacamahac, poplar.

Family Name. Salicaceae.

Range. Very similar to quaking aspen but does not occur in the Appalachians, or as far south in the central states, or as far west or south in the western mountains.

Dimensions. 60 to 80 feet in height and 1 to 2 feet in diameter.

Bark. On young stems and limbs the bark is greenish brown to reddish brown, on older trunks eventually becoming gray to grayish black and dividing into flat, scaly, or shaggy ridges separated by narrow fissures.

Silvics. The tree is medium-sized with a long, cylindrical bole, a narrow, open, pyramidal crown, and a shallow root system. It is characteristic of alluvial bottomlands and river banks and is typical of northern Canada. In the southern part of its range it usually occurs in isolated patches.

Gross Features of the Wood. The wood is very similar to aspen, although the heartwood occasionally has a reddish-brown tinge.

Microscopic Features. See quaking aspen.

Nonmechanical Physical Properties

Specific gravity	green volume	0.30
	air-dry volume	0.33
	oven-dry volume	0.35
Density, lb./cu. ft.	green	40
	air-dry	23
	oven-dry	22

Moisture content, when green: 112% based on oven-dry weight (53% on green basis).

Shrinkage, from green condition: v, 10.5%; r, 3.0%; t, 7.1%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1220	2920
Compressive stress at p.l. ⊥, lb./sq. in.	170	370
Shear, maximum stress //, lb./sq. in.	500	790
Static bending FSPL, lb./sq. in.	2100	4200
Static bending E, lb./sq. in.	0.75×10^6	1.10×10^6
Static bending R, lb./sq. in.	3900	6800
Toughness, in.	16	14
Hardness //, lb.	240	380
Hardness ⊥, lb.	230	300
Cleavability, lb./in. width	130	200

Chemical Properties

Calorific value: 17.2×10^6 B.t.u. per air-dry cord.

Pathology

Resistance to decay: low.

Bronze birch borer (Agrilus anxius) mines and kills.

Utilization

Lumber. Average annual cut of about 8 million bd. ft., chiefly from the Lake States; boxes and crates, veneer baskets.

Pulping. Average annual cut from 1931-1940 was about 17,500 cords, chiefly from the Lake States.

Sulfite process. Reduces very easily; unbleached pulp of excellent color; very easily bleached; yield, 49%.

Sulfate process. Yield, 50%.

Soda process. Reduces readily; fairly easily bleached; yield, 47%.

Other uses. Excelsior.

Supply. 500 million bd. ft. of saw timber in the United States (1941).

NORTHERN BLACK COTTONWOOD

Scientific Name. Populus trichocarpa hastata Henry.

Synonyms. Cottonwood, balm.

Family Name. Salicaceae.

Range. From southern Alaska to northern California; eastward in Washington and Oregon to northwestern Montana, then north in the Rockies to the Yukon territory.

Dimensions. Maximum in western Washington 175 to 225 feet in height and 7 to 8 feet in diameter; maximum in the Rockies 100 feet in height.

Bark. The bark is tawny yellow to gray and smooth on young stems; later, it becomes dark gray to grayish brown and is separated by deep furrows into narrow flat-topped ridges.

Silvics. Forest trees have a long, clear bole and a narrow, cylindrical, round-topped crown. They usually grow on moist, sandy, gravelly, or deep alluvial soils in pure stands or groups, or occur in mixture with Douglas fir, lowland white fir, and red alder. Growth is rapid and the tree is very intolerant.

Gross Features of the Wood. The wood is similar to quaking aspen.

Microscopic Structure. The wood is similar to quaking aspen.

Nonmechanical Physical Properties

Specific gravity	green volume	0.32
	air-dry volume	0.35
	oven-dry volume	0.37
Density, lb./cu. ft.	green	46
	air-dry	24
	oven-dry	23

Moisture content, when green: 132% based on oven-dry weight (57% on green basis).

Shrinkage, from green condition: v, 12.4%; r, 3.6%; t, 8.6%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1760	3270
Compressive stress at p.l. ⊥, lb./sq. in.	200	370
Shear, maximum stress //, lb./sq. in.	600	1020
Static bending FSPL, lb./sq. in.	2900	5300
Static bending E, lb./sq. in.	1.07×10^6	1.26×10^6
Static bending R, lb./sq. in.	4800	8300
Toughness, in.	20	22
Hardness //, lb.	280	540
Hardness ⊥, lb.	250	350
Cleavability, lb./in. width	170	220

Chemical Properties

Calorific value: 15.5×10^6 B.t.u. per air-dry cord.

Pathology

Resistance to decay: low.

Agrilus populi borer mines wood; satin moth (Stilpnotia salicis) feeds on leaves.

Utilization

Use properties. Similar to aspen, but size gives tremendous advantage.

Lumber. 7 million bd. ft. cut annually, largely from Oregon; plywood, matches, boxes.

Pulping. Soda pulp.

Other uses. Excelsior.

Supply.

225 million cu. ft. in the United States (1939).
145 million cu. ft. in Canada (1935).
188 million cu. ft. in Douglas fir region (1933).
19 million cu. ft. in the ponderosa pine region (1936).

SOUTHERN COTTONWOOD

Scientific Name. Populus deltoides virginiana (Castiglioni) Sudworth.

Synonym. Cottonwood

Family Name. Salicaceae.

Range. From southern Saskatchewan to central Texas eastward to Vermont and northern Florida, except in the Appalachians and in northern Michigan and Wisconsin. The type species, called eastern cottonwood, is believed to be confined chiefly to western New York and the vicinity of Lake Champlain.

Dimensions. 80 to 100 feet in height and 3 to 4 feet in diameter.

Bark. The bark is light greenish yellow on young stems, eventually becoming ash gray and dividing into thick, flattened or rounded ridges separated by deep fissures.

Silvics. In the forest the tree is tall, clear, and cylindrical, with a rather widespread crown and an extensive superficial root system. It grows principally along streams and water courses in mixture with various willows, sycamore, American elm, and some of the bottomland oaks.

Gross Features of the Wood. Similar to quaking aspen.

Microscopic Structure. Similar to quaking aspen; fiber length is 1.3 mm.

Nonmechanical Physical Properties

Specific gravity	green volume	0.37
	air-dry volume	0.40
	oven-dry volume	0.43
Density, lb./cu. ft.	green	49
	air-dry	28
	oven-dry	26

Moisture content, when green: 111% based on oven-dry weight (53% on green basis).

Shrinkage, from green condition: v, 14.1%; r, 3.9%; t, 9.2%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1740	3490
Compressive stress at p.l. ⊥, lb./sq. in.	240	470
Shear, maximum stress //, lb./sq. in.	680	930
Static bending FSPL, lb./sq. in.	2900	5700
Static bending E, lb./sq. in.	1.01×10^6	1.37×10^6
Static bending R, lb./sq. in.	5300	8500
Toughness, in.	21	20
Hardness //, lb.	380	580
Hardness ⊥, lb.	340	430
Cleavability, lb./in. width	220	270

Chemical Properties

Calorific value: 16.8×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	McGovern and Keller (1)	Bray and Paul (2)
Hot-water soly., %	2.0	
Ether soly., %	0.4	
Alcohol-benzene soly., %	1.8	0.9
Pentosans, %	19.0	18.0
Lignin, %	23.6	22.0
C. & B. cellulose, %	63.2	56.2
Alpha-cellulose, %	46.5	47.5
1% NaOH soly., %	15.4	14.8

1. Southern Pulp Paper J. 5, no. 11:7-10(April, 1943).
2. Paper Trade J. 115, no. 16:33(Oct. 15, 1942); these data are for eastern cottonwood (Populus deltoides).

Pathology

Resistance to decay: low.

A white rot in sapwood and heartwood, caused by Fomes applanatus, occurs chiefly in trees wounded mechanically or by fire.

Bronze birch borer (Agrilus anxius) mines and kills; cottonwood borer (Plectrodera scalator) is moderately common throughout the middle West and is very destructive on living trees.

Utilization

Lumber. 76 million bd. ft. of southern, eastern, and swamp cottonwood cut annually, chiefly in Mississippi, Arkansas, Louisiana, and Missouri; boxes and crates.

Pulping

Sulfite process. Probably similar to aspen; yield, 47%.

Sulfate process. Yield, 47%.

Soda process. Reduces readily; fairly easily bleached; yield, 47%.

Mechanical process. Yield, 94%; comparable in strength to commercial groundwood.

Other uses. Excelsior; 25,000 cords annually.

Supply

3.5 billion bd. ft. in the United States.
104 million cu. ft. in the North Louisiana delta (1933).

SWAMP COTTONWOOD

Scientific Name. Populus heterophylla Linnaeus.

Synonyms. Cottonwood, river cottonwood.

Family Name. Salicaceae.

Range. On the coastal plain from Connecticut to northern Florida, then west to western Louisiana, and north in the Mississippi valley to southern Illinois, Indiana, and western Ohio; also in the region west of Lake Champlain.

Bark. The bark is furrowed and somewhat scaly.

Silvics. A medium-sized tree occurring scattered through the bottomland forests and similar in habits to other cottonwoods.

Gross Features of the Wood. Similar to quaking aspen.

Microscopic Features. Similar to quaking aspen.

Pathology

Resistance to decay: low.

Bronze birch borer (Agrilus anxius) mines and kills.

Utilization

Use properties Similar to southern cottonwood.

Lumber. Similar to southern cottonwood.

Pulping. Similar to southern cottonwood.

Supply. 2.5 billion bd. ft. in the United States.

BLACK WILLOW

Scientific Name. Salix nigra Marshall.

Synonym. Willow

Family Name. Salicaceae

Range. From southern New Brunswick to eastern North Dakota; south to west central Texas; east to southern Mississippi, central Alabama, northern Georgia to the coast of North Carolina. A southern variety is found in southern Arkansas and Louisiana.

Dimensions. 30 to 40 feet in height and 14 inches in diameter.

Bark. The bark is brown to nearly black, divided into deep fissures separating thick, interlacing, sometimes scaly ridges.

Silvics. This relatively small tree has a broad, irregular crown and a superficial root system. The trunk has a tendency to branch not far above the ground, but the form and size of the tree are much better in the lower Mississippi valley. Usually this species is found on moist or wet soils along streams or lakes, or in swamps.

Gross Features of the Wood. The sapwood is whitish and the heartwood light brown to pale reddish brown or brown, frequently with darker streaks. The wood is soft and light without characteristic odor or taste. The growth rings are inconspicuous. The pores are numerous and small, the largest barely visible with the naked eye in the springwood, decreasing gradually in size through the summerwood, semi-ring to diffuse-porous, arranged solitary or in short radial groups of 2 or more. Parenchyma are terminal, generally invisible at low magnifications. The rays are very fine, scarcely visible with a hand lens.

Microscopic Structure

Vessels. 30 to 120 per sq. mm., the largest 90 to 160 mu in diameter; perforation plates simple; intervessel pits orbicular to angular, 6 to 10 mu in diameter; volume occupied, 38.1%.

Fibers. Thin-walled to moderately thick-walled; average, 16 to 32 mu in diameter and 1.1 mm. in length; volume occupied, 54.5%.

Rays. Unstoried, uniseriate, heterogeneous with upright cells in 1 or more (usually 1) marginal rows and not infrequently also in the body of the ray; pits leading to vessels restricted to the upright cells, fairly numerous, and forming a more or less reticulate pattern; volume occupied, 7.4%.

Longitudinal parenchyma: Terminal, forming a narrow, continuous or interrupted line, 1 to 2 seriate; volume, trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.34
	— oven-dry volume	0.41
Density, lb./cu. ft.	green	50
	oven-dry	26

Moisture content, when green: 139% based on oven-dry weight (58% on green basis).

Shrinkage, from green condition: v, 13.8%; r, 2.5%; t, 7.8%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	---	460
Compressive stress at p.l. //, lb./sq. in.	960	2020
Compressive stress at p.l. /, lb./sq. in.	220	480
Shear, maximum stress //, lb./sq. in.	620	1050
Static bending FSPL, lb./sq. in.	1800	3900
Static bending E, lb./sq. in.	0.56×10^6	0.72×10^6
Static bending R, lb./sq. in.	3800	6200
Toughness, in.	36	20
Hardness //, lb.	350	550
Hardness /, lb.	360	450
Cleavability, lb./in. width	230	290

Chemical Properties

Proximate analysis:

	McGovern and Keller (1)
Hot-water soly., %	3.6
Ether soly., %	0.3
Alcohol-benzene soly., %	2.2
Pentosans, %	18.8
Lignin, %	21.9
C. & B. cellulose, %	61.6
Alpha-cellulose, %	46.6
1% NaOH soly., %	17.4

1. Southern Pulp Paper J. 5, no. 11:7-10(April, 1943).

Pathology

Resistance to decay: low.

A soft white rot caused by Daedalea confragosa sometimes occurs on living trees in the vicinity of wounds.

Borer (Agrilus politus); mottled willow borer (Cryptorynchus lapathi) girdles twigs; oyster shell scale (Lepidosophes ulmi); browntail moth (Nygmia phaeorrhoea) attacks leaves; gypsy moth (Porthetria dispar) attacks leaves; carpenter worm (Prionoxystus robiniae) bores wood.

Utilization

Use properties. Soft, weak, moderately light, uniform in texture, and easily worked.

Lumber. Boxes, crates, furniture, slack cooperage, core stock, artificial limbs, cabinets, vehicles.

Pulping.

Sulfite process. Reduces readily; unbleached pulp of excellent color; fairly easily bleached; yield, 50%.

Soda process. Reduces readily; fairly easy to bleach; yield, 45%.

Mechanical process. About equal to commercial groundwood in strength; dark color; yield, 94%.

Other uses. Charcoal, excelsior.

Supply. 135 million cu. ft. in the North Louisiana delta (1933).

CHESTNUT OAK

Scientific Name. Quercus montana Willdenow.

Synonym. Rock oak.

Family Name. Fagaceae.

Range. Southern Maine, through central New York, northeastern Ohio, and southern Indiana; south to central Alabama; northeastward in the Appalachians to the coast of New Jersey.

Dimensions. 70 to 80 feet in height and 20 to 30 inches in diameter.

Bark. Brown to nearly black; very deeply and coarsely furrowed on older trees.

Silvics. The above dimensions are for trees on good sites, but this species is commonly found on dry, sterile soils and rocky ridges where it is a much smaller tree. On the poorest of these sites it sometimes occurs in open, pure stands of limited extent; on slightly better soil it associates with black oak, blackjack oak, chestnut, pitch pine, and other dry-soil species.

Gross Features of the Wood. The sapwood is whitish to light brown, and the heartwood is dark brown. The wood is hard, medium heavy to heavy, without characteristic odor or taste. This ring-porous wood has a distinct, conspicuous growth ring and a high ray fleck. The springwood pores are large, distinctly visible with the naked eye, forming a conspicuous band 1 to 3 pores in width; tyloses are present but not abundant. The transition from springwood to summerwood is abrupt or somewhat gradual; the summerwood pores are numerous, small, not distinct with a hand lens, scattered in radially aligned, flame-shaped tracts of light-colored tissue, thin-walled. Parenchyma are visible with a hand lens, forming part of the conjunctive tissue between the springwood pores and the rays, composing most of the tissue in the flame-shaped areas, usually zonate in fine, more or less regular, tangential lines in the outer portion of the ring. The rays are of two types, broad and narrow. The broad compound rays are very conspicuous to the naked eye, separated by several to many narrow rays, appearing on the tangential surface as rather widely spaced, staggered lines of varying length which frequently extend an inch or more along the grain, forming a handsome, high fleck on the radial surface. The narrow simple rays are much more numerous than the broad rays, indistinct without magnification.

Microscopic Structure

Vessels. Summerwood vessels 20 to 120 per sq. mm.; largest springwood vessels 180 to 380 mu in diameter; perforation plates simple; intervessel pits elliptical to orbicular, 6 to 10 mu in diameter.

Tracheids. Present, intermingled with parenchyma, forming most of the conjunctive tissue between the springwood vessels and the rays and composing part of the flame-shaped areas in which the summerwood vessels are embedded.

Fibers. Medium thick- to thick-walled, frequently gelatinous, 14 to 22 mu in diameter.

Rays. Unstoried, homogeneous; broad rays 12 to 30+ seriate and 150 to 400+ mu wide in middle, many cells (into hundreds) in height; narrow cells, very numerous, uniseriate or occasionally in part biseriate, very variable in height (1 to 20+ cells).

Longitudinal parenchyma. Abundant; paratracheal, metatracheal, and usually metatracheal-zonate; the paratracheal intermingled with tracheids and distributed as described above, metatracheal restricted to the fibrous areas and toward the outer portion of the ring exhibiting more or less of a tendency toward aggregation into concentric lines of metatracheal.

Nonmechanical Physical Properties

Specific gravity	green volume	0.57
	oven-dry volume	0.67
Density, lb./cu. ft.	green	61
	oven-dry	42

Moisture content, when green: 72% based on oven-dry weight (42% on green basis).

Shrinkage, from green condition: v, 16.7%; r, 5.5%; t, 9.7%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2890	4420
Compressive stress at p.l. ⊥, lb./sq. in.	660	1040
Shear, maximum stress //, lb./sq. in.	1210	1490
Static bending FSPL, lb./sq. in.	4600	9000
Static bending E, lb./sq. in.	1.37×10^6	1.59×10^6
Static bending R, lb./sq. in.	8000	13,300
Toughness, in.	35	40
Hardness //, lb.	970	1250
Hardness ⊥, lb.	890	1130
Cleavability, lb./in. width	330	330

Chemical Properties

Destructive distillation: methanol, 1.22%; acetic acid, 4.88%; tar, 10.2%; charcoal, 39.6%.

Tannin in bark in commercial quantities.

Pathology

Resistance to decay: intermediate +.

Golden oak scale (Asterolecanium variolosum) does extensive damage.

Utilization

Use properties. Hard, heavy, strong, fairly easy to work, takes finish well, prominent ray fleck, not durable, good resistance to wear.

Lumber. One of the four principal producers of "white oak" lumber, the others being white, overcup, and swamp chestnut; piles, props, ties, flooring, car construction, cooperage, boxes, furniture, turnery, interior trim, fixtures, sash, doors, shipbuilding, vehicles, implements, cabinets, toilet seats, refrigerators, caskets.

Pulping. Sometimes used for soda pulp.

Other uses. Charcoal; bark is an important native source of tannin.

Supply. 6.8 million bd. ft. estimated (1940).

BLACK GUM

Scientific Name. Nyssa sylvatica Marshall.

Synonyms. Black tupelo, sour gum, tupelo, pepperidge.

Family Name. Nyssaceae.

Range. Southern Maine west to central Michigan; southwest to southeastern Oklahoma and eastern Texas; not in central or southern Florida.

Dimensions. 80 to 100 feet tall and 3 to 4 feet in diameter.

Bark. The bark on larger trees is "blocky" or with the appearance of alligator hide; volume, 12.4%.

Silvics. This species is commonly found on moist or wet sites but will not live under extreme conditions such as tupelo gum can stand.

Gross Features of the Wood. The wide sapwood is white to grayish white, and the heartwood is greenish or brownish gray in color. The wood is moderately hard and medium heavy, usually with interlocked grain, and without characteristic odor or taste. Flat grain boards exhibit a faint growth ring, although even under a lens the growth rings in the x-section are generally indistinct. In quarter section a distinct but not pronounced ribbon figure is present because of the interlocked grain. The texture is fine. The pores are small, not visible with the naked eye, quite uniform in size, numerous and fairly evenly distributed, solitary or occasionally in short radial groups. Parenchyma are not visible. The rays are fine, not distinct in the x-section without a hand lens, very close and appearing to form about half the area.

Microscopic Structure

Vessels. 80 to 180 per sq. mm., the largest 60 to 90 mu in diameter. The perforation plates are scalariform with numerous thin bars. Spiral thickening is occasionally present and is restricted to the tapering ends of the vessel segments. Intervessel pits orbicular to elliptical or more frequently rectangular, in transverse rows of 1 to 54, 4 to 20 (mostly 8 to 10) mu in diameter. Volume occupied, 38.4%.

Fibers. Moderately thick- to thick-walled; average, 20 to 32 mu in diameter and 1.8 mm. long. Volume occupied, 45.0%.

Rays. 8 to 13 per mm. tangentially on x-section, unstoried, 1 to 4 seriate, heterogeneous with the upright cells generally restricted to one row on the upper and lower margins and less than 60 mu high. Volume occupied 16.6%.

Longitudinal parenchyma. Paratracheal and metatracheal, scattered. Trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.46
	oven-dry volume	0.55
Density, lb./cu. ft.	green	45
	air-dry	35
	oven-dry	34

Moisture content, when green: 55% based on oven-dry weight (35% on green basis).

Shrinkage, from green condition: v, 13.9%; r, 4.4%; t, 7.7%.

Electrical resistance: 31,700 megohms at 7% moisture content
275 megohms at 12% moisture content

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	—	500
Compressive stress at p.l. //, lb./sq. in.	2490	3470
Compressive stress at p.l. /, lb./sq. in.	600	1150
Shear, maximum stress //, lb./sq. in.	1100	1340
Static bending FSPL, lb./sq. in.	4000	7300
Static bending E, lb./sq. in.	1.03×10^6	1.20×10^6
Static bending R, lb./sq. in.	7000	9600
Toughness, in.	30	22
Hardness //, lb.	790	1240
Hardness /, lb.	640	810
Cleavability, lb./in. width	330	340

Chemical Properties

Proximate analysis:

	F.P.L.
C. & B. cellulose, %	56.7
Lignin, %	28.4
Hot-water soly., %	4.0
Ether soly., %	0.4

Pathology

Resistance to decay: low.

Gray-olive stain on cut ends of logs caused by Lasiosphaeria pezizula.

Forest tent caterpillar (Malacosoma disstria).

Utilization

Use properties. Fine texture, does not splinter easily, rather easy to work, tendency to warp and twist in drying, almost white, susceptible to blue stain, not resistant to decay, able to take finish, holds nails well, good resistance to wear.

Lumber. 103 million bd. ft. cut in 1940; leading producers are Louisiana, South Carolina, Alabama, Mississippi; veneers, floors, ties, car construction, boxes and crates, furniture, interior trim, vehicles, toilet seats, cigar boxes, laundry appliances.

Pulping. Sulfite process. Reduces readily; fairly easy to bleach; yield, 48%. Soda process. Reduces readily; slightly stronger than aspen pulp; rather difficult to bleach; yield, 43%. Mechanical process. Standard strength; very light colored and fine fibered; yield, 90%.

Supply. Black plus tupelo gum estimated at 15 billion bd. ft.

18 million cu. ft. in the North Louisiana delta (1933).
358 million cu. ft. in southeast Texas (1935).
585 million bd. ft. in northeast Florida (1934).
1.2 billion bd. ft (includes tupelo) in southern Georgia (1934).

TUPELO GUM

Scientific Name. Nyssa aquatica Linnaeus.

Synonyms. Tupelo, water tupelo.

Family Name. Nyssaceae.

Range. Costal plain from southeastern Virginia to southern Texas and up the Mississippi valley to southwestern Indiana; not in central or southern Florida.

Dimensions. 80 to 100 feet high and 3 to 4 feet in diameter.

Bark. Thin, brownish gray with scaly ridges.

Silvics. The trunk bulges characteristically at the base and rapidly tapers to a long, clear bole. Tupelo is one of the most characteristic of southern swamp trees and is found on sites which are periodically, if not always, under water. It occurs in almost pure stands or mixed with cypress. The growth on well-drained bottomlands is rapid, whereas that on extremely swampy sites is much slower.

Gross Features of the Wood. Usually somewhat softer, lighter, and more porous, with more crowded, slightly larger vessels than black gum. Otherwise, the woods are the same.

Microscopic Structure. Within the limits given for black gum.

Nonmechanical Physical Properties

Specific gravity	green volume	0.46
	oven-dry volume	0.52
Density, lb./cu. ft.	green	56
	air-dry	35
	oven-dry	32

Moisture content, when green: 97% based on oven-dry weight (49% on green basis).

Shrinkage, from green condition: v, 12.5%; r, 4.2%; t, 7.6%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	—	700
Compressive stress at p.l. //, lb./sq. in.	2690	4280
Compressive stress at p.l. /, lb./sq. in.	590	1070
Shear, maximum stress, //, lb./sq. in.	1190	1590
Static bending FSPL, lb./sq. in.	4200	7200
Static bending E, lb./sq. in.	1.05×10^6	1.26×10^6
Static bending R, lb./sq. in.	7300	9600
Toughness, in.	30	23
Hardness //, lb.	800	1200
Hardness /, lb.	710	880
Cleavability, lb./in. width	340	360

Chemical Properties

Destructive distillation: methanol, 1.56%; acetic acid, 4.49%; charcoal, 45.9%; tar, 11.4%.

Pathology

Resistance to decay: low.

Diseases and insect pests similar to black gum.

Utilization. Similar in use properties and uses to black gum; 178 million bd. ft. cut in 1940; black gum and tupelo formerly were marketed together, but recently there has been a tendency to sell lumber under the individual name.

Supply. 6 billion bd. ft. in the United States (1933).

SWAMP BLACK GUM

Scientific Name. Nyssa biflora Walter.

Synonyms. Black gum, swamp tupelo.

Family Name. Nyssaceae.

Range. Southern Maryland to eastern Texas, but not in southern Florida.

Dimensions. Small or medium-sized tree.

Silvics. Grows in the swamps of the coastal plain.

Chemical Properties

Proximate analysis:

	F.P.L.	F.P.L.	F.P.L.
Hot-water soly., %	4.4	4.2	3.3
Ether soly., %	0.3	0.3	0.5
Alcohol-benzene soly., %	2.7	2.5	3.1
Pentosans, %		18.9	18.5
Lignin, %	29.0	26.7	29.5
C. & B. cellulose, %	54.3	59.2	56.7
Alpha-cellulose, %	44.0	44.7	47.2
1% NaOH soly., %	16.3	13.8	16.2

Utilization

Pulping. Mechanical process. Light colored, if ground soon after cutting; short fibered; lacks strength, when compared with softwoods, but could be used as filler stock.

SOUR TUPELO GUM

Scientific Name. Nyssa ogeche Marshall.

Synonyms. Sour tupelo, Ogeechee tupelo, Ogeechee lime.

Family Name. Nyssaceae.

Range. Southern South Carolina, Georgia, and northern Florida; in northern Florida extending westward through about two thirds of the state.

Dimensions. Small to medium-sized tree.

Silvics. Found near the coast only.

YELLOW BIRCH

Scientific Name. Betula lutea Michaux f.

Synonym. Birch.

Family Name. Betulaceae.

Range. Newfoundland; along the north bank of the St. Lawrence River westward to northwestern Manitoba; south to northeastern Iowa, northern Illinois, northern Indiana, northern Ohio, and south along the Appalachians to northern Georgia; then northeast along the mountains to Delaware.

Dimensions. 60 to 70 feet in height and 1 to 2 feet in diameter.

Bark. On young stems and branches, golden gray to bronze, separating at the surface and peeling horizontally into thin, curly, papery strips; eventually breaking up into reddish-brown plates on mature trunks.

Silvics. The tree has a long, well-formed bole, an irregularly rounded crown, and a shallow, widespreading root system. This species is the most typical of northeastern hardwoods and occurs in mixture with sugar maple, beech, hemlock, red spruce, balsam fir, and white pine.

Gross Features of the Wood. The sapwood is light yellow and the heartwood a distinctive reddish brown. The wood is moderately hard to hard, moderately heavy to heavy, without characteristic odor or taste. Flat grain boards show a faint growth ring. The growth ring is indistinct to the naked eye, delineated by a fine line of denser fibrous tissue at the outer margin and usually by smaller pores in the summerwood portion of the ring. The wood is diffuse-porous with pores appearing as whitish dots to the naked eye, the larger obviously wider than the widest rays, nearly uniform in size and evenly distributed throughout the growth ring, solitary or in short radial groups of 2 or more. Parenchyma are not visible. The rays are fine, not distinct with the naked eye but plainly visible with a hand lens, narrower than the largest pores.

Microscopic Structure

Vessels. 50 to 100 per sq. mm., the largest 60 to 160 mu in diameter; perforation plates scalariform; intervessel pits orbicular to hexagonal, minute (2 to 4 mu in diameter); volume occupied, 21.4%.

Fibers. Thin- to moderately thick-walled, 20 to 36 mu in diameter and 1.85 mm. long; volume occupied, 65.8%.

Rays. Unstoried, 1 to 5 seriate, homogeneous; volume occupied, 10.8%

Longitudinal parenchyma. Metatracheal, paratracheal, and terminal; volume occupied, 2.0%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.55
	oven-dry	0.66
Density, lb./cu. ft.	green	57
	air-dry	43
	oven-dry	41

Moisture content, when green: 67% based on oven-dry weight (40% on green basis)

Shrinkage, from green condition: v, 16.7%; r, 7.2%; t, 9.2%.

Coefficient of thermal expansion per degree F. at ordinary temperatures: l, 0.0000011; r, 0.0000146; t, 0.0000178.

Thermal conductivity: 1.00 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 87,000 megohms at 7% moisture content.
200 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	—	920
Compressive stress at p.l. //, lb./sq. in.	2620	6130
Compressive stress at p.l. ⊥, lb./sq. in.	530	1190
Shear, maximum stress //, lb./sq. in.	1110	1380
Static bending FSPL, lb./sq. in.	4200	10,100
Static bending E, lb./sq. in.	1.50×10^6	2.01×10^6
Static bending R, lb./sq. in.	8300	16,600
Toughness, in.	48	55
Hardness //, lb.	810	1480
Hardness ⊥, lb.	780	1260
Cleavability, lb./in. width	270	520

Chemical Properties

Calorific value: 26.2×10^6 B.t.u. per air-dry cord.

Destructive distillation of heartwood:

	Wisconsin	Pennsylvania
Methanol, %	1.45	1.62
Acetic acid, %	6.71	6.19
Tar, %	9.6	12.6
Charcoal, %	39.0	36.4

Special: Oil of wintergreen from bark of twigs.

Proximate analysis:

		Ritter and Fleck (1)				Freeman and Peterson (2)	
	F.P.L.	Sap	Heart	Sap	Heart	Sap	Heart
Ash, %		0.26	0.40	0.18	0.23	0.11	0.5
Hot-water soly., %	4.0	1.98	5.69	2.10	3.96	1.30	0.29
Cold-water soly., %		1.05	4.16	1.74	2.76	1.20	0.93
Ether soly., %	0.6	0.48	0.81	0.88	0.99	0.36	0.30
Alcohol-benzene soly., %						0.97	1.89
1% NaOH soly., %	19.9	16.8	20.5	19.8	21.1		
Acetic acid, %	4.30	2.34	1.78	3.75	2.83	3.79	6.11
Methoxyl, %	6.07	5.66	5.46	5.47	5.27	6.01	6.04
Pentosans, %	26.3	23.0	21.8	24.1	24.3	26.9	26.9
Lignin, %		24.7	24.6	27.8	28.1	18.6	20.2
Holocellulose, %						79.5	76.5
Pentosans, %						26.5	24.9
Acetyl, %						6.13	5.81
Methoxyl, %						1.31	0.93
C. & D. cellulose, %	61.3	58.9	56.9	56.6	54.9	59.4	58.4
Pentosans		12.2	12.5	12.6	12.0	19.3	17.0
Alpha-cellulose, %		30.7	35.8	29.6	29.4		

1. Ind. Eng. Chem. 15:1056(1923).
2. Ind. Eng. Chem., Anal. Ed. 13:803(1941).

Pathology

Resistance to decay: low +.

Red heart stain; brown mottled heart rot (Pholiota adiposa); Nectria canker; reddish yellow sap stain; white mottled rot (Fomes fomentarius) in heart; white trunk rot (Fomes igniarius)is common.

Pitch ray flecks caused by cambium miner (Agromyza pruinosa); bronze birch borer (Agrilus anxius) mines wood and inner bark.

Utilization

Use properties. Hard, heavy, stiff, strong, easily veneered, takes a good polish, glues easily, shrinks moderately, dries easily, wears well.

Lumber. Annual use from 1931-1940 was 148 million bd. ft., of which 75% was yellow, 15% sweet, and 10% paper birch; leading producers are Wisconsin Michigan, New York, Maine, Vermont, New Hampshire; flooring, furniture, turnery, veneer, cabinets, interior trim, ties, car construction, fixtures, woodenware, vehicles, spools, toys, matches, boxes, airplanes. Most important commercial hardwood in Canada.

Pulping. Sulfite process. Reduces readily; good color; fairly easily bleached; yield, 45%. Soda process. Reduces with some difficulty; fairly easy to bleach; yield, 42%.

Other uses. Destructive distillation; charcoal; fuel; 114,000 cords in 1937.

Supply

Estimate in 1938 of all birch in the United States was 18.5 billion bd. ft.
Estimate in 1942 of yellow birch saw timber in United States was 10 billion bd. ft.
5.6 billion cu. ft. in Canada.
3.9 billion bd. ft. and 24 million cords in the Lake States (1942).
3.7 billion bd. ft. in Upper Michigan (1935).

PAPER BIRCH

Scientific Name. Betula papyrifera Marshall.

Synonyms. White birch, canoe birch, silver birch.

Family Name. Betulaceae.

Range. Newfoundland; central Labrador westward across James Bay to eastern Manitoba; south through western Minnesota, northeastern Iowa, northern Illinois, southern Michigan, northern Ohio, central Pennsylvania, to Long Island; also in the Black Hills of South Dakota.

Dimensions. 50 to 70 feet in height and 1 to 2 feet in diameter.

Bark. The bark is dark brown at first, soon turning chalky to creamy white, separating into thin, papery strips; nearly black and deeply fissured at the base of old trees; volume, 13.2%

Silvics. This species is characteristically Canadian and occurs in the northern United States only in moist, cool locations. The tree has a long, cylindrical bole, an irregularly rounded crown, and a shallow root system. It occurs as a scattered tree in the mixed coniferous-hardwood forests of the north, mixed with white pine, red spruce, white spruce, balsam fir, maple, beech, yellow birch, and black ash. In some places, with white spruce and balsam fir, it comprises a large part of the permanent forest. On burned areas very commonly a mixture of white birch and aspen is found, especially if the site is moist.

Gross Features of the Wood. The wood is very similar to yellow birch in appearance, except that it is usually whiter in color.

Microscopic Structure. Similar to yellow birch except in volume occupied.

Vessels. 10.6%

Fibers. 75.7%

Rays. 11.7%

Longitudinal parenchyma. 2.0%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.48
	oven-dry volume	0.60
Density, lb./cu. ft.	green	50
	oven-dry	37

Moisture content, when green: 65% based on oven-dry weight (39% on green basis).

Shrinkage, from green condition: v, 16.2%; r, 6.3%; t, 8.6%.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	1640	3610
Compressive stress at p.l. ⊥, lb./sq. in.	340	740
Shear, maximum stress //, lb./sq. in.	840	1210
Static bending FSPL, lb./sq. in.	3000	6900
Static bending E, lb./sq. in.	1.17×10^6	1.59×10^6
Static bending R, lb./sq. in.	6400	12,300
Toughness, in.	49	34
Hardness //, lb.	470	890
Hardness ⊥, lb.	560	910
Cleavability, lb./in. width	210	540

Chemical Properties

Calorific value: 23.4×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	F.P.L.	F.P.L.	F.P.L.	F.P.L.	Freeman and Peterson (1) Sap	Freeman and Peterson (1) Heart	Richter (2)
Ash, %					0.24	0.21	
Hot-water soly., %	2.7	2.8	3.1	2.1	2.39	2.15	1.8
Cold-water soly., %					1.28	1.12	
Ether soly., %	1.0	0.9	1.0	1.0	0.79	2.19	1.7-3.5
Alcohol-benzene soly., %		3.2	5.8	3.2	3.31	6.44	2.1-4.3
1% NaOH soly., %		19.3	20.8	17.3			
Acetyl, %					7.12	7.6	
Methoxyl, %					6.10	5.75	
Pentosans, %				26.5	28.8	28.6	21.9-23.6
Lignin, %	25.7	23.8	26.3	26.8	17.6	19.6	22.5-25.1
Holocellulose, %					76.6	70.9	
Pentosans, %					28.5	25.7	
Acetyl, %					6.01	5.29	
Methoxyl, %					0.97	0.95	
C. & B. cellulose, %	60.6	61.4	60.0	60.4	55.6	51.0	
Pentosans, %					18.0	14.0	
Alpha-cellulose, %		41.6	39.7	43.9			

1. Ind. Eng. Chem., Anal. Ed. 13:803(1941).
2. Ind. Eng. Chem. 33:78(1941); extremes of 7 samples; sapwood and heartwood data also given.

Pathology

Resistance to decay: low +.

Brown rot (Polyporus betulinus) in dead sapwood; red heart stain; brown mottled heart rot (Pholiota adiposa); Nectria canker; reddish yellow sap stain; white mottled heart rot (Fomes fomentarius).

Pith ray flecks caused by cambium miner (Agromyza pruinosa); bronze birch borer (Agrilus anxius) mines wood and inner bark.

Utilization

Use properties. Works well under tools and, although not as strong as yellow birch, is quite a strong, tough, serviceable wood.

Lumber. Only 10% of birch lumber cut in the United States; turnery, toothpicks, spools, toys.

Pulping. Sulfite process. Reduces readily; poor color; fairly easy to bleach; yield, 45%. Soda process. Reduces with some difficulty; fairly easy to bleach; yield, 42%. Mechanical process. Short fibered, weak, highly absorbent; yield, 90-95%.

Other uses. Fuel; bark for native canoes.

Supply

Estimate of birch for the entire United States was 18.5 billion bd. ft. in 1938.
7 billion cu. ft. in Canada.
1.2 billion bd. ft. and 12.5 million cords in the Lake States (1938).
300 million bd. ft. in Upper Michigan (1935).

BEECH

Scientific Name. Fagus grandifolia Ehrhart.

Synonyms. American beech, red beech.

Family Name. Fagaceae.

Range. From Nova Scotia and New Brunswick west to the Soo and eastern half of the upper peninsula of Michigan, to southeastern Oklahoma and eastern Texas; not found in central or southern Florida.

Dimensions. 70 to 80 feet in height and 2 to 3 feet in diameter.

Bark. Thin, smooth, and light blue gray in color.

Silvics. Under forest conditions a clear, straight, massive trunk is developed. The root system is shallow and extensive. This species attains its best development in the lower Ohio valley and at lower elevations in the southern Appalachians in mixture with basswood, yellow poplar, black cherry, ash, sycamore, and bottomland oaks. It does not grow on the main bottomlands of the lower Mississippi River valley but on branch bottoms of streams in the pine types. In the north it usually associates with maple, birch, and hemlock.

Gross Features of the Wood. The sapwood is whitish and the heartwood whitish with a reddish tinge to reddish brown. The wood is moderately hard, medium heavy, without characteristic taste or odor. The wood is diffuse-porous with distinct growth rings delineated by a dark line or band of denser summerwood. Flat grain boards exhibit a faint growth ring figure. Pores are small, indistinct without a hand lens, usually crowded and largest in the springwood, decreasing in number and size through the central portion of the growth ring, scattered and very small in the late summerwood. Parenchyma are not visible with a hand lens or zonate in the late summerwood, the lines then appearing very finely punctate. The rays are of two types, compound and simple, the broad ones plainly visible with the naked eye, and the narrow rays, fine, not visible without magnification.

Microscopic Structure

Vessels. 50 to 200 per sq. mm., the largest 60 to 90 mu in diameter; tyloses present in the heartwood; perforation plates simple or those in the smaller vessels occasionally scalariform; intervessel pits round to elliptical, 6 to 20 mu in diameter.

Fibers. Thick-walled, 16 to 22 mu in diameter and 1.2 mm. long.

Rays. Unstoried, homogeneous or with marginal upright cells; compound rays 15 to 25+ seriate, 1 to several mm. high; narrow rays much more numerous, 1 to 5 seriate, up to 500+ mu high.

Longitudinal parenchyma. Abundant, metatracheal and metatracheal-zonate, the lines of the latter more evident toward the outer margin of the ring.

Nonmechanical Physical Properties

Specific gravity	green volume	0.56
	oven-dry volume	0.67
Density, lb./cu. ft.	green	54
	air-dry	44
	oven-dry	42

Moisture content, when green: 54% based on oven-dry weight (35% on green basis).

Shrinkage, from green condition: v, 16.3%; r, 5.1%; t, 11.0%.

Coefficient of thermal expansion per degree F. at ordinary temperatures: // .0000014; ⊥ .0000341

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	—	1010
Compressive stress at p.l. //, lb./sq. in.	2550	4880
Compressive stress at p.l. ⊥, lb./sq. in.	670	1250
Shear, maximum stress //, lb./sq. in.	1290	2010
Static bending FSPL, lb./sq. in.	4300	8700
Static bending E, lb./sq. in.	1.38×10^6	1.72×10^6
Static bending R, lb./sq. in.	8600	14,900
Toughness, in.	43	41
Hardness //, lb.	970	1590
Hardness ⊥, lb.	850	1300
Cleavability, lb./in. width	410	490

Chemical Properties

Calorific value: 27.8×10^6 B.t.u. per air-dry cord.

Destructive distillation:

Methanol, %	2.0	2.2
Acetic acid, %	5.6	5.8
Tar, %	9.7	9.1
Charcoal, %	43.1	40.6

Alcohol production: 6 gallons of ethanol per ton.

Proximate analysis:

	Freeman & Peterson (1)	
	Sap	Heart
Ash, %	0.31	0.57
Hot-water soly., %	2.17	0.43
Cold-water soly., %	2.33	0.23
Ether soly., %	0.20	0.57
Alcohol-benzene soly., %	1.37	0.91
Acetyl, %	7.13	6.05
Methoxyl, %	6.28	6.44
Pentosans, %	25.6	24.5
Lignin, %	20.6	22.3
Holocellulose, %	76.2	76.9
Pentosans, %	24.5	23.5
Acetyl, %	5.15	5.76
Methoxyl, %	0.95	1.24
C. & B. cellulose, %	60.8	60.7
Pentosans, %	17.9	18.3

1. Ind. Eng. Chem., Anal. Ed. 13:803(1941).

Pathology

Resistance to decay: low +.

Old trees subject to heart rot; cull high; beech bark disease (Nectria sp.) kills many trees; grayish-olive stain on ends of logs; white mottled heart rot (Fomes fomentarius) but mostly on dead timber; white heart rot (Fomes igniarius) especially severe in Adirondacks.

Wooly beech scale (Cryptococcus fagi) gives an opening for the entrance of beech bark disease.

Utilization

Use properties. Hard, heavy, strong, difficult to season, finishes with a smooth hard surface, holds glue well, high shrinkage, not very resistant to decay, close-textured, holds shape well, good nail holder, good resistance to wear.

Lumber. 91 million bd. ft. cut annually from 1931-1940; leading producers are West Virginia, Pennsylvania, Ohio, Indiana, and New York; flooring, furniture, turnery, ties, boxes, woodenware, vehicles, interior trim, laundry appliances, toys, butcher's blocks, shuttles, bobbins, toilet seats.

Pulping. Average annual cut from 1931-1940 was 26,000 cords; reduces with slightly more difficulty than aspen; easy to bleach; yield, 46%

Other uses. Destructive distillation (114,000 cords in 1937); charcoal; fuel; medicinal tar creosote; fruits could be used for hog feed and vegetable oils; veneers (10 million bd. ft. annually).

Supply

9 billion bd. ft. in the United States (1939).
1 billion cu. ft. in Canada.
1 billion bd. ft. in Upper Michigan (1935).

CHESTNUT

Scientific Name. Castanea dentata (Marshall) Borkhausen.

Synonyms. American chestnut, sweet chestnut.

Family Name. Fagaceae

Range. From southern Maine west to southeastern Michigan; southwest to northeastern Arkansas; east through northern Mississippi, central Alabama, northern Georgia, to western South Carolina; northeast in the Appalachian and Piedmont regions to Delaware.

Dimensions. 70 to 90 feet in height and 3 to 4 feet in diameter.

Bark. Dark brown and shallow fissured into broad, flat ridges.

Silvics. Unfortunately the chestnut blight has all but wiped out this fast-growing species. Whether eventually resistant sprouts or hybrids will develop is a moot question. The resistance of the wood to decay makes logging possible long after the death of the tree.

Gross Features of the Wood. The narrow sapwood of chestnut is whitish to light brown, and the heartwood is grayish brown to brown and darkens with age. The wood is moderately soft, light, not strong, without a characteristic odor but with a mild astringent taste. The growth rings are conspicuous as a result of the ring-porous structure. The springwood pores are very large, plainly visible with the naked eye, forming a broad, conspicuous band several pores in width; the transition from springwood to summerwood is abrupt; the summerwood pores are small, arranged in obliquely radial (flame-shaped) patches of light tissue which are not so obvious in narrow rings. Parenchyma are indistinct. The rays are very fine, barely visible with a lens.

Microscopic Structure

Vessels. In summerwood 80 to 130 per sq. mm.; largest springwood vessels 240 to 360 mu in diameter; perforation plates simple; or those in the summerwood vessels occasionally scalariform; intervessel pits orbicular to elliptical, 8 to 18 mu in diameter; volume occupied, 39.8%.

Tracheids. Present, confined to the vicinity of the springwood vessels.

Fibers. Thin-walled, 16 to 34 mu in diameter and 1.0 mm. long; volume occupied, 46.8%.

Rays. Unstoried, uniseriate or rarely in part biseriate, homogeneous; volume occupied, 11.9%.

Longitudinal parenchyma. Paratracheal sparse and restricted to occasional cells; metatracheal is abundant, especially in the summerwood; volume occupied, 1.5%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.40
	oven-dry volume	0.45
Density, lb./cu. ft.	green	55
	air-dry	30
	oven-dry	28

Moisture content, when green: 122% based on oven-dry weight (55% on green basis).

Shrinkage, from green condition: v, 11.6%; r, 3.4%; t, 6.7%.

Coefficient of thermal expansion per degree F.: // 0.0000036; ⊥ 0.0000181.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	—	460
Compressive stress at p.l. //, lb./sq. in.	2080	3780
Compressive stress at p.l. ⊥, lb./sq. in.	380	760
Shear, maximum stress //, lb./sq. in.	800	1080
Static bending FSPL, lb./sq. in.	3100	6100
Static bending E, lb./sq. in.	0.93×10^6	1.23×10^6
Static bending R, lb./sq. in.	5600	8600
Toughness, in.	24	19
Hardness //, lb.	530	720
Hardness ⊥, lb.	420	540
Cleavability, lb./in. width	240	250

Chemical Properties

Calorific value: 20.2×10^6 B.t.u. per air-dry cord.

Destructive distillation: methanol, 0.90%; acetic acid, 5.50%; tar, 4.7%; charcoal, 47.6%.

Special: Tannin obtained from wood by leaching with water.

Pathology

Resistance to decay: durable.

Chestnut blight (Endothia parasitica), a bark disease, has almost exterminated chestnut and so far the numerous sprouts which come up have been killed back after reaching a certain size; brown friable rot

(Polyporus sprague) on heartwood; white pocket rot (Polyporus croceus) on living or dead; spongy butt rot (Polyporus frondosus) of heartwood; Strumella canker; white pocket rot (Hymenochaete rubiginosa) on dead decorticated chestnut.

Very susceptible to insects and worms; chestnut borer (Agrilus bilineatus) mines and kills; Balaninus weevil destroys nut; Columbian timber beetle (Corthylus columbianus) bores in sapwood; Parandra brunnea beetle damages telegraph and telephone poles.

Utilization. Estimated annual cut from 1929-1933 for all purposes was 400 million bd. ft.

Use properties. Works easily, seasons well, takes a good finish, moderate strength and weight, very durable, beautiful grain and color, straight-grained, must be nailed carefully.

Lumber. Average annual cut from 1931-1940 was 78 million bd. ft.; leading producers are North Carolina, West Virginia, and Virginia; core stock, caskets, interior trim, furniture, boxes, poles, posts, props, and ties.

Pulping. Average cut in 1940 was 75,000 cords; leading producers are Tennessee and North Carolina; either unextracted or extracted chips are used, unextracted chips being cooked by the soda process and extracted chips by the kraft and semichemical processes.

Other uses. Tannin from wood--chief domestic source of vegetable tannin (441,000 long cords used annually from 1937-1940); distillation.

Supply. Estimated stand of live timber in 1934 was 4.5 billion bd. ft. of sawlogs and 20 million cords of smaller material; an indefinite amount of standing blight-killed timber. Possibly 90% of the stand is located in West Virginia, North Carolina, Tennessee, and Kentucky.

CUCUMBER TREE

Scientific Name. Magnolia acuminata Linnaeus.

Synonyms. Cucumber, cucumber magnolia.

Family Name. Magnoliaceae.

Range. Central New York westward through southeastern Michigan, northern Indiana, southeastern Illinois, southern Missouri, to eastern Oklahoma; eastward through southern Arkansas, central Mississippi, central Alabama, to northern Georgia; north in the Appalachians to New York.

Dimensions. 80 to 90 feet in height and 3 to 4 feet in diameter.

Bark. The brown bark is fissured into narrow flaky ridges.

Silvics. This medium-sized, rather intolerant tree has a straight, clear bole and a deep but widespreading root system. It is usually found on moist, deep, fertile soils of loose texture in mixture with white oak, pin oak, hickory, black gum, beech, ash, and yellow poplar. It reaches its best development in the southern Appalachians but is nowhere an abundant species.

Gross Features of the Wood. The sapwood is whitish and the heartwood yellow or greenish yellow to brown. The wood is soft to moderately hard, medium heavy, with no characteristic odor or taste. The growth rings are distinctly delineated by a whitish line of terminal parenchyma. The diffuse-porous wood has small pores, indistinct without a hand lens, quite uniform in size; fairly evenly distributed throughout the ring, solitary or in radial groups of 2 or more. Parenchyma are terminal and plainly visible with the naked eye. The rays are distinct with the naked eye in the x-section, nearly uniform in width.

Microscopic Structure

Vessels. 60 to 120 per sq. mm., the largest 80 to 100 mu in diameter; perforation plates simple; intervessel pitting scalariform (the pits linear or rarely elliptical), 12 to 50 mu in diameter; volume occupied, 38.6%.

Fibers. Thin- to moderately thick-walled, 28 to 40 mu in diameter and 1.6 mm. long; volume occupied, 47.5%.

Rays. 4 to 7 per mm. tangentially on the x-section, unstoried, 1 to 5 (mostly 1 to 2) seriate, homogeneous to heterogeneous, where heterogeneous the upper and lower margins generally consisting of one row of upright cells less than 60 mu in height; volume occupied, 13.9%.

Longitudinal parenchyma. Terminal, 1 or more seriate. Trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.44
	oven-dry volume	0.52
Density, lb./cu. ft.	green	49
	air-dry	34
	oven-dry	32

Moisture content, when green: 80% based on oven-dry weight (44% on green basis).

Shrinkage, from green condition: v, 13.6%; r, 5.2%; t, 8.8%.

Coefficient of thermal expansion per degree F.: // 0.00000595; ⊥ 0.0000429.

Electrical resistance: 43,700 megohms at 7% moisture content.
435 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	—	660
Compressive stress at p.l. //, lb./sq. in.	2810	4840
Compressive stress at p.l. ⊥, lb./sq. in.	410	710
Shear, maximum stress //, lb./sq. in.	990	1340
Static bending FSPL, lb./sq. in.	4200	8000
Static bending E, lb./sq. in.	1.56×10^6	1.82×10^6
Static bending R, lb./sq. in.	7400	12,300
Toughness, in.	30	35
Hardness //, lb.	600	950
Hardness ⊥, lb.	520	700
Cleavability, lb./in. width	260	290

Chemical Properties

Pentosans, 17.7%.

Use properties. Easily worked and finishes with a satiny luster, takes stain well, fairly easily dried although it has a slight tendency to warp and twist.

Lumber. About 1/2 million bd. ft. sold as such, the rest as yellow poplar: boxes, furniture, siding, vehicles, fixtures, venetian blinds.

Pulping.

Sulfite process. Reduces readily; dark colored and rather difficult to bleach. Soda process. Reduces fairly readily; rather difficult to bleach.

Supply No data available.

EVERGREEN MAGNOLIA

Scientific Name. Magnolia grandiflora Linnaeus.

Synonyms. Magnolia, southern magnolia, big laurel.

Family Name. Magnoliaceae.

Range. Southeastern North Carolina to southeastern Arkansas to southeastern Texas, but not in the southern half of Florida.

Dimensions. 60 to 80 feet in height and 2 to 3 feet in diameter.

Bark. The scaly bark is light brown to gray.

Silvics. This medium-sized tree has a tall, straight bole and a somewhat pyramidal crown. It is usually found on the drier sites of the southern bottomlands in mixture with yellow poplar, beech, ash, red gum, oaks, and hickories.

Gross Features of the Wood. Very similar to the cucumber tree, but the heartwood is said to be darker generally.

Microscopic Structure. Similar to cucumber tree with the following exceptions:

Vessels. Perforation plates scalariform with 6 to 10 stout bars; spiral thickening present.

Fibers. Length, 1.7 mm.

Nonmechanical Physical Properties

Specific gravity	green volume	0.46
	oven-dry volume	0.53
Density, lb./cu. ft.	green	59
	air-dry	35
	oven-dry	33

Moisture content, when green: 105% based on oven-dry weight (51% on green basis).

Shrinkage, from green condition: v, 12.3%; r, 5.4%; t, 6.6%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	—	740
Compressive stress at p.l. //, lb./sq. in.	2160	3420
Compressive stress at p.l. /, lb./sq. in.	570	1060
Shear, maximum stress //, lb./sq. in.	1040	1530
Static bending FSPL, lb./sq. in.	3600	6800
Static bending E, lb./sq. in.	1.11×10^6	1.40×10^6
Static bending R, lb./sq. in.	6800	11,200
Toughness, in.	54	29
Hardness //, lb.	780	1280
Hardness /, lb.	740	1020
Cleavability, lb./in. width	340	430

Chemical Properties

Ash 0.60%.

Ash composition: K_2O - 11.87, Na_2O - 2.52, CaO - 23.64, MgO - 4.89, P_2O_5 - 5.31, SO_3 - 3.46, Cl - 0.23, SiO_2 - 7.32, Fe_2O_3 - 1.60, C - 17.22, CO_2 - 22.16%.

Pathology. Decay caused by Fomes geotropus.

Utilization

Use properties. Similar to the cucumber tree.

Lumber. 27 million bd. ft. marketed as magnolia, others included with poorer grades of yellow poplar (1936); leading producers are Louisiana, Texas, Florida, and Mississippi.

Pulping. Probably similar to the cucumber tree.

Other uses. Ornamentals.

Supply. No data available.

SWEET BAY

Scientific Name. Magnolia virginiana Linnaeus and its southern variety, Magnolia virginiana australis Sargent.

Synonym. White bay.

Family Name. Magnoliaceae.

Range. Central New Jersey southwestward to south central Arkansas and eastern Texas.

Dimensions. Rarely exceeds 25 feet in height, except under more favorable conditions in the south when it reaches 50 feet or more.

Silvics. This small tree occurs chiefly in the swamps or other moist places along the coast.

Wood characteristics. Probably similar to the cucumber tree or evergreen magnolia.

Chemical Properties

Cellulose by 5% HNO_3 method, 44.2%; alpha-cellulose, 34.0% [Chen and Cameron, Ind. Eng. Chem. 34:224(1942)].

Utilization

Pulping

Sulfite process. Reduces readily; poor color; easily bleached. Soda process. Reduces readily; rather difficult to bleach.

Supply. No data available.

YELLOW POPLAR

Scientific Name. Liriodendron tulipifera Linnaeus.

Synonyms. Tulip tree, tulip poplar, whitewood.

Family Name. Magnoliaceae.

Range. Rhode Island west through central and western New York to southern Michigan; south through eastern and southern Illinois, southeastern Missouri, eastern Arkansas, to northeastern Louisiana; then east to northern Florida.

Dimensions. Average sized old trees 100 feet tall and 4 to 6 feet in diameter.

Bark. On young trees the bark is dark green and smooth, with small white spots, soon breaking up into long, rough, interlacing, rounded furrows separated by ashy-gray fissures; inner bark is bitter and aromatic.

Silvics. The tree has a straight trunk, a small oblong crown, and a deep, widespreading root system. It is commonly found on moist but well-drained soils of loose texture and at least moderate depth. This species is usually associated in mixture with hickory, chestnut, magnolia, black walnut, butternut, white pine, white oak, basswood, and black cherry.

Gross Features of the Wood. The sapwood is wide in young trees but narrow in virgin ones; it is whitish, often variegated or striped; the heartwood is clear yellow to dark yellowish, greenish, or pinkish brown. The wood is soft to moderately hard, moderately heavy, uniformly textured, and has no characteristic taste or odor. The growth rings are distinctly delineated by a whitish line of terminal parenchyma. The wood is diffuse-porous with small pores which are invisible without a lens, fairly uniformly distributed throughout the ring, solitary and in radial groups of 2 or more. Parenchyma are terminal, the line plainly visible to the naked eye. The rays are distinct with the naked eye on the x-section, nearly uniform in width.

Microscopic Structure

Vessels. 60 to 180 per sq. mm., the largest 80 to 130 mu in diameter; perforation plates scalariform with 6 to 10 thin bars; intervessel pits orbicular (or angular) to elliptical or rarely linear, 6 to 20 mu in diameter; volume occupied, 36.6%.

Fibers. Thin- to moderately thick-walled, 24 to 40 mu in diameter and 1.9 mm. long; volume occupied, 49.2%.

Rays. 4 to 7 per mm. tangentially on the x-section, unstoried, 1 to 5 (mostly 2 to 3) seriate, homogeneous to heterogeneous (one row of upright

cells on the upper and lower margins, less than 60 mu high); volume occupied, 14.2%.

Longitudinal parenchyma. Terminal, 1 or more seriate. Trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.38
	oven-dry volume	0.43
Density, lb./cu. ft.	green	38
	oven-dry	27

Moisture content, when green: 64% based on oven-dry weight (39% on green basis).

Shrinkage, from green condition: v, 12.3%; r, 4.0%; t, 7.1%.

Coefficient of thermal expansion per degree F.: t, 0.0000166; r, 0.0000157.

Electrical resistance: 24,000 megohms at 7% moisture content.
250 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	—	520
Compressive stress at p.l. //, lb./sq. in.	1930	3550
Compressive stress at p.l. ⊥, lb./sq. in.	330	580
Shear, maximum stress //, lb./sq. in.	740	1100
Static bending FSPL, lb./sq. in.	3400	6100
Static bending E, lb./sq. in.	1.09×10^6	1.50×10^6
Static bending R, lb./sq. in.	5400	9200
Toughness, in.	18	20
Hardness //, lb.	390	560
Hardness ⊥, lb.	340	450
Cleavability, lb./in. width	220	280

Chemical Properties

Proximate analysis:

	Ritter and Fleck (1)		Bray and Paul (2)			
	Sap	Heart	Sap	Heart	Sap	Sap
Ash, %	0.48	0.39	0.36	0.33		
Cold-water soly., %	1.29	1.50	1.45	1.45		
Hot-water soly., %	1.98	2.06	2.51	2.89		
Ether soly., %	0.27	0.43	0.13	0.58		
1% NaOH soly., %	16.7	17.7	16.9	17.6	16.7	16.9
Acetic acid, %	3.12	2.89	3.33	2.73		
Methoxyl, %	5.81	5.86	5.89	6.03		
Pentosans, %	21.7	21.6	20.0	20.2	18.4	18.8
Lignin, %	23.1	22.2	23.9	23.7	23.1	23.9
C. & B. cellulose, %	58.1	59.6	58.0	59.5	58.1	58.0
Alpha-cellulose, %	29.1	36.5	19.9	21.8		
Pentosans, %	10.3	10.4	11.5	11.5	15.5	19.0

1. Ind. Eng. Chem. 15:1056(1923).
2. Paper Trade J. 115, no. 16:33(Oct. 15, 1942).

Pathology

Resistance to decay: intermediate.

Blue stain; pink stain; Nectria canker; white flaky rot of sap and heartwood caused by the oyster mushroom (Pleurotus ostreatus).

Columbian timber beetle (Corthylus columbianus) mines sapwood; tulip tree scale (Toumeyella liriodendri).

Utilization

Use properties. Soft, even-textured, tendency toward brashness, light, easily worked, veneers easily, takes and holds paint exceptionally well, seasons easily, holds shape exceptionally well.

Lumber Average annual cut from 1931-1940 was 215 million bd. ft.; leading producers are Virginia, North Carolina, and Georgia; furniture, boxes, fixtures, core stock, car construction, siding, vehicles, interior trim, patterns, cabinets, woodenware, caskets, toys, cigar boxes, instruments.

Pulping. 92,000 cords used in 1936.

Sulfite process. Reduces readily; poor color; difficult to bleach; yield, 47%. Soda process. Reduces fairly readily; stronger than aspen; fairly easily bleached; yield, 45%.

Supply

38.7 million cords in the United States (1933).
10 billion bd. ft.

RED GUM

Scientific Name. Liquidambar styraciflua Linnaeus.

Synonyms. Sweet gum, liquidambar, gum, sap gum, hazelwood.

Family Name. Hamamelidaceae.

Range. Connecticut southwestward through the Ohio valley to southeastern Oklahoma and eastern Texas; not found in the southern half of Florida. This species grows also in central and southern Mexico and Guatemala.

Dimensions. 80 to 120 feet in height and 3 to 4 feet in diameter.

Bark: Grayish brown and deeply furrowed into narrow, somewhat rounded flaky ridges.

Silvics. This is a typical southern bottomland species and occurs for the most part on rich, moist, alluvial soils, although it is widely distributed on a great variety of sites with the exception of poorly drained locations. At its best this is a large tree with a long, straight bole, a small oblong or pyramidal crown, and a shallow widespreading root system. Red gum is very intolerant.

Gross Features of the Wood. The sapwood is white, frequently with a pinkish tinge and often discolored with bluish sap stain. The heartwood is pinkish gray to varying shades of reddish brown, the darker grades frequently with darker streaks of pigment figure. The wood is moderately hard, medium heavy, frequently with interlocked grain, without characteristic odor or taste. A faint growth ring is evident and occasionally irregular darker streaks in "figured" gum. The diffuse-porous wood has small pores invisible with the naked eye, quite uniform in size throughout the growth ring, numerous and frequently crowded, solitary or in short radial groups. Parenchyma are not visible. The rays are not distinct with the naked eye, are very close and apparently form half the area on the transverse surface. Longitudinal traumatic (wound) gum ducts are sometimes present in tangential rows which usually appear at wide intervals, frequently occluded with white deposits.

Microscopic Structure

Vessels. 120 to 180 per sq. mm., the largest 60 to 95 mu in diameter; perforation plates scalariform with many bars; spiral thickening present, restricted to the tapering ends of the vessel segments; intervessel pits in transverse rows of 1 to 3, orbicular to elliptical or linear through fusion, 6 to 30 mu in diameter; volume occupied 54.9%.

Gum canals. When present, they are arranged in a uniseriate tangential row, with angled orifice.

Fiber tracheids. Moderately thick-walled, 20 to 40 mu in diameter, with conspicuous bordered pits 7 to 9 mu in diameter and 1.7 mm. long; volume occupied, 26.8%.

Rays. 6 to 9 per mm. tangentially on the x-section, unstoried, 1 to 3 (mostly 1 to 2) seriate, mostly heterogeneous; upright cells in 1 to 5+ rows, 30 to 100 mu in height; volume occupied, 18.3%.

Longitudinal parenchyma. Paratracheal and metatracheal, sparse.

Nonmechanical Physical Properties

Specific gravity	green volume	0.44
	oven-dry volume	0.53
Density, lb./cu. ft.	green	50
	oven-dry	33

Moisture content, when green: 81% based on oven-dry weight (45% on green basis).

Shrinkage, from green condition: v, 15.0%; r, 5.2%; t, 9.9%.

Electrical resistance: 38,000 megohms at 7% moisture content.
160 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.		800
Compressive stress at p.l. //, lb./sq. in.	2230	4700
Compressive stress at p.l. ⊥, lb./sq. in.	460	860
Shear, maximum stress //, lb./sq. in.	1070	1610
Static bending FSPL, lb./sq. in.	3700	8100
Static bending E, lb./sq. in.	1.15×10^6	1.49×10^6
Static bending R, lb./sq. in.	6800	11,900
Toughness, in.	33	32
Hardness //, lb.	630	950
Hardness ⊥, lb.	520	690
Cleavability, lb./in. width	330	380

Chemical Properties

Calorific value: 17.7×10^6 B.t.u. per air-dry cord.

Destructive distillation of heartwood: methanol, 1.76%; acetic acid, 5.70%; tar, 11.7%; charcoal, 36.8%.

Alcohol production: 11.0 gallons of ethanol per ton.

Proximate analysis:

	F.P.L.	F.P.L.	Private Communication
Hot-water soly., %	2.5		6.8
Ether soly., %	0.5		
Alcohol-benzene soly., %	2.0		4.2
Methoxyl, %		4.61	6.3
Pentosans, %	20.7	21.1	17.9
Lignin, %	21.4		23.5
Methoxyl, %			20.2
C. & B. cellulose, %	60.5		59.0
Pentosans, %	13.7		11.2
Alpha-cellulose, %	44.5		
1% NaOH soly., %	12.0		24.9

Pathology

Resistance to decay: intermediate.

Green mold caused by Penicillium; grayish-olive stain on ends of logs; blue stain; Polyporus adjustus causes a white rot and considerable loss on red gum logs and stored lumber; Polystictus hirsutus is a white rot on sapwood.

Forest tent caterpillar (Malacosoma disstria) and evergreen bagworm (Thyridopteryx ephemeraeformis) defoliate.

Utilization. Estimated average annual consumption for all purposes in recent years was 900 million bd. ft.

Use properties. Tends to warp unless dried carefully, moderately heavy and strong, splits easily after kiln-drying, sap stain, interlocked grain which gives a ribbon stripe on quartering, sometimes figured with color, fine-textured, beautiful satiny finish, easily stained, veneers well, glues well, good nail- and screw-holding qualities, easily worked, heartwood very difficult to penetrate with preservatives, proportion of sap and heart lumber in typical logs of delta region is 3 to 2.

Lumber. Average annual cut from 1931 to 1940 was 430 million bd. ft. (second to oak); leading producers are Louisiana, South Carolina, Arkansas, and Mississippi; furniture, interior trim, cabinets, vehicles, boxes, fixtures, woodenware, boot and shoe findings, laundry appliances, cigar boxes, butcher's blocks, props, ties.

Pulping.

Sulfite process. Reduces readily; dark colored and rather difficult to bleach; yield, 46%.

Soda process. Reduces fairly readily; rather difficult to bleach; yield, 45%.

Other uses. Storax gum from bark of living trees; formation induced by cuts and wounds which expose the surface of the wood; veneer (258 million bd. ft. annually); slack cooperage (90 million bd. ft. annually).

Supply

Estimated stand for the United States in 1938 was 25 billion bd. ft.
320 million cu. ft. in the North Louisiana delta (1933).
620 million cu. ft. in southeastern Texas (1935).
474 million bd. ft. in northeastern Florida (1934).
1 billion bd. ft. in southern Georgia (1934).

SYCAMORE

Scientific Name. Platanus occidentalis Linnaeus.

Synonyms. Buttonwood, buttonball tree, plane tree.

Family Name. Platanaceae.

Range. Southern Maine through northern New York, southern Ontario, central Michigan, south central Wisconsin, to southeastern Nebraska; south to central Texas and in the east down to northern Florida.

Dimensions. Commonly over 100 feet high and 3 to 8 feet in diameter.

Bark. The bark on young branches is creamy white, soon turning brown; characteristically mottled (brown and white) by the exfoliation of the outer bark exposing the lighter layers beneath; the bark near the base of older trees is often entirely brown and scaly.

Silvics. This tree is one of the commonest of stream-bank and bottomland species. The root system is superficial. Its associates include American elm, the soft maples, bur oak, red birch, cottonwood, and willows.

Gross Features of the Wood. The sapwood is whitish to light reddish brown, and the heartwood is a light to dark reddish brown. The wood is moderately hard, medium heavy, generally with interlocked grain, with no characteristic taste or odor. The growth rings are distinct, delineated by a narrow band of lighter tissue at the outer margin. The wood is diffuse-porous with small pores, indistinct or barely visible with the naked eye, numerous and frequently crowded. Parenchyma are not visible. The rays are comparatively wide, conspicuous with the naked eye, nearly uniform in width, close, appearing as short, closely packed lines on the tangential surface, forming a high, reddish-brown or silvery fleck on the radial surface.

Microscopic Structure

Vessels. 100 to 140 per sq. mm., the largest 60 to 100 mu in diameter; perforation plates simple for the most part, occasionally scalariform with a few bars; intervessel pits elliptical to orbicular, 4 to 8 mu in diameter; volume occupied, 51.9%.

Fibers. Moderately thick-walled, 20 to 36 mu in diameter and 1.6 mm. long; volume occupied, 28.9%.

Rays. Unstoried, 4 to 14 seriate, up to 3+ mm. in height, homogeneous; volume occupied, 19.2%.

Longitudinal parenchyma. Paratracheal and metatracheal; the paratracheal are restricted to occasional cells, never forming a sheath; the metatracheal are abundant, scattered and zonate in short lines which exhibit no regularity.

Nonmechanical Physical Properties

Specific gravity	green volume	0.46
	oven-dry volume	0.54
Density, lb./cu. ft.	green	52
	air-dry	35
	oven-dry	34

Moisture content, when green: 83% based on oven-dry weight (45% on green basis).

Shrinkage, from green condition: v, 14.2%; r, 5.1%; t, 7.6%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	—	720
Compressive stress at p.l. //, lb./sq. in.	2400	3710
Compressive stress at p.l. /, lb./sq. in.	450	860
Shear, maximum stress //, lb./sq. in.	1000	1470
Static bending FSPL, lb./sq. in.	3300	6400
Static bending, E, lb./sq. in.	1.06×10^6	1.42×10^6
Static bending R, lb./sq. in.	6500	10,000
Toughness, in.	26	26
Hardness //, lb.	700	920
Hardness /, lb.	610	770
Cleavability, lb./in. width	330	400

Chemical Properties

Calorific value: 18.5×10^6 B.t.u. per air-dry cord.

Pentosans: 21.6%.

Alcohol production: 9.7 gallons of ethanol per ton.

Pathology.

Resistance to decay: low.

Anthracnose caused by Gnomonia veneta severely attacks leaves and twigs; evergreen bagworm (Thyridopteryx ephemeraeformis) defoliates.

Utilization. Total annual cut estimated at 35 million bd. ft.

Use properties. Moderately hard but not strong, somewhat difficult to work, sometimes brittle, often with interlocked grain which gives a ribbon stripe on quartering, shrinks moderately, inclined to warp but is easily kiln-dried.

Lumber. Average annual cut 22 million bd. ft. from 1931-1940; leading producers are Mississippi, Louisiana, and Arkansas; boxes, secondary furniture, interior trim, vehicles, implements, veneers, laundry appliances, butcher's blocks.

Pulping. Chip when wet.

Sulfite process. Reduces readily; easily bleached.

Soda process. Reduces readily; fairly easy to bleach.

Supply. No data available.

SUGAR MAPLE

Scientific Name. Acer saccharum Marshall.

Synonyms. Hard maple, rock maple.

Family Name. Aceraceae.

Range. Southern Newfoundland and the mouth of the St. Lawrence River west to northern Minnesota; south to northeastern Texas; east to northern Georgia and north in the Piedmont region to New Jersey.

Dimensions. 60 to 80 feet in height and 2 feet in diameter.

Bark. The gray bark is very variable, being deeply furrowed, with long, irregular, thick plates or ridges, sometimes scaly; volume, 13.7%.

Silvics. Under forest conditions this tree develops a clear, straight, full bole with a shallow and widespreading root system. Best growth occurs on moist, fertile, well-drained soils, but the species will persist on more sterile sites. In the northern hardwood forest, yellow birch, beech, hemlock, and white pine are common associates; farther south, sugar maple is found mixed with the central hardwoods such as basswood, ash, yellow poplar, hickories, and oaks. This species is very tolerant.

Gross Features of the Wood. The sapwood, which is several inches wide in mature trees, is whitish with a reddish tinge; the heartwood is light reddish brown. The wood is hard, medium heavy to heavy, uniformly textured, with no characteristic taste or odor. The growth rings are usually fairly distinct, delineated by a narrow, darker line of denser fibrous tissue, which gives a faint growth ring figure. Occasional samples show bird's-eye, curly, or wavy grain. The wood is diffuse-porous with small pores, indistinct without a hand lens, quite uniform in size, evenly distributed throughout the growth ring, solitary or in short radial groups of 2 or more. Parenchyma are not visible. The rays are of two widths; the broad rays are visible with the naked eye, fully as wide as the largest pores, forming a pronounced close ray fleck on the quarter surface, appearing on the tangential surface as short, crowded lines which are visible to the naked eye; the narrow rays are scarcely visible with a hand lens.

Microscopic Structure

Vessels. 40 to 80 per sq. mm., the largest 70 to 90 mu in diameter; perforation plates simple; spiral thickening present; intervessel pits orbicular to hexagonal, 6 to 10 mu in diameter; volume occupied, 21.0%.

Fibers. Thin- to moderately thick-walled, 16 to 30 mu in diameter; volume occupied, 61.1%.

Rays. Unstoried, essentially homogeneous; the broader rays 3 to 8 (mostly 5 to 7) seriate, up to 800+ mu in height; the narrow rays 1 to 3

(mostly 1) seriate, usually less than 200 mu in height; volume occupied, 17.9%.

Longitudinal parenchyma. Sparse, terminal paratracheal and metatracheal. Trace.

Nonmechanical Physical Properties —

Specific gravity	green volume	0.56
	oven-dry volume	0.68
Density, lb./cu. ft.	green	56
	air-dry	44
	oven-dry	42

Moisture content, when green: 58% based on oven-dry weight (37% on green basis).

Shrinkage, from green condition: v, 14.9%; r, 4.9%; t, 9.5%.

Coefficient of thermal expansion per degree F.: // 0.0000012; ⊥ 0.0000602.

Thermal conductivity: 1.16 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Electrical resistance: 72,400 megohms at 7% moisture content.
105 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2850	5390
Compressive stress at p.l. ⊥, lb./sq. in.	800	1810
Shear, maximum stress //, lb./sq. in.	1460	2330
Static bending FSPL, lb./sq. in.	5100	9500
Static bending E, lb./sq. in.	1.55×10^6	1.83×10^6
Static bending R, lb./sq. in.	9400	15,800
Toughness, in.	40	39
Hardness //, lb.	1070	1840
Hardness ⊥, lb.	970	1450

Chemical Properties

Calorific value: 29.0×10^6 B.t.u. per air-dry cord.

Destructive distillation: methanol, 1.94%; acetic acid, 5.42%; tar, 12.4%; charcoal, 39.8%.

Alcohol production: 9 gallons of ethanol per ton.

Special: chemistry of maple sap and syrup.

Proximate analysis:

	F.P.L.	F.P.L.	Freeman and Peterson (1) Sap	Heart
Ash, %	0.44		0.32	0.84
Hot-water soly., %	4.36	3.4	2.08	1.20
Cold-water soly., %	2.65		0.81	0.52
Ether soly., %	0.25	2.3	0.1	0.89
Alcohol-benzene soly., %		5.2	1.31	1.22
Acetic acid, %	4.46		6.56	4.94
Methoxyl, %	7.25		6.34	6.50
Pentosans, %	23.2	21.3	22.8	23.0
Lignin, %		23.2	20.3	21.8
Holocellulose, %			72.3	76.0
Pentosans, %			22.7	22.6
Acetyl, %			5.12	4.05
Methoxyl, %			0.83	0.97
C. & B. cellulose, %	60.8	56.8	60.4	60.3
Pentosans, %	14.8		16.0	14.3
1% NaOH soly., %	17.6	19.7		
Alpha-cellulose, %		41.9		

1. Ind. Eng. Chem., Anal. Ed. 13:803(1941).

Pathology

Resistance to decay: low +.

Green stain (mineral streak); reddish-yellow stain of sapwood; soft, spongy white rot of heartwood caused by Hydnum septantrionale; the important, soft, white rot of heartwood caused by Fomes connatus.

Green-striped maple worm (Anisota rubicunda) defoliates; flat-headed apple-tree borer (Chrysobothris femorata) mines outer wood; pitted ambrosia beetle (Corthylus punctatissimus); maple borer (Glycobius speciosus) mines wood; forest tent caterpillar (Malacosoma disstria) defoliates; maple case-bearer (Paraclemensia acerifoliella) mines leaves; pigeon horntail (Tremex columba) mines wood.

Utilization

Use properties. Hard, heavy, splendid resonance; works well, taking a fine smooth surface and a high polish; glues well, holds nails and screws well but is difficult to nail; easy to finish; very strong and stiff; not durable; seasons slowly; shrinkage fairly high; heartwood moderately difficult to penetrate with a preservative; good resistance to wear.

Lumber. Average annual cut from 1931-1940 was 373 million bd. ft; Michigan has been leader since 1899, Wisconsin second, and Pennsylvania, West Virginia, or New York third; flooring, car construction, boxes, furniture, turnery, interior trim, vehicles, implements, musical instruments, fixtures, refrigerators, shuttles, athletic goods, toys, boot and shoe findings, toilet seats, woodenware, millwork, bowling alleys and pins,

spools and bobbins.

Pulping. Average annual consumption from 1931-1940 was 77,000 cords.

Sulfite process. Reduces very easily; excellent color; bleaches easily; yield, 44%.

Soda process. Reduces with some difficulty; rather difficult to bleach; yield, 42%.

Other uses. Fuel; destructive distillation (140,000 cords annually); charcoal; syrup; sugar; veneer (32 million bd. ft. annually).

Supply. Sugar maple is the predominant maple in all states where maple grows and is estimated to make up three fourths of the total stand. The total stand is estimated at 25 billion bd. ft.; hence, 18 billion bd. ft. are hard maple.

6.7 billion bd. ft. in Upper Michigan (1935).
3.7 billion cu. ft. of all maples in Canada.

RED MAPLE

Scientific Name. Acer rubrum Linnaeus.

Synonyms. Soft maple, swamp maple, scarlet maple.

Family Name. Aceraceae.

Range. Southern Newfoundland and mouth of the St. Lawrence River to the Lake of the Woods; south to eastern Texas and east to the Atlantic coast.

Dimensions. 50 to 70 feet high and 1 to 2 feet in diameter.

Bark. Smooth and light gray on young trees, eventually breaking up into long, narrow, scaly plates separated by shallow fissures.

Silvics. The tree is medium-sized with a long, fairly clear bole, an irregular or rounded crown, and a shallow root system. It is characteristic of swamp sites and is associated with black ash, black gum, cottonwood, American elm, and the bottomland oaks. In the north it is also found on drier locations with white pine and the northern hardwoods.

Gross Features of the Wood. The wide sapwood is white and the heartwood is light brown to brown with a reddish tinge, sometimes with a faint purplish cast. The wood is soft to moderately hard, medium heavy, without characteristic odor or taste. The growth rings are not very distinct, delineated by a narrow, darker line of denser fibrous tissue. The wood is diffuse-porous with small pores, indistinct without a hand lens, evenly distributed throughout the growth ring, mostly solitary or in short radial groups of 2 or more. Parenchyma are not visible. The rays are visible with the naked eye, intergrading in width, the broadest about as wide as the largest pores, forming a pronounced close ray fleck on the radial face, appearing on the tangential surface as short crowded lines which are visible without magnification.

Microscopic Structure

Vessels. 30 to 80 per sq. mm., the largest 60 to 80 mu in diameter; perforation plates simple; spiral thickening present; intervessel pits orbicular to hexagonal, 4 to 10 mu in diameter. Volume occupied, 18.0%.

Fibers. Thin- to moderately thick-walled, 16 to 30 mu in diameter and 0.7 mm. long; volume occupied, 68.7%.

Rays. Unstoried, essentially homogeneous; 1 to 5 seriate. Volume occupied, 13.3%.

Longitudinal parenchyma. Sparse, terminal, paratracheal, and metatracheal, trace.

Nonmechanical Physical Properties

Specific gravity	green volume	0.49
	oven-dry volume	0.55
Density, lb./cu. ft.	green	50
	oven-dry	34

Moisture content, when green: 63% based on oven-dry weight (39% on green basis).

Shrinkage, from green condition: v, 13.1%; r, 4.0%; t, 8.2%.

Thermal conductivity: 1.04 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Compressive stress at p.l. //, lb./sq. in.	2360	4650
Compressive stress at p.l. ⊥, lb./sq. in.	500	1240
Shear, maximum stress //, lb./sq. in.	1150	1850
Static bending FSPL, lb./sq. in.	3800	8700
Static bending E, lb./sq. in.	1.39×10^6	1.64×10^6
Static bending R, lb./sq. in.	7700	13,400
Toughness, in.	32	32
Hardness //, lb.	780	1430
Hardness ⊥, lb.	700	950
Cleavability, lb./in. width	290	500

Chemical Properties

Calorific value: 24.0×10^6 B.t.u. per air-dry cord.

Destructive distillation: methanol, 1.69%; acetic acid, 6.30%; tar, 12.1%; charcoal, 41.2%.

Pathology. Resistance to decay: low +.

Utilization

Use properties. The wood of red maple is very similar to hard maple but is not so hard, strong, or heavy as that species, although in these respects it is superior to silver maple.

Lumber. About 6 billion bd. ft. of soft maples cut annually. Uses are practically the same as those for hard maple and, except for the most exacting requirements with respect to hardness and strength, they are not differentiated in commercial application; secondary furniture, boxes, body frames, veneer baskets, ironing boards, woodenware, ties, slack cooperage.

Pulping

Sulfite process. Reduces very easily; rather poor color; easily bleached; yield, 44%.

Soda process. Reduces very easily; fairly easy to bleach; yield 42%.

Other uses. Fuel; charcoal.

Supply. 800 million bd. ft. in Upper Michigan (1935).

SILVER MAPLE

Scientific Name. Acer saccharinum Linnaeus.

Synonyms. Soft maple, white maple.

Family Name. Aceraceae.

Range. Central New Brunswick through southern Quebec, southern Ontario, central Michigan, central Wisconsin, to central Minnesota; south through southeastern South Dakota to northeastern Oklahoma, southeastward to western Florida; then north but not on the immediate coast.

Dimensions. 60 to 80 feet high and 2 to 3 feet in diameter.

Bark. Silvery gray on young trees, later breaking up into long, thin, scaly plates which are unattached at the ends.

Silvics. The tree is medium-sized and usually has a short bole which divides near the ground into several upright branches; the crown is widespreading and the root system shallow. This species is a characteristic bottomland one.

Gross Features of the Wood. Similar to those of red maple.

Microscopic Structure. Similar to red maple. The following volumes are given, however: vessels, 21.4%; fibers 66.7%; rays, 11.9%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.44
	oven-dry volume	0.51
Density, lb./cu. ft.	green	45
	oven-dry	32

Shrinkage, from green condition: v, 12.0%; r, 3.0%; t, 7.2%.

Moisture content, when green: 66% based on oven-dry weight (40% on green basis).

Thermal conductivity: 1.04 B.t.u./hr./sq. ft. with 1° F. gradient/inch thickness.

Mechanical Properties

	Green	Air-dry
Tensile ⊥, lb./sq. in.	--	500
Compressive stress at p.l. //, lb./sq. in.	1930	4360
Compressive stress at p.l. ⊥, lb./sq. in.	460	910
Shear, maximum stress //, lb./sq. in.	1050	1480
Static bending FSPL, lb./sq. in.	3100	6200
Static bending E, lb./sq. in.	0.94×10^6	1.14×10^6
Static bending R, lb./sq. in.	5800	8900
Toughness, in.	29	25
Hardness //, lb.	670	1140
Hardness ⊥, lb.	590	700
Cleavability, lb./in. width	300	340

Chemical Properties

Calorific value: 21.7×10^6 B.t.u. per air-dry cord.

Pentosans: 22.1%.

Alcohol production: 14 gallons of ethanol per ton.

Pathology. Resistance to decay: low +.

Utilization

Use properties. Light in color, and considerably softer, lighter, and weaker than sugar maple. Inferior to red maple.

Lumber. Mixed with red and sugar maples, except for most exacting uses.

Pulping. Probably similar to red maple

Other uses. Fuel; charcoal.

Supply. No data available.

YELLOW BUCKEYE

Scientific Name. Aesculus octandra Marshall.

Synonyms. Buckeye, sweet buckeye.

Family Name. Hippocastanaceae.

Range. Southwestern Pennsylvania west to northern Missouri, southeastern Kansas, eastern Oklahoma and northeastern Texas; east to northern Georgia; north in the Appalachians.

Dimensions. 60 to 90 feet tall and 2 to 3 feet in diameter.

Bark. No information available.

Silvics. Best development is made on deep fertile soils in the mountains of Tennessee and North Carolina, where it occurs in mixture with other hardwoods. In the northern part of its range it is a bottomland species; farther south it leaves the stream banks and ascends high mountainous slopes where it is locally sometimes one of the principal species in the stand.

Gross Features of the Wood. The sapwood is white to grayish white, gradually merging into the heartwood which is creamy white to pale yellowish white, frequently with grayish streaks of stain. The wood is light, soft, straight-grained, and is difficult to split; it is weak and not very stiff. It has no characteristic taste or odor. The growth rings are not visible or barely distinct and delineated by a light-colored line, generally narrow. The diffuse-porous wood has numerous minute pores not visible without a hand lens, nearly constant in size, and quite evenly distributed throughout the growth ring, solitary and in radial groups of 2 or more. Parenchyma are not visible or barely visible as a light line terminating the growth ring. The rays are very fine, scarcely visible with a hand lens, close and often apparently forming half of the area on the cross section, usually storied and forming fine ripple marks on the tangential surface.

Microscopic Structure

Vessels. 120 to 200 per sq. mm., the largest 40 to 80 mu in diameter; perforation plates simple; spiral thickening present; intervessel pits orbicular to angular, 6 to 12 mu in diameter.

Fibers. Thin-walled, 16 to 30 mu in diameter and 0.9 mm. long.

Rays. Usually storied, uniseriate, homogeneous to heterogeneous.

Longitudinal parenchyma. Terminal and paratracheal; the terminal is a more or less continuous, 1 or more seriate line; paratracheal sparse, restricted to occasional cells.

Nonmechanical Physical Properties

Specific gravity	green volume	0.33
	oven-dry volume	0.38
Density, lb./cu. ft.	green	49
	air-dry	25
	oven-dry	24

Moisture content, when green: 141% based on oven-dry weight (58% on green basis).

Shrinkage, from green condition: v, 12.0%; r, 3.5%; t, 7.8%.

Mechanical Properties

	Green	Air-dry
Tensile /, lb./sq. in.	—	520
Compressive stress at p.l. //, lb./sq. in.	1680	3010
Compressive stress at p.l. /, lb./sq. in.	210	440
Shear, maximum stress //, lb./sq. in.	660	960
Static bending FSPL, lb./sq. in.	2600	5100
Static bending E, lb./sq. in.	0.98×10^6	1.17×10^6
Static bending R, lb./sq. in.	4800	7500
Toughness, in.	18	16
Hardness //, lb.	360	470
Hardness /, lb.	290	350
Cleavability, lb./in. width	180	240

Pathology

Resistance to decay: low.

Blue stain common.

White-marked tussock moth (Hemerocampa leucostigma) defoliates; oyster shell scale (Lepidosaphes ulmi).

Utilization

Use properties. Light, soft, straight-grained, weak, difficult to split, not very stiff, little or no figure, heartwood not distinct, blue stain common during seasoning, low resistance to wear.

Lumber. Cut 1.3 million bd. ft. in 1933; leading producers are Tennessee, North Carolina, Indiana; boxes, cigar boxes, woodenware and novelties, toys, specialty millwork, signs, artificial limbs.

Pulping. Probably similar to Ohio buckeye.

Supply. No information available.

OHIO BUCKEYE

Scientific Name. Aesculus glabra Willdenow.

Synonyms. Buckeye, fetid buckeye.

Family Name. Hippocastanaceae.

Range. Central Pennsylvania west to northeastern Nebraska; south to central Oklahoma and southern Arkansas; east to western North Carolina; north in the Appalachians.

Dimensions. Smaller than yellow buckeye.

Bark. No information available.

Silvics. A medium-sized tree. Similar in habits to yellow buckeye.

Gross Features of the Wood. Similar to yellow buckeye.

Microscopic structure. Similar to yellow buckeye.

Physical Properties. Similar to yellow buckeye.

Pathology. Similar to yellow buckeye.

Utilization

Use properties. Similar to yellow buckeye.

Lumber. Mixed with yellow buckeye, but relatively little enters the trade because of its limited range and small size.

Pulping.

Sulfite process. Reduces readily; the pulp is silver gray in color and is rather difficult to bleach.

Soda process. Reduces fairly readily; the pulp is rather difficult to bleach.

Supply. No data available.

BASSWOOD

Scientific Name. Tilia glabra Ventenat.

Synonyms. Linn, American linden.

Family Name. Tiliaceae.

Range. New Brunswick to the eastern shore of Lake Superior, and from its western shore to southeastern Manitoba; south to eastern Kansas and southern Missouri; in the East, along the coast to Delaware and inland through the Appalachians and Ohio valley to Kentucky.

Dimensions. 70 to 80 feet in height and 2 to 3 feet in diameter.

Bark. On young trees green or grayish green, later breaking up into narrow ridges, somewhat scaly on the surface.

Silvics. This tree has a long, clear, cylindrical, sometimes buttressed bole, and a deep but widespreading root system. Best development is reached in the southern part of its range where it occurs on deep, moist soils in mixture with other hardwoods; in the North it grows on drier, more rocky sites.

Gross Features of the Wood. The sapwood is whitish to creamy white or pale brown, merging more or less gradually into the darker heartwood which is pale brown, sometimes with a reddish tinge. It is soft, light, straight-grained, fine, even-textured, with a faint characteristic odor on a fresh-cut surface, and tasteless. Growth rings are fairly distinct, pores numerous, small, distinctly visible with a hand lens, quite evenly distributed, solitary and in radial or tangential groups of 2 or more. Parenchyma are not distinct or barely visible with a hand lens, zonate. The rays are variable in width, the broader not distinct in the cross section without a hand lens, forming high, scattered ray flecks on the quarter surface.

Microscopic Structure

Vessels. 100 to 160 per sq. mm., the largest 60 to 160 mu in diameter; perforation plates simple; spiral thickening present; intervessel pits orbicular to angular, 5 to 7 mu in diameter; volume occupied, 55.6%.

Fibers. Thin-walled, 24 to 36 mu in diameter and 1.1 mm. in length; volume occupied, 36.1%.

Rays. Unstoried, of two widths; broad rays 1 to 6 seriate, up to 1.2+ mm. in height, essentially homogeneous; narrow rays uniseriate for the most part, much lower than the broad rays (mostly less than 300 mu high), the cells nearly uniform in size but higher than those in the broad rays. Volume occupied, 6.1%.

Longitudinal parenchyma. Abundant, metatracheal-zonate, the lines numerous and uniseriate; volume occupied, 2.2%.

Nonmechanical Physical Properties

Specific gravity	green volume	0.30
	oven-dry volume	0.37
Density, lb./cu. ft.	green	42
	oven-dry	26

Moisture content when green: 105% based on oven-dry weight (51% on green basis).

Shrinkage, from green condition: v, 15.8%; r, 6.6%; t, 9.3%.

Electrical resistance: 36,300 megohms at 7% moisture content.
45 megohms at 12% moisture content.

Mechanical Properties

	Green	Air-dry
Tensile //, lb./sq. in.	--	350
Compressive stress at p.l. //, lb./sq. in.	1690	3800
Compressive stress at p.l. ⊥, lb./sq. in.	210	450
Shear, maximum stress //, lb./sq. in.	600	990
Static bending FSPL, lb./sq. in.	2700	5900
Static bending E, lb./sq. in.	1.04×10^6	1.46×10^6
Static bending R, lb./sq. in.	5000	8700
Toughness, in.	16	16
Hardness //, lb.	290	520
Hardness ⊥, lb.	250	410
Cleavability, lb./in. width	150	230

Chemical Properties

Calorific value: 17.0×10^6 B.t.u. per air-dry cord.

Proximate analysis:

	F.P.L.	McMillen, et al. (1)
Ash, %	0.86	0.37
Cold-water soly., %	2.12	
Hot-water soly., %	4.07	
Ether soly., %	1.96	
1% NaOH soly., %	23.8	
Acetic acid, %	5.79	
Methoxyl, %	6.00	
Pentosans, %	22.1	14.8
Lignin, %		16.7
C. & B. cellulose, %	61.2	61.0
Alpha-cellulose, %		41.9

1. Ind. Eng. Chem. 30:1408(1938); F.P.L. modified methods.

Pathology

Resistance to decay: low.

Brown mottled rot (Pholiota adiposa) in heartwood; soft spongy rot (Collybia velutipes) in sapwood; dark streak strain; Nectria canker.

White-marked tussock moth (Hemerocampa leucostigma) destroys leaves.

Utilization

Total annual cut-about 100 million bd. ft.

Use properties. Soft, light, straight-grained, easily worked, sapwood has clear white appearance, seasons without difficulty, smooth finish, takes and holds paints excellently, not durable, good gluing and nail-holding properties.

Lumber. Average annual cut 69 million bd. ft. from 1931-1940, 50% from Wisconsin and Michigan; leading producers are Wisconsin, Michigan, West Virginia; boxes, baskets, crates, dairymen's supplies, furniture, caskets, handles, laundry appliances, refrigerators, toys, venetian blinds, piano keys, trunks, woodenwork and novelties.

Pulping. Approximately 5000 cords used annually, almost completely by the soda process.

Sulfite process. Very shivy; cannot be bleached satisfactorily.

Soda process. Reduces readily; fairly easy to bleach.

Other uses. Excelsior, hand carving, modelling, flour-barrel heads, thick veneer as furniture core.

Supply.

4 billion bd. ft. in the United States in 1938.
2 billion bd. ft. in the Lake States (1938).
375 million cu. ft. in Canada (1938).
0.5 billion bd. ft. in Upper Michigan (1935).

WHITE BASSWOOD

Scientific Name. Tilia heterophylla Ventenat.

Synonyms. Basswood, Linn, Wahoo.

Family Name. Tiliaceae.

Range. Typically a southern species found from southeastern Indiana, southeast through West Virginia, the Piedmont region of the Carolinas, and Georgia, to western Florida and central Alabama; north to central Kentucky.

Silvics. In size and silvical features it is similar to basswood.

Utilization. In use properties and uses it is similar to basswood.

MICHAUX BASSWOOD

Scientific Name. Tilia heterophylla michauxii (Nuttall) Sargent.

Synonym. White basswood.

Family Name. Tiliaceae

Range. Central Pennsylvania, southwestern New York, southern Ohio to northeastern Missouri and northwestern Arkansas; east to central Alabama and northern Georgia; north in the Appalachians to Pennsylvania.

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