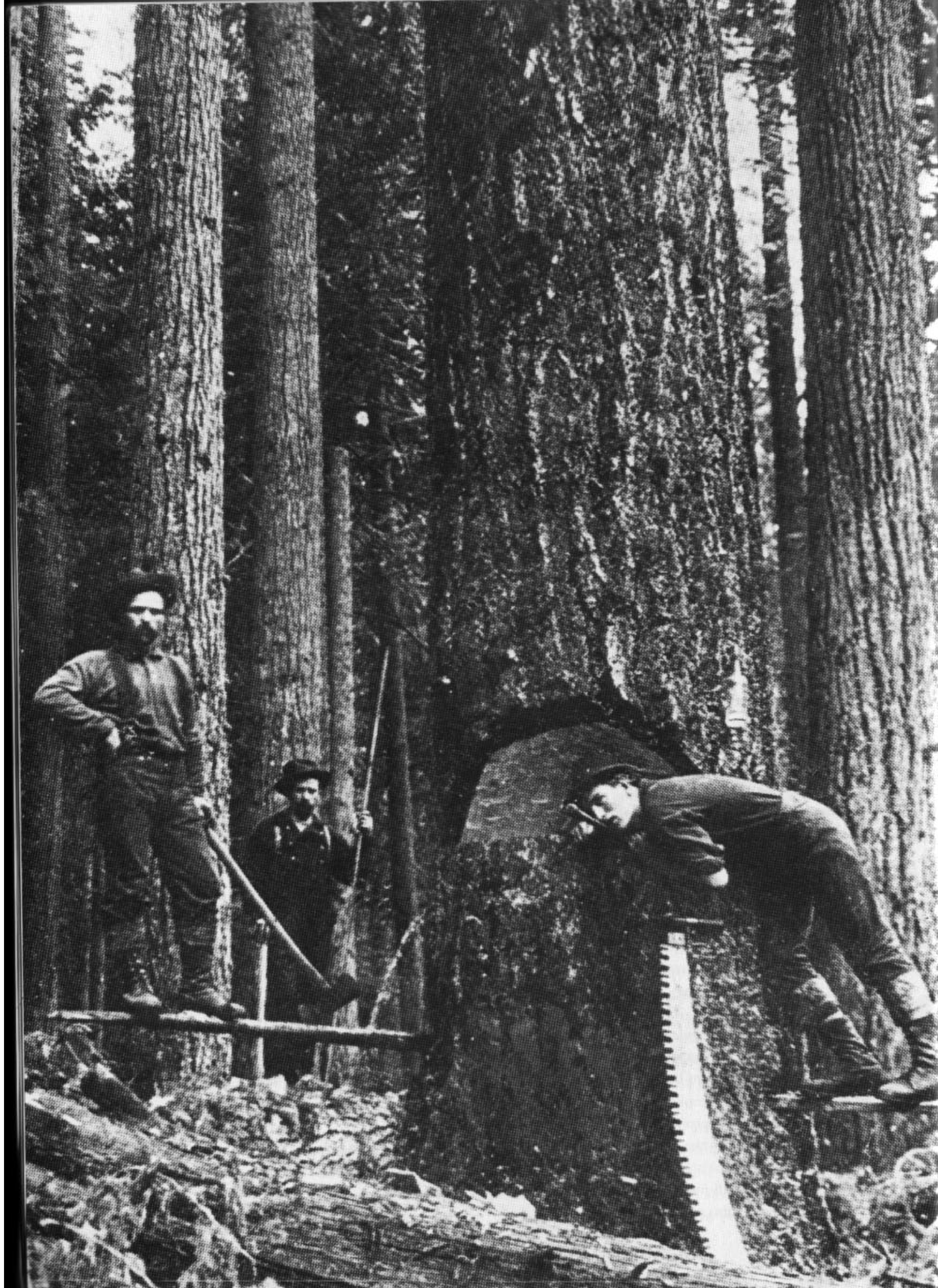


1

Wood

1777 Circular saw patented (Britain)

1832 Balloon framing introduced in Chicago

c. 1850 Circular saw first employed in processing lumber

1860s Great Lakes area becomes center of the U.S. lumber industry

1867 Rotary veneer lathe developed

1870s Double-edged axe introduced

Peak of investigations of chemical preservatives by U.S. railroad interests

1880s Saws with raker teeth used in felling

1883 Completion of railroad to Puget Sound opens forests of northwestern U.S.

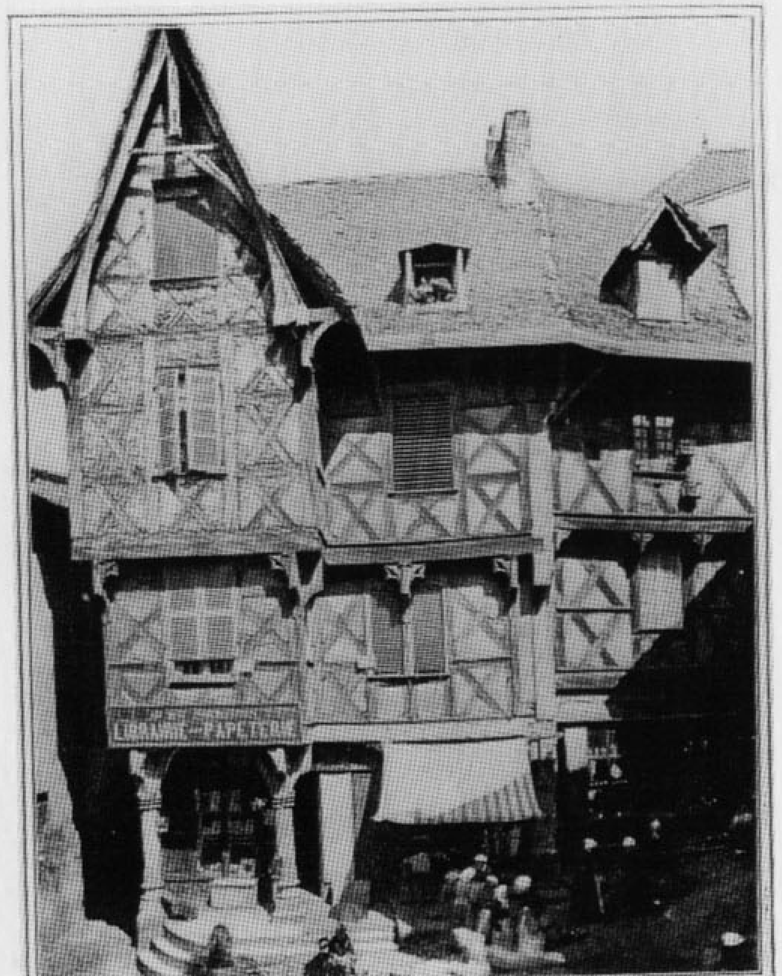
1884 Production of three-ply chair seats in Estonia

1890s "Hot ponds" make year-round operation possible for sawmills in North America

c. 1900 Resawing introduced

1905 Softwood plywood displayed at Lewis and Clark Expedition Centennial

1933 Synthetic resin glues produced in Germany



European life until the nineteenth century was largely based on the use of wood and the exploitation of the continent's vast forest lands. Wood provided fuel for industrial and household purposes, raw material from which tools and utensils were fashioned, and timbers from which carts, ships, and buildings were assembled. As the European population grew and spread toward the deep woodlands of the north, trees were felled in increasing numbers. Wood and charcoal had provided heat for Greek smelting and other crafts, and charcoal braziers heated Greek buildings when the sun's rays were not sufficient. Greek ships of trade or war required much timber, and when the Delian League was established in the fifth century B.C. to protect Greek interests in the Aegean Sea, the city-states were pledged to contribute a fleet of about three hundred warships. By that time so many trees had already been cut that the Greek landscape had been altered significantly. Indeed, the Greek city-states had introduced restrictions designating those processes for which wood or charcoal might be used as fuel. Several centuries later, Rome was confronted with a similar problem. Forests near the city were so depleted that it was necessary to obtain wood from almost a thousand miles away. By the fourth century A.D. the needs of Rome were served by a fleet of "wood ships," which brought timber from France and North Africa to the port of Ostia, from where it was moved upriver to Rome.

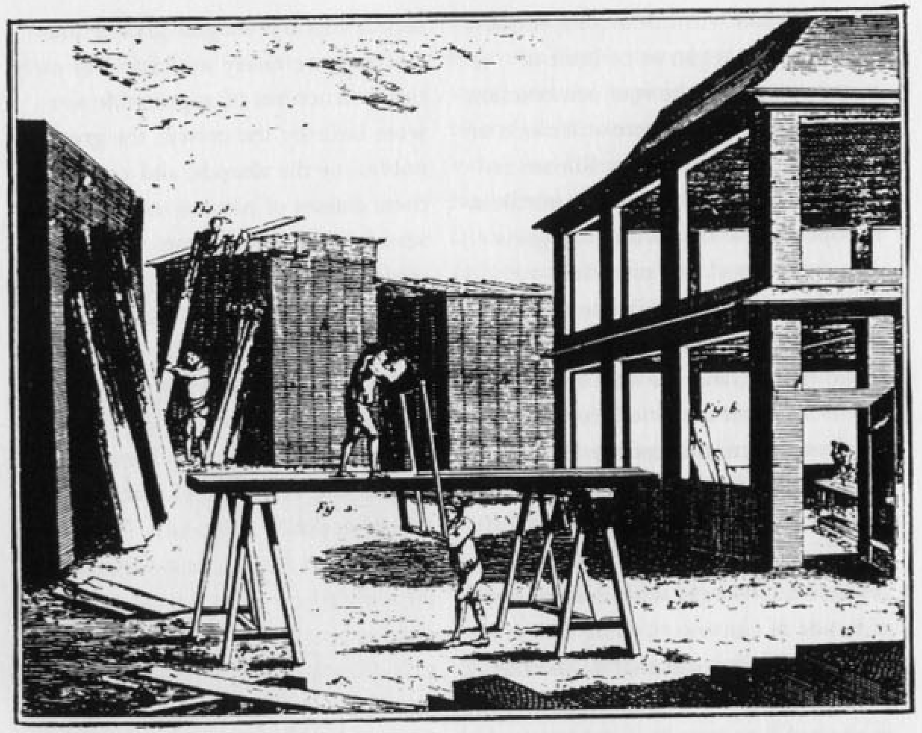
Although the amount of wood used in the construction of buildings was certainly less than that used as fuel and probably less than that used in ship building, deforestation made lumber more expensive, especially for the heavy timbers needed in roof construction. In the sixth century B.C., Greek temples, which had previously been of wood with terra-cotta surfacing attached, began to be built of stone, except for the roof construction and ceilings, which were still made of wood.[1] In later centuries, Roman settlements were constructed in northern Europe, where the forests still grew dense and wood was plentiful. Remains of the structures testify that there was a plentiful supply of seasoned timber, and the skill with which it was assembled is evidence of the efficient organization of the Roman army and the variety of iron tools that were available at that time.[2]

Accounts of medieval building projects often begin with descriptions of bands of carpenters going into a forest to fell the oaks that would be used. This meant that the lumber might not be properly cured by the time it was used, with the accompanying probability of warpage, but the slow progress of work on large projects in that period often provided for them a degree of curing during construction. In the fifteenth century, average sizes of wood framing in England would be about 13 by 11 inches for principal posts and 10 by 7 inches for joists spaced with around 8 inches between them (fig. 1.1).[3] Improving craftsmanship and rising costs of lumber reduced those formidable dimensions so that after the Great Fire of London (1666) joists were more likely to be 7 by 3 inches, less than half the cross-sectional area of earlier times.

When Abbot Suger required 12 beams of extraordinary size for one of his projects, his carpenters and those he consulted in Paris knew of no French forests in which timbers so large could be found, and the abbot and his aides are said to have searched the woods until suitable trees were discovered.[4] In England an exhaustive inquiry was required to locate the long timbers required for construction of the lantern at Ely Cathedral, for by that time, the middle of the fourteenth century, lengths greater than 30 feet were rarely available.[5] In early times structures of appreciable size were built by the crown, the greater nobles, or the church, and each of these classes of patrons usually possessed broad forests from which trees could be selected for the projects that they might undertake. As building came to be a more widespread activity and English forests were more rapidly depleted, there arose a trade in timber, shipping fir and oak from the Baltic ports to England. This commerce brought timber principally from the Hanseatic ports of Danzig, Riga, and Memel and exchanged it for English cloth. Oak was the wood most highly prized for English ships and buildings, whether built for government or for trade, and the forests upriver from Baltic ports held rich stands of oak, as well as fir and pine. The forests of Sweden and Norway were an additional source of timber, a source that grew to be so important that in the seventeenth century it was said that "the Norwegians warmed themselves by the [Great] fire of London."[6] From German forests, logs were floated down the Rhine to be shipped from Dutch ports.

To prepare lumber for use in construction, medieval carpenters (for in most areas carpenters undertook the work from felling the trees to completing the joinery) rough-hewed the logs with an adze or split the wood with iron wedges and mallets. It was usually after the squared logs were removed from the forest that pit sawing took place. For sawing, a log or a riven half-log was raised on trestles or laid on the ground above a pit. The line to be followed in sawing was marked by a chalked cord and a pair of sawyers, one standing atop the log and another beneath, used a two-handled saw or a frame saw in which the blade was stretched within a wooden rectangle (fig. 1.2). The saw

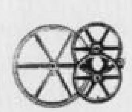
1.1 As in this fifteenth-century house in central France, when medieval buildings were made of wood, massive timbers occupied much of the exterior wall surface, leaving small interstitial areas to be filled with masonry or other materials. Connections, which were mortised and pegged, required that the timbers be large. (*Architectural Record*, April 1900.)



1.2 In this view of an eighteenth-century lumberyard, a frame saw is used to divide a plank laid across trestles. Most of the energy for sawing in this manner was provided by the lower sawyer, and the worker above was responsible for guiding the cut along a chalked line. (Diderot, *Encyclopedie*, 1762–1777, "Menuiserie," plate 1.)

1.3 A sixteenth-century design for a hand-cranked gang saw. In this period, drawings of mechanical inventions were often published to demonstrate the principles involved; the inventions may never have been actually constructed and operated. (*Iconographic Encyclopedia*, 1889, vol. 6.)

cut as it was pulled downward by the worker who stood, covered with sawdust, in the bottom of the pit. Pit sawing, or similar methods, is still practiced today by residents of some of the least developed regions of the world.



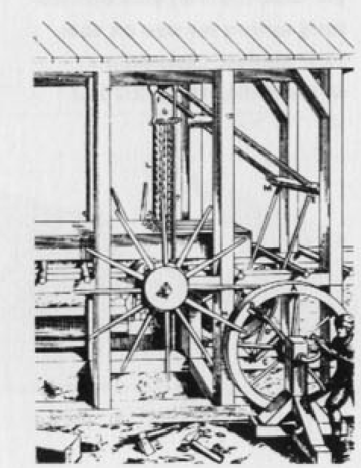
The work of the pit sawyer was easily mechanized. During the sixteenth century, sawmills powered by water or wind were erected in Norway, Holland, and some Baltic areas.[7] An estimate at the end of the eighteenth century said that "one mill, attended by one man . . . will saw more than twenty men with whip saws, and much more exactly," but it is difficult to estimate the financial advantages because one must consider the relative wages of the different sorts of workers and the amount saved by not shipping wood that would become useless sawdust. Apparently, English pit sawyers were apprehensive about changes that might result from mechanization. Water-powered mills for other purposes were built in England from the thirteenth century, but there were few sawmills, although many travelers gave detailed accounts of those they had seen on the Continent. In the sixteenth century, an increase of the English birth rate caused a population explosion, and unemployment among unskilled workers accompanied migration from rural districts into towns. In the early seventeenth century, a young traveler wrote his father an enthusiastic description of a sawmill he had seen in Germany but closed with a comment that he "would recommend the use of mills to saw timber in England, were it not that it would hinder the employment of poor men."[8] The public's fear of the social results of technological change persisted. As late as the 1760s, when a prosperous timber merchant built a wind-driven sawmill, a mob of irate pit sawyers attacked and pulled it down.[9]

The earliest sawmills of note were based on a turning source of power (whether from wind or water), a crank that converted that rotary motion to a linear motion, a rocker arm attached to the vertical frame that held the sawblade, guides in which the frame moved, and perhaps a spring system (sometimes formed by a bent piece of wood) that would return the frame after the completion of each stroke (fig. 1.3). In addition, a system of weights or rollers was required to move the timber forward and maintain its contact with the saw blades. The frames of these saws were heavy, which limited the speed with which they could be operated. In nineteenth-century Mississippi, 120 strokes per minute was the greatest speed at which a sash (or frame) sawmill could run. This allowed the mill to saw between 3,000 and 5,000 feet daily, with a kerf somewhat greater than a half-inch.

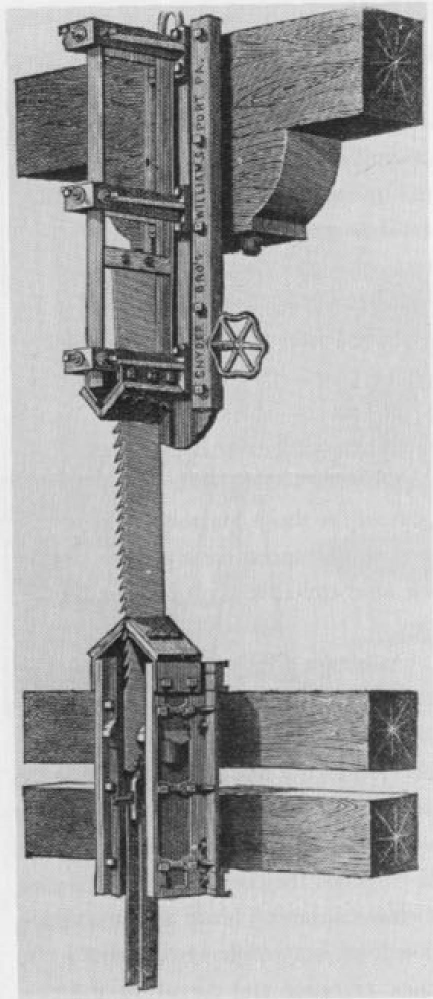
The muley saw—its name derived from the German word for "mill"—was a later mechanism using vertical reciprocating action. Dispensing with the heavy frame of previous saws, the blade of the muley saw was mounted at top and bottom in a manner that allowed adjustment according to the size of the logs being sawed (fig. 1.4).[10] The greatest advantage of the muley saw was the smoothness of its cut, its kerf being somewhat narrower than that of previous saws. (The width of saw kerf, which set the amount of sawdust produced and hence largely determined how much wood would be wasted, mattered little in the early spendthrift period of a forest's exploitation, but as the wealth of wood dwindled lumbermen became acutely concerned about narrowing kerfs.) The principal disadvantage of the muley saw was its speed, which was no greater than that of the saws introduced earlier.[11]

The gang saw resulted from placing several blades together, so that a series of boards could be cut with one pass of a log through the saw (fig. 1.5). It was the first of a series of devices that accelerated the work of sawmills and consequently required the invention of machines that would assist in tending the saws. Lumber moved so quickly through the new saws that it was no longer sensible for workmen to bring logs to the saw, turn logs on the saw, move timbers from one saw to another, and carry finished boards to the drying shed without the assistance of machines devised for those purposes. The demands of speed were particularly felt after the advent of the circular saw.

Although a British patent was awarded as early as 1777 and it was introduced into the United States in 1814, until the middle of the nineteenth century the circular saw was used principally for cutting veneer. At high speeds the centrifugal forces within a spinning blade and its expansion from heat while sawing could cause vibration and curvature of the blade. The need to mechanically flatten circular blades in their manufacture and during their use limited the hardness of the metal from which they could be made, and the use of soft metal led to a thicker blade and teeth that were quickly dulled.[12] Strains within the blades were somewhat relieved by providing radial slots toward the center of blades, and the effect of centrifugal pressures was reduced by tapering the thickness of blades (fig. 1.6). The greatest improvement of the circular saw resulted from inserting teeth of hard steel around the edges of a disc of softer steel. The maximum depth of cut for a circular saw was slightly less than half the blade's diameter, and increasing the diameter beyond certain limits would, of course, increase the saw's vibration and thus widen its



1.4 In the muley saw, variable lengths of the blade could be exposed between the adjustable muley heads. This ability to adapt the saw to the dimensions of logs resulted in a narrower kerf and consequent savings. (*Appleton's Cyclopedia*, 1880, 2:708.)



kerf. By the middle of the nineteenth century, the practical maximum diameter for a circular saw was usually considered to be around 5½ feet, which would saw a log little larger than 2½ feet in diameter. A solution to this problem was found by mounting a second and smaller circular blade above the first, increasing the total cut by about half this smaller saw's diameter (fig. 1.7). Whatever the difficulties inherent in the circular saw, it was fast. Other saws might average cutting as much as 5,000 feet daily (gang saws affording the pronounced advantage of their multiple blades), but in the 1850s circular saws could be expected to cut at least 1,000 feet per hour. Before many years had gone by that number quadrupled.[13]

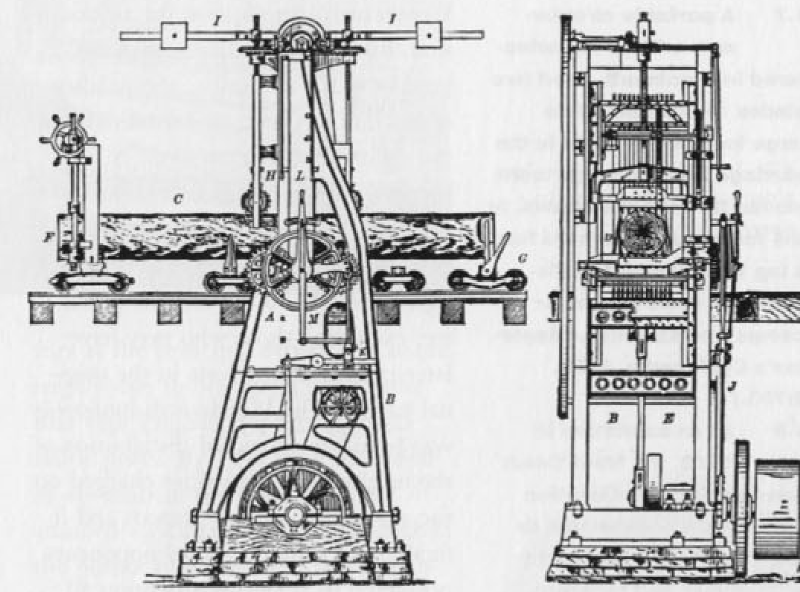
Circular and muley saws had kerfs of 5/16 of an inch at best, but usually cut a width of 3/8 of an inch, the same dimension as the kerf of vertical frame saws (fig. 1.8). A kerf of that width resulted in a loss of more than a third of the wood after a log was squared, the tree's taper was accounted for, and the remaining timber was sawed into boards one inch thick.[14] Vast piles of waste accumulated at mills with little possible use for them. Sawdust could be dumped into a stream, but it quickly accumulated and interfered with floating logs to mills downstream. A fraction of the sawdust might be sold for use in filling ice houses or as an agricultural fertilizer, and a small portion of the bark was needed by tanneries. Steam power for a sawmill could be produced with little cost by burning a sawmill's plentiful waste, trimmings, bark, and sawdust. In fact, fuel was so plentiful that in the 1890s mills in the northern parts of the United States instituted year-round operation, a result of the introduction of the "hot pond," the pool in which logs were kept being heated by a pipe carrying steam from the sawmill's boiler. Still, enough waste remained to cause a constant danger of fire, a risk always confronting lumbermen.

Although the band saw was invented and patented quite early in the nineteenth century, it was not useful until a blade could be manufactured that would run at high speeds without snapping. After the Civil War, the rising quality of metal and workmanship in the United States permitted manufacture of fine-toothed band saw blades of well-tempered metal. Blades as long as 60 feet and about 15 inches wide were looped over wheels above and below, and there was virtually no limit to the size of log that could be taken by a band saw. The narrow kerf of these blades produced, in most cases, less than half the amount of sawdust that came from other saws. Until the start of the twentieth century, much lumber was sawn at the start to the size at which it was to be used. Resawing, a method of shaping large timbers from a log and sawing them into boards and planks after shipping and as needed, was common by the end of World War I. For the second sawing, bandsaws mounted as multiple blades proved to be useful because of the accuracy and speed of their cut.[15]

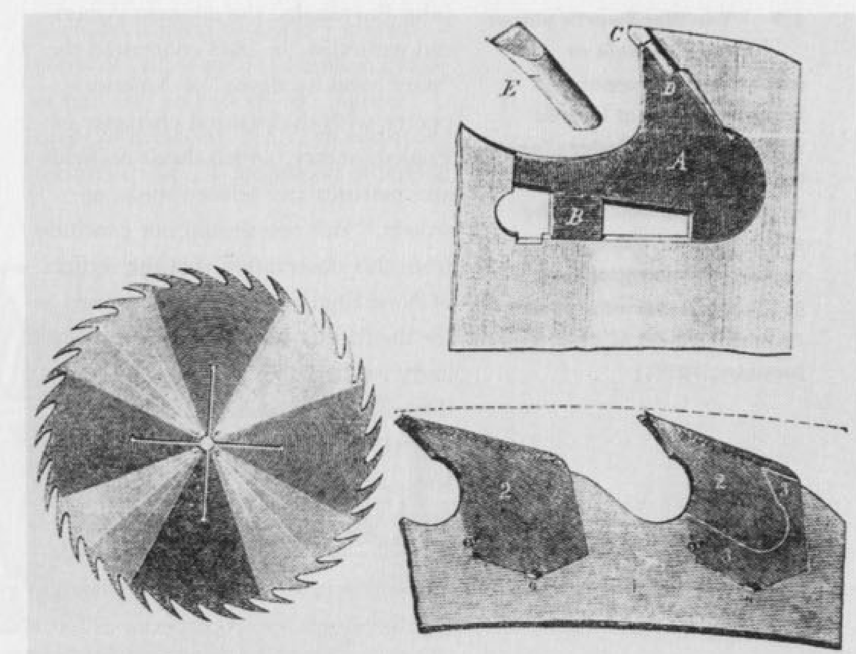
It should be understood that at no time did one type of saw completely supplant the preceding types. At all times the larger share of sawmills were small plants, perhaps the wintertime occupation of a farm family. In such situations, investment in laborsaving equipment was seldom logical, for there was no serious shortage of man-hours for the work. Different species of trees and the probable uses for their wood often governed the choice of machinery. Only a few decades ago it was reported that the vertical frame saw (first to follow the pit-sawyer) was finding new favor in the United States and Canada, because it was well suited for sawing small and medium-sized logs.[16] One of the criteria for the planning of many mills was the simplicity with which the machinery might be dismantled when an area of forest land had been depleted and the time had come to relocate the saw at a place that offered a fresh stand of trees.

Machines for finishing lumber were a popular area of invention, so popular indeed that the case of the Woodworth planer, which combined feed rollers and cylindrical rotating cutters, became a *cause célèbre* of U.S. patent law. Woodworth's son in 1842 applied for an extension of his father's 1828 patent on the grounds that his father had been forced to sell off rights to the patent after workmen's protest demonstrations closed his initial display of the machine in New York (fig. 1.9). In 1836 a law had been enacted

1.5 This gang saw of the 1880s includes a mechanism that moves the log forward at the same moment that the blades cut on their downward stroke. The bar below (*E*), which pulled the frame of blades down, was called the "pitman," an echo of the days of pit sawyers. (*Appleton's Cyclopedia*, 1880, 2:709.)



1.6 To avoid cupping of circular saw blades, slots could widen if the rim of the blades became hot and expanded or narrow if the center became hot. Inserted teeth were shaped of metal harder than that of the blade. The planer-tooth (above) was said to produce smooth-sided kerfs; the clipper-saw (below) was particularly suited for use on thin saw blades. (*Appleton's Cyclopedia*, 1880, 2:700.)

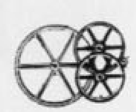


1.7 A portable circular-saw mill, as manufactured in Cincinnati, used two blades to accommodate large logs. At the right is the carriage on which logs were moved through the blades. In the foreground, workers turn a log with peaveys, indispensable tools at lumber camps and sawmills. (*Appleton's Cyclopedia*, 1880, 2:703.)

1.8 At an exhibition in 1918, the West Coast Lumbermen's Association displayed a section of a fir log 4 feet in diameter, cut into lumber and reassembled. Note the similarity of this example to the methods of obtaining rectangular panes from a disc of crown glass (fig. 5.2). (*Scientific American Supplement*, 29 June 1918.)

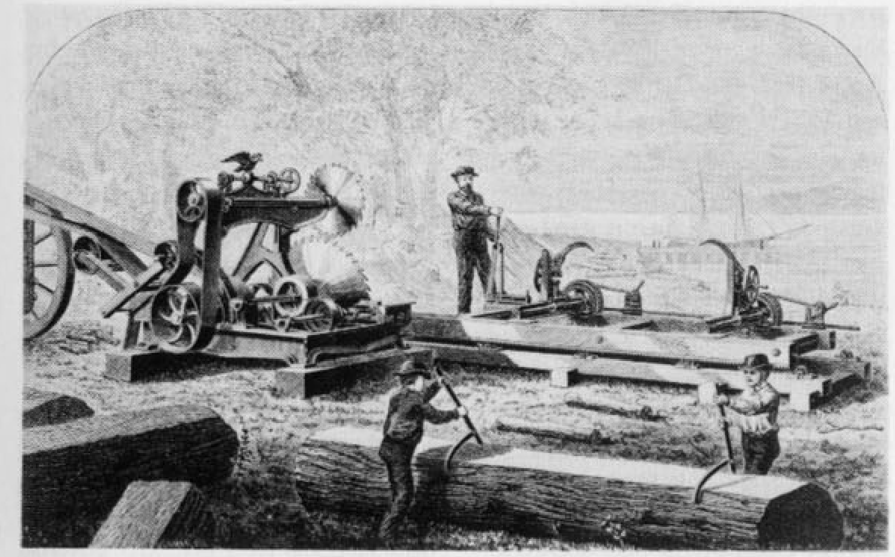
1.9 The Woodworth planer was capable of smoothing the upper and lower surfaces of boards with rotating cylinders, each having three blades. Edges of the boards could at the same time be smoothed or tooled with tongues and grooves. (*Asher and Adams Pictorial Album of American Industry*, 1876.)

permitting extensions of patents when the inventor "without neglect on his part [has] failed to obtain from the use and sale of his invention a reasonable remuneration for the time, ingenuity, and expense bestowed upon the same."[17] In legal action that followed Woodworth's application for an extension, his opponents questioned the legality of the extension, the validity of the initial patent, and ownership of the rights after an extension. A succession of courts, and eventually the U.S. Supreme Court, determined that upon issuance of an extension all rights reverted to the original patentee, excluding those who may have later purchased interests in the original patent. The Woodworth monopoly was based on restricted distribution of the machines and royalties charged on the amount of lumber planed, and it finally ended in 1865 after opponents presented to Congress a petition 50 feet long.[18]



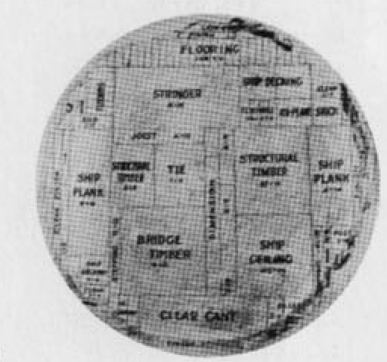
John Burroughs, the eminent American naturalist, in 1883 contrasted the "piny, woodsy flavor" of American poetry with the pastoral character of English poetry, which dwelt on fields and pastures and seldom spoke of woods.[19] But one should not conclude from this observation that the settlers of New England felt great affection for the forests that surrounded them and extended so far westward. As Theodore Roosevelt wrote, they viewed the land as "a region of sunless, tangled forests . . . with underbrush . . . dense and rank, between the boles of tall trees making a cover so thick that it nowhere gave a chance for the human eye to see even as far as a bow could carry."[20] To the pioneers, forests seemed threatening depths filled with insects, swamps, disease, and marauding redmen. Only by felling trees and clearing the land could space be created for agriculture, houses built, and income produced. Much of the colonial culture was grounded on the use of the region's wood. Barrels for Spanish wines and Barbadan sugar and molasses proved profitable, and New England pines, taller than those of northern Europe, provided masts that need not be weakened by being spliced. A small enterprise of shipbuilding began in New England and prospered. Yet no matter what commercial value could be found in the trees, they occupied land that was wanted for agriculture. For the most part, settlers moved west by wantonly clearing land, planting their crops among the gaunt, leafless trunks of trees that they had girdled and left to rot.

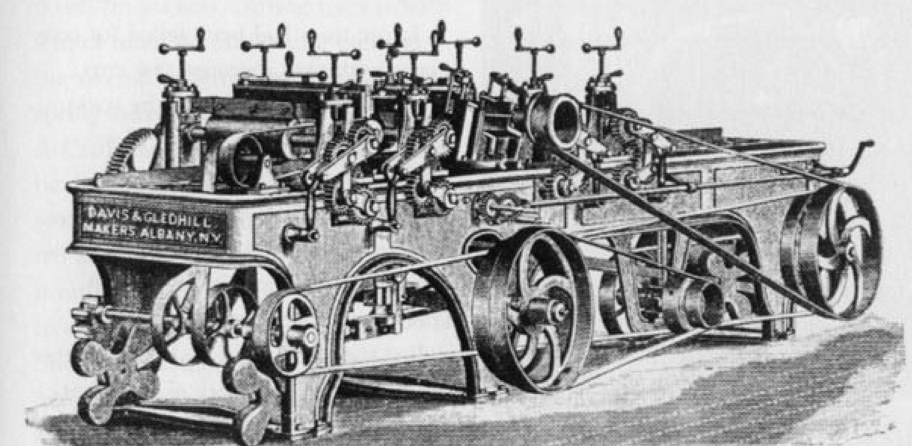
If the forests of North America proved to be a valuable resource, they also proved to be an exhaustible resource. By 1773 Rhode Island had cut all its available firewood and wood was bought from other colonies. A century later the woods of New York and New England had been so depleted that much of their logging activity moved westward to the forests surrounding the Great Lakes.[21] By the end of the shameful Black Hawk War, native peoples of the Lake area were confined to small reservations, rich farmland was made available to settlers, and dense timberland became available to loggers. In the 1850s hard times hit the eastern lumbermen and hastened their migration. Around 1860 the Lake area became the leading source of lumber in the United States. Chicago became the center of the U.S. timber trade, with lumberyards in 1856 already occupying 6 miles along the Chicago River and twice as much 15 years later. The South had a small antebellum timber industry,



largely coastal and marketing yellow pine and naval stores (turpentine, pitch, and rosin). During Reconstruction lumbering expanded, and after 1870 yellow pine from southern woods began to be seen in the North, even on the Chicago market. But when the timber available in the Lake region began to diminish in size, quality, and ease of access, lumbermen and loggers looked to the South and to the West, where vast stands of trees remained untouched.

The forests of Canada and the United States provided a rich source of timber for the westward expansion of those countries in the nineteenth century and a source of exports to Europe. By 1810 timber had replaced furs as the principal export of Canada, largely due to Napoleon's blockades that kept English ships away from Baltic ports. By 1890 the production of sawmills in the United States attained a value one-third greater than the output of all metallic production for that year.[22] In 1906 it was estimated that the lumber industry in the United States cut "approximately 40 million feet, board measure, of lumber, 11 billion shingles, 100 million railroad ties, 4 million poles, 20 million fence posts, 170 million cubic feet of round mining timbers, 3 million cords of pulpwood, 1½ million cords of tanbark, and about 100 million cords of firewood."[23] In the mid-nineteenth century, a succession of federal





laws—the principal ones including the Swamplands Act of 1850, the Morrill Act of 1862, the Timber Cutting Act and Timber and Stone Act of 1878—included provisions that were used by lumbermen seeking possession of forest lands.[24] The luxuriant stands of pine around the Great Lakes were dwindling and lumbermen of that area looked westward to fresh forests beyond the Rockies. After the California gold rush, some timber had been cut for local use on the West Coast and a few shipments were made to the Orient. When the Northern Pacific Railway Company in 1883 opened a route from Puget Sound to the Great Lakes, the timber of the northwest region suddenly became available. In the fashion of the business world of that time, there came to be timber barons who amassed vast stretches of woodland and operated both logging and milling phases of the business. Reformers, trust busters, and muckrakers loudly protested deforestation and predicted the depletion of the forests. Proponents described reforestation programs and the economic advantage to be gained from expansion of the timber industry. Since lumbermen made most of their profits from land and trees that were government property, this debate became repeatedly the subject of campaign promises and very seldom the topic of effective legislation.

A similar dichotomy is found in the descriptions of logging camps. By the latter part of the nineteenth century, logging camps had moved far from their owners' sawmills, for the machinery of a large sawmill handling large logs was no longer adapted to changing its location as loggers exhausted one mountainside of trees and moved on to another. Some journalists wrote heartwarming descriptions of robust lumberjacks filling the bunkhouses with jolly songs. Other descriptions pictured immigrant workers ill-fed, underpaid, and constantly endangered by the perils of their work.

Large trees had been felled for centuries with axes, because saw cuts became hopelessly clogged by rosin and sawdust. In the 1870s, West Coast choppers abandoned single-edged axes for a double-edged type. This new kind of axe allowed one edge to be used in trimming hard knots and other work that quickly dulled the axe's edge, and it saved the other edge for the work of undercutting, lessening the time required for sharpening the axe (fig. 1.10). It was the 1880s before saws with "raker teeth" were introduced. Typically, these saws bore groupings of about four cutting teeth with pairs of cleaning teeth between them, cut much shorter to pull sawdust from the cut. In addition, sawyers carried with them bottles of kerosene with which resin could be periodically cleaned from the saw blade.[25] The use of saws was said to double the number of trees that could be felled by a pair of lumberjacks, and an additional economy resulted from the fact that sawyers, needing much less skill than choppers, could be paid, according to Minnesota wage practices, little more than half the wage of choppers. In every logging camp, saw filers were charged with the responsibility of sharpening the saws, with due consideration of the length of a sawyer's stroke, the kind of trees being cut, and weather conditions. Power saws for this purpose were not introduced until the 1930s.

It is difficult to describe the way in which trees were cut and brought to a mill. Climate, terrain, the species being felled, the size of the lumbering enterprise, and even local traditions might determine the choice of procedures. Southern locations often were hampered by having to move heavy logs through muddy swampland; northern locations were more governed by seasons, cutting trees in the winter months and floating them to the sawmill when melting snow and spring rains made the rivers run high. A California redwood might offer particular problems, because its brittle wood could be shattered as the tree fell and a log 26 feet in diameter was invariably cumbersome and dangerous to move down even gentle slopes. Such factors could cause adjacent timber camps to use different methods, but at the same time similar methods might be employed by camps far apart in place and time.

For bringing logs from the forest to the sawmill or a waterway leading to the sawmill, the procedures varied according to the terrain. Logging began along the edges of rivers, where logs had to be moved only a short distance to the water. In flat, swampy woodland, such as the forests of the southeast United States, horses or oxen pulled logs along "corduroy" logging roads, surfaced by laying tree trunks across the route. On steeper slopes the "skidway" was often lined with logs to ease the handling, sprinkled in winter with water to make an icy coating and smeared with grease in warmer weather. In some mountainous locales flumes were erected, narrow triangular troughs holding a flow of spring water in which logs or sawn timbers would hurtle downhill for miles, one after another, and splash at the end into a river or lake. When engines were in common use, steam tractors pulled logs and portable "donkey engines" turned reels on which cables were wound to run derricks, hoists, and drag lines to move the logs. If logs that were destined for several sawmills floated in the same stream, they were marked, so that downstream each mill could identify and rescue the logs dispatched from its own logging camps.

On waterways used for other purposes, a more controlled method of moving logs was accomplished by assembling rafts. Units of logs were assembled in crisscross layers with 250 to 500 square feet of surface area. These cribs were linked together as rafts with overall dimensions as much as 135 feet by 160 feet, or even greater when they were assembled for travel down the Mississippi.[26] Workmen overseeing the drift downstream might assemble small huts on the rafts' top sides. On the St. Lawrence,

1.10 Standing on "springboards," fellers make a saw cut about one-third into the trunk and well above the hard grain and heavy sap of the base. Axes were used for undercutting before the workers turned their attention to the other side of the trunk, where the saw and iron wedges were used to fell the tree. By carefully sighting the direction in which the tree would fall, damage to it and other logs could be avoided. (*World's Work*, February 1904.)

1.11 On an Oregon river early in this century, logs float toward a cradle into which they will be loaded by a derrick. The cradle (foreground) is anchored along its back side to a row of pilings. After the cradle is filled and its logs are chained together, the frames on the near side of the cradle will be pulled away and the completed raft freed (background) for its trip to a mill in San Francisco. (*World's Work*, February 1904.)

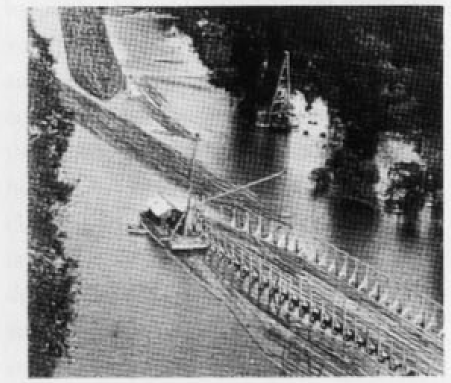
rafts were numerous and substantial, because the action of tides in the river slowed the journey to the sawmills. In the 1840s, Charles Dickens observed the many rafts of logs on the Saint Lawrence and wrote that their huts with flagstaffs erected beside them seemed "like a nautical street" floating downriver.[27] For transportation on the seas, workers assembled a "cradle" of wood, pointed and shaped like the hull of a broad-bottomed ship. In the fresh water at a river's mouth, where marine borers would not attack it, the cradle was half-filled with logs or trimmed timbers before a network of chains was fastened to hold its shape (fig. 1.11). When chaining was completed, the upper part of the raft curved to almost match its curvature below the water line. The cradle was then removed and the raft, which could be as long as 800 feet, as wide as 55 feet, and as deep as 35 feet, was ready to be towed across the Baltic Sea or southward along the coast of California.[28] Eighty to 100 tons of chains might be required to make a raft of average size sufficiently sound to be towed from the Columbia River of Oregon to a sawmill in San Diego.

The supply of timber has always been closely associated with the development of transportation. Although early demand for timber to be used in shipbuilding was undoubtedly less than that for fuel, both navies and merchant ships required the largest trees of the choice species, and their requirements pressed forcefully for the extension of timbering. During the seventeenth and eighteenth centuries the finest trees of England and her American colonies were hunted out and marked to indicate that they were reserved for the royal navy. It was nearly the end of the nineteenth century before shipbuilding had changed from wood to steel, and by that time the railroads had proved to be a hungrier market for timber. At first locomotives and railroad cars rolled on oak timbers with iron strips spiked on top. After iron rails came into use, they were secured to wooden crossties 6 by 8 inches in crosssection and spaced with 16 for each rail 30 feet long. This meant that the railroads' demand for wooden ties (their major, but not only, use of wood) was roughly the equivalent of providing a paving two inches thick and almost 9 feet wide along every one of the thousands of miles of railroad tracks, sidings, and spurs spread across the broad continent of North America. (European rail networks have been more inclined to use concrete crossties.) Since the average life of a railroad tie might be between eight and fifteen years, depending on the bed on which they rested, the amount of travel they supported, the wood from which the tie was cut, and the climate of the installation, there was a huge annual expenditure for the renewal of ties.

As the price of crossties increased, experiments were made in the application of preservative treatments that might extend their serviceable life, thereby reducing the annual cost of replacement. The situation worsened until in 1907 a railroad engineer grumbled, "It is no longer possible in the United States to purchase 80,000,000 first class cross ties per year." Some of the first railroad companies to investigate the use of preservatives were those that crossed the broad prairies of the western United States, far from forests and therefore burdened with higher prices for ties. Salt had been used in ancient times as a preservative for ship timbers, and

wood for buildings was sometimes charred to prevent rot. In the middle of the seventeenth century the German chemist Johann Glauber developed a system by which timbers were charred, coated with tar, and then soaked in an acid resulting from the destructive distillation of wood. In the 1830s many more preservative treatments were developed involving such substances as a "decoction of tobacco leaves" and a "solution of India rubber."[29] Those preservative methods that continued in application included methods of immersion and pressure treatment using copper sulphate, mercuric chloride, and zinc chlorides, processes commonly marketed under their inventors' names (such as Boucherizing, Kyanizing, and Burnettizing).[30]

In the same period a method was patented in Britain for treating wood by pressure with the "dead oil of tar," which was also known as creosote. The carbonizing of coal produced a tar that could compete with Stockholm tar, long imported for caulking ships, and a variety of oils, those heavier than water being designated as creosote. Although some plants were established for the sole purpose of producing coal tar and coal tar oils, the introduction of gas lighting resulted in firms that were interested primarily in utilizing the gases that came from carbonizing coal and anxious to be rid of the odorous by-products.[31] Creosote was one of the first of an extraordinary array of products developed from coal tar as the chemical industries grew in scope and scientific knowledge. In the United States, railroad companies tested both creosote and metallic salts during the 1870s and found creosote most effective for use in coastal areas where marine borers were a problem and metallic salts suited for application in inland areas.[32] Any loss to the timber



industry from the decrease of the demand for railroad ties was certainly offset by the market for pulpwood in the late nineteenth century, when it became a principal raw material for the manufacture of paper.

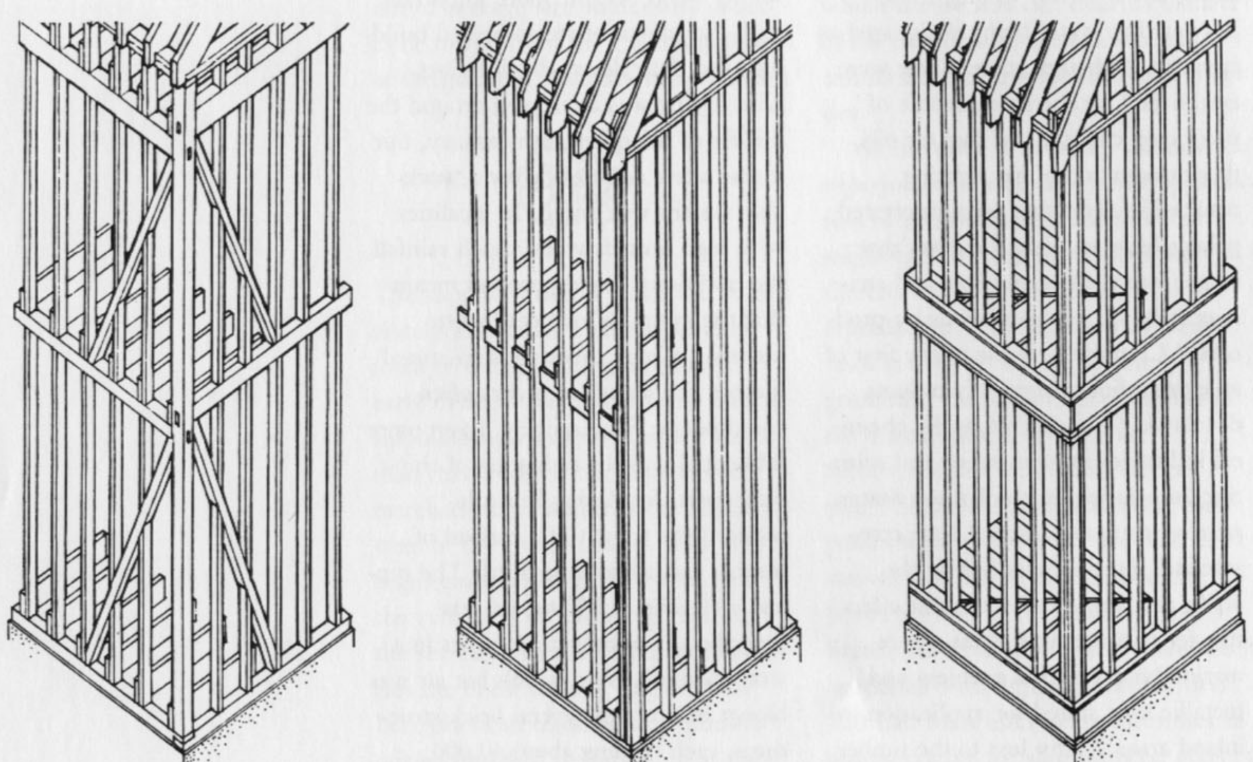
Traditionally lumber had been seasoned at the sawmill by stacking it in open stacks or under cover, but seasoning wood became more important with the advent of steam-heated buildings and their desert-dry interiors. Kiln drying was attempted around the middle of the nineteenth century, but it was a few decades before a workable system was found. In localities with high humidity and much rainfall, the traditional drying process meant that the sawmills' owners had to maintain a large investment in stored lumber and a rush of orders often could not be filled quickly. Even more influential was the reduction of shipping costs, for drying in a kiln reduced the weight of a carload of lumber by at least one-third. The typical early kiln in Minnesota was described as having steam pipes in a steel chamber, from which hot air was blown into any of several brick structures, each holding about 40,000

1.12 **From left to right in the order of their development and use: braced or eastern framing, balloon framing, and platform or western framing. The simplification of carpentry was a principal factor in this progression. (Drawing by author.)**

board feet of lumber. Air-drying lumber had been inexpensive, but sawdust and trimmings could provide the fuel for drying. The cost of building a kiln was soon paid for by savings in shipping costs, and lumber could be prepared quickly in response to orders and price fluctuations.

In 1832 George Washington Snow introduced to Chicago a method of framing buildings that used light pieces of lumber, usually not exceeding two inches in the smaller dimension, and relying more on nails than the traditional mortise-and-tenon connections. With the introduction of Jacob Perkins's nail machine in 1795, the price of a pound of nails had dropped from 25 cents to 8 cents by 1828 and would be 3 cents by 1842.[33] Balloon framing, so named because of its lightness, tolerated inexperienced carpenters and could be assembled quickly (fig. 1.12). It was, all in all, well suited for the buildings that settlers needed as they moved west. Balloon framing had been developed sufficiently by the 1880s to rely only on nails, without mortises. At the end of the century it was the predominant system of wood construction in the United States, and so it remained until it was succeeded by the western or platform system of framing, in which shorter members were employed.

As lumbermen found forests farther west in the United States, the distance from the sawmill to the consumer of lumber grew, and it became increasingly necessary to have recognized standards by which the quality of lumber could be described to the buyer and the needs of consumers could be communicated to the supplier. Sweden in 1764 had instituted a grading system that recognized four grades of commercial lumber, and seventy years later four similar grades were adopted in Maine. In 1873 the Lumbermen's Exchange in Chicago established grading standards (again using four levels: clear, select, common, and culls), but many regions or individual mills followed their own systems. It was difficult to enforce



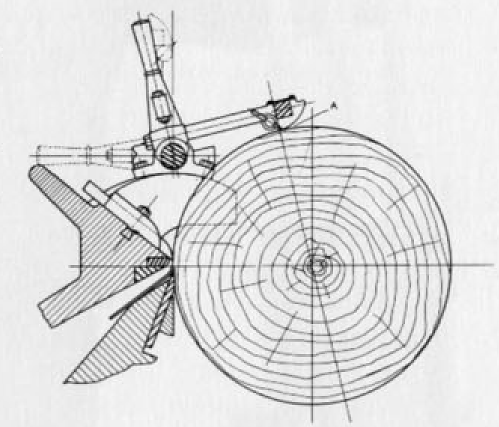
uniformity among the various lumbermen's associations, especially when the Panic of 1873, which for several years lowered the demand for lumber, was followed by clear signs of depletion in the pine forests of Michigan.

Grading standards were a major subject of debate when the first meeting of the Mississippi Valley Lumbermen's Association was held in 1891. In spite of the organization's name, it represented the northern white pine interests; few of its officers were not from Minnesota or Wisconsin and the most southerly director was from Hannibal, Missouri. Agreement on grading, of course, made it simpler to compare prices and, like many manufacturer's organizations of that period, the Association circulated recommended price lists to its members. As a member of the Northwestern Stave and Heading Association explained, "We are not getting up a trust or anything of the sort. We simply wish to establish uniformity of prices."[34] A year before the founding of the Mississippi Valley Lumbermen's Association, Congress had passed the Sherman Antitrust Act, destined to be more used against labor than against trusts, and one year after it was founded the Association was tried for violation of that law. In one of the first blows to the effectiveness of the Sherman Act, the judge ruled: "An agreement between a number of dealers and manufacturers to raise prices, unless they practically controlled the entire commodity, cannot operate as a restraint to trade, nor does it tend to injuriously affect the public."[35]

Timber companies had long been criticized for the manner in which they had taken advantage of legislation regarding federal lands. The wealth of open land had been openly used as a currency with which the U.S. government could forward certain policies. Grants of land rewarded war veterans, encouraged a westward movement of settlers, attracted immigrants, promoted the drainage of swampland, subsidized the extension of railroads, and financed the foundation of state colleges. Each of these laudable purposes seemed in some way to involve loopholes by which lumber barons were able to gain possession of vast areas of wooded land at extremely low cost. Men were paid to sign up for their 160 acres of wooded land under homestead laws, and then turned their claims over to lumber companies. A law of 1897 permitted landholders to donate their acreage to a protected area of wooded land and receive an equal acreage in another location. Under this program lumbermen traded the land they had already denuded for fresh timberland, and the Northern Pacific Railroad swapped over half a million acres of the least desirable land it had been granted when building the railroad across the northwest (only a fraction of the total amount of land they had received) in return for prime stands of timber in Oregon, Idaho, and Washington.[36]

Allegations and occasional convictions on charges of land grabbing and price fixing were not all that plagued the lumber interests. The IWW (Industrial Workers of the World), formed in 1905, a few years later concentrated its efforts on unionizing lumber workers, one of the few groups in which the IWW had a degree of success. Lumber companies resisted organization of their workers, a conflict that produced bloodshed and years of bitterness that are recorded in labor annals.

Veneers were used, as long ago as ancient Egypt, to apply the color and



1.13 This diagrammatic drawing indicates the relative position of the veneer knife (at left) and pressure bar. One of the spur knives (*A*), which cut the veneer to an exact length, is shown in position on the top of the log. A similar device, replacing the knife with a crayon, could mark the tight-cut side of the veneer, an important consideration when the veneer was assembled into plywood sheets. (A. D. Wood and T. G. Linn, *Plywoods*, 1943.)

pattern of rare woods to furnishings of simpler stuffs. The simplest method of preparing veneer was sawing a thin layer, which could be glued over a wood that was more practical because of its strength, price, or workability. The wide kerfs of early saws meant that much was wasted, but a larger area of precious wood could be shown as veneer than if it were used for the full thickness of the work. By 1805 a circular saw was being used in England for cutting veneer, and later developments produced the segment saw, fine-toothed segments of thin steel being held around the rim of a large center casting. The whole saw was usually at least ten feet in diameter, but it cut only near the rim, where the thin blades were exposed.[37] While they produced veneer about one millimeter thick, segment saws could not provide flitches of veneer that were significantly larger than usual. The veneer slicer, introduced in France around 1830, did little to increase the size of flitches, but by shaving off layers of wood it saved the amount that saws wasted as sawdust. Although a rotary veneer lathe, a machine that rotated a log so that a blade might cut off a continuous band of wood (as paper comes off a roll), was patented in the United States as early as 1840, it was about 1870 before a practical version was in operation (fig. 1.13).

Veneer panels, glued with the grain of layers crisscrossed, were in use long before the term "plywood" originated around World War I. The English furniture maker Thomas Sheraton used such panels in his designs, and maple plywood was used for the wrest blocks of pianos (the piece holding metal pins by which piano strings are tuned). By the middle of the nineteenth century Steinway and Sons had begun using laminated sawn veneers for the curved sides of its pianos, and several manufacturers provided their sewing machines with cases having curved plywood surfaces.[38] Development of the rotary lathe permitted larger sheets of veneer, and in 1884 a factory in Reval (Tallinn), Estonia, started producing three-ply birch seats for bentwood chairs. At the turn of the century, plywood was a frequent material in the mass production of furniture. Estonian and Latvian manufacturers provided Great Britain with the plywood for furniture and for the chests in which tea and rubber were shipped from the Orient.[39] In the United States, factories around the Great Lakes produced plywood for furniture and sliced splints for making fruit baskets.

At the 1905 Lewis and Clark Expedition Centennial in Portland, Oregon, one firm displayed softwood plywood, less costly than the hardwood veneers used for furniture and suitable for structural purposes. The first uses for their product were door panels and the bottoms of cabinet drawers, and most plywood mills in the Northwest were linked to companies manufacturing doors and window sashes. By the 1920s an important market had been found in providing the material for automobile running boards and floor boards. However, because the glues used at that time were not sufficiently water-resistant, plywood was replaced by sheet metal in automobile production, and the exterior application of the material in building construction was limited.

Hide glue, an ancient substance made from the skins and bones of animals, was the first adhesive used to glue veneers, but 1912 saw the introduction of blood albumin glue, which, when applied with steam-heated presses, afforded a more water-resistant bonding material. By World War I, casein glue, made from milk curd, was the dominant type, and it was succeeded in the 1930s by soya bean glue, which was lower in price. In efforts to control costs, simplify manufacturing processes, and approach waterproof qualities, mixtures of such glues were devised to balance their individual characteristics. German companies in 1933 began manufacturing synthetic resin glues, a type that had been proposed in 1912 by Leo Hendrik Baekland, inventor of the first completely synthetic material, Bakelite. These phenolformaldehyde resins could be applied to veneer as a spray or a film. Their maximum waterproof qualities were obtainable with heat, and this discovery quickly revived the hot-pressing techniques that had been employed with blood albumin glues.

A drawback in the structural utilization of wood had always been the linear limitations of its strength. In the direction of its fibers, wood is a relatively powerful material, both supple and malleable. In other ways wood is weak, tending to split and shear easily. As linear structural members, timbers performed well, but at connections the more complex forces were limited by the lateral weakness of the material. By gluing crossed layers of veneer, plywood balanced these capabilities of wood, so long as it was used as a sheet. Laminated wood, a similar gluing of boards parallel, overcame the increasing restriction of available lengths and sizes, but the directional imbalance of strength remained.

The introduction of plywood suitable for use in building construction heralded a new era in the use of lumber. With advances in the chemistry of adhesives it was possible to reconstitute wood fibers, utilizing waste and eliminating many of the structural disadvantages of the linear anatomy of wood as it came from the tree. Chemical treatment of lumber under pressure could alter some of the natural characteristics of wood, enhancing its durability. Most important, steps toward reforestation were initiated. With varying degrees of urgency and success, the lumber industry began a transformation from being an exploitation of natural resources into what may become in essence an agricultural enterprise.