Wood comes from organisms that live and die, from trees that grow in many sizes and shapes. Wood has as many differences in strength, machinability, resistance to decay, glulability, and so on as there are species of trees. To determine the properties of the various woods and to investigate the multitude of problems of wood utilization were the tasks assigned the Forest Products Laboratory when it was founded in 1910. From a half century of research at the Laboratory in Madison, Wis., has come knowledge that makes the mature timbers from commercial species of North American trees true engineering materials. Their strength properties and reactions to stress have been determined. Applications for wood undreamed of in 1910 now form the bases for a range of expanding industries. Yet each scientific advance opens up new avenues of thought and creates new challenges. Ahead lie expanding opportunities for the wiser use of our forest resources. Although our annual per capita consumption of lumber has declined slowly since 1900, markets for other wood and wood-based products have increased greatly our total demand for wood.

Paper is an example. About 450 pounds of paper are used annually per capita. In the early days, only a few long-fibered species—primarily the spruces and hemlock—were considered suitable for pulping. The southern yellow pines were too resinous. The hardwoods, which were already contributing a large part of our total forest growth, were too short fibered to yield acceptable pulp by conventional pulping methods; many of them were also too low in quality to have significant value as lumber. Modifications of the kraft pulping process brought the southern pines into the acceptable category for paper. The hardwoods remained a problem.

Chemists developed a promising new pulping process in the mid-twenties, a process in which hardwood chips are softened by cooking in a chemical solution and then reduced mechanically to fibers. It is called the neutral sulfite semichemical process. It received its first commercial trial in a scheme to utilize chestnut wood chips left as a residue after the extraction of tannins for tanning leather. The success of the trial launched the process into industrial application. The new semichemical process has two advantages over its completely chemical predecessors. The yield of pulp from a given weight of wood is much higher. It has unlocked the door to vast
areas of low-grade hardwood forests and made them available as a raw material for a paper industry hard pressed to find enough wood. Some 50 mills use the neutral sulfite semichemical process or the newer cold soda chemimechanical processes, developed later at the Laboratory. The cold soda process requires less capital investment and gives even higher yields with the hardwoods. Aspen, once considered to be a weed tree, has risen in popularity to a point where it is the leading pulpwood species in the Lake States.

Chemists have believed that the less desirable trees should be worth harvesting solely for the value of the organic chemicals in them. The chemical utilization of wood was not economically feasible in the United States under normal conditions. Fundamental and applied data have been gathered, however, to the point where a chemical industry based on wood could now be an economic success. Chemicals worth some 60 million dollars annually are produced from wood, but they are largely secondary operations that rely on residues from a primary operation for raw material. A sound chemical conversion plant will probably have to make use of all three major fractions of wood, the lignin, cellulose, and hemicellulose.

Wood is approximately two-thirds fiber and one-third binder. The binder, lignin, has a complex organic structure that someday may become even more valuable than the fiber portion as a source of industrial chemicals. The fiber fraction is much more orderly and can be separated into two carbohydrate fractions. The most easily obtained fraction, the hemicellulose, consists largely of sugars that can be converted economically to furfural and other polymer-forming chemicals used in the production of nylon and similar synthetic fibers and resins. It is probable that a growing part of our production of organic chemicals will be based on these sugars from low-grade hardwoods. The cellulose fraction, more difficult to obtain in pure form, is the primary constituent of paper. Purified, it is reformed in high tonnage as rayon for tire cord and textiles.

Glucose is the sugar that can be obtained from the pure cellulose in wood. Since food sugars are available at low cost from other natural sources, research on glucose from wood has been primarily to establish the optimum reaction conditions for its conversion to promising industrial-type organic chemicals, such as hydroxymethylfurfural and levulinic acid. Glucose also can be fermented biochemically to glycerin, various alcohols, and food yeast. The yeast is high in protein and vitamins and could be useful in countries that rely heavily on a carbohydrate diet.

Our total wood supply can be conserved and used more wisely if we can modify individual pieces to make them last longer. Wood will last indefinitely if it is properly seasoned to remove its natural moisture and is then kept dry. A few years ago, for instance, archaeologists found sound wood beams in the tomb of King Gordius,
Improved gluing technology enabled engineers to extend the use of wood as an engineering material, like these huge laminated members.

Engineers at the Forest Products Laboratory use a machine that can exert a million pounds of force to test prototypes of laminated arches.

Technicians at the laboratory in Madison, Wis., establish the cutting and gluing characteristics of wood to be used for veneers.

Technicians make paper so as to study in finished-products form the characteristics of experimental pulps.
a king who reigned some 2,700 years ago in what now is Turkey. A few houses of wood built in New England in the 1630's still stand. Only exterior items, such as siding, have had to be replaced because of the gradual eroding effects of weather.

In many of its normal uses, however, wood cannot remain sufficiently dry. When it reaches a moisture content much above 20 percent, it becomes susceptible to damage by decay fungi or other wood-destroying micro-organisms. Window sills, posts, poles, railroad ties, and such other items in contact with the soil should be given added protection against decay and destructive insects. Creosote is still a standard preservative for piles, railroad ties, and such uses, but for uses where odor, appearance, or paintability are critical, only the newer preservatives are acceptable. Pentachlorophenol, a result of research at the Laboratory, is among the leaders in this class. It is a solid preservative that must be dissolved in a solvent. It is used at the rate of 11 million pounds a year, more than all other solid preservatives together. In a new approach to preservation, scientists at the Laboratory are attempting to avoid the costly deposition of quantities of toxic chemicals in wood to kill invading fungi. Their goal is to modify the cellulose in wood inexpensively so that fungi cannot digest it or possibly to destroy certain vitamins and other chemical compounds present only in trace amounts but necessary if fungi are to survive. Similarly, they are looking for ways to modify some one or more of the several stages in the combustion of wood so that the wood will not actually burn and contribute fuel to a fire.

As the new, young forests replaced the old, virgin stands of timber in this country, research workers had to find new ways of combining the smaller sizes of available timber. The research engineers found that modern adhesives are more efficient than the typical mechanical fastener, the nail. It was the beginning of a range of new structural products. Efficient gluing and techniques of cutting veneers made possible today's plywood industry. Nearly 8 billion square feet of softwood construction-grade plywood was produced in the western softwood region in 1960. Completely waterproof synthetic adhesives made it possible to make plywood for exterior and marine use. The first building with exterior siding of plywood, built in 1934, stands on the grounds of the Forest Products Laboratory and houses its facilities for research on packaging. It is the first structure in the United States built with glue-laminated arches. Through laminating, wood has become a truly beautiful, engineered structural material. You see it in modern churches, sports arenas, and gymnasiums, which must have a large, unobstructed floor space.

Although man for centuries has been building with wood, many of the crafts that rely on wood were not based thoroughly on a sound, technical understanding of its strengths and limitations. The
conventional homebuilding industry is typical. To meet the housing needs of the Nation efficiently and inexpensively during the early thirties, engineers at the Laboratory adapted the principles of wood aircraft design to the factory production of houses. Called the stressed-skin principle, the design involved the gluing of plywood or other sheet material to light framing members, so that all parts contributed to the strength of the unit. The units, which had a high strength-to-weight ratio, were then used for walls, floors, and roofs. Today, when more than a million houses are built every year, nearly 13 percent of new houses are factory built. Most of them are based on the original stressed-skin principle.

Supply problems in wartime gave impetus to research in packaging. Shipping space and the amount of lumber used had to be kept low, yet the packaged goods, from aircraft engines to combat clothing, had to withstand the violence of winter gales on the North Atlantic and the rain, waves, and tropical humidity of the South Pacific. Some 1,500 packaging specifications had been completed at the Laboratory by 1945 for the Ordnance Department and the Air Force, 16 thousand persons from privates to generals had been trained in techniques of efficient packaging, and four ships were moving the cargo that in 1941 had required five ships.

Because wood is a structural material of many uses, yet is organic in nature, research on forest products enters many fields of natural and applied sciences. The chemist, physicist, engineer, wood technologist, mathematician—each must have the support and ideas of the others if his research is to be fruitful. So, research men from several universities went to work in the Laboratory when it opened for business in 1910 with a staff of 45. Wood research was barely hitting its stride when the United States was confronted for the
Tests of preservatives and treating methods and conditions indicate the ability of wood to withstand severe exposure to insects and fungi.

first time with the logistics problem of long-distance war. Wood of the best quality was gravely needed in 1917 for gunstocks, truck bodies, aircraft propellers, and barracks.

Because time was so precious, probably the most valuable of these inspired efforts culminated in Harry Tiemann’s design of a radical water-spray kiln. This device kept the surface of lumber from getting too dry while the moisture within was being removed rapidly without warping, twisting, and general degrading of the lumber. His kiln eliminated months of air seasoning between the sawmill and the manufacturing plant. By the thirties, a great variety of projects had produced a wealth of information for industry and had indicated an even greater need for research. An expanded program was begun in 1932. Soon came technical publications on preservative treatment, painting, prefabricating, machining, laminating, plywood, and chemical products, all eagerly sought by industries.

Another war brought more problems and answers in such fields as packaging, stabilizing dimensions of wood, industrial chemicals, waterproof plywood, and sandwich-type construction, an improvement on the stressed-skin principle, to name a few. Successes brought new industries and new research ideas for the postwar years. But still there are products to be improved, processes to be developed, chemical mysteries to be unraveled. The research has a monetary value now. It is laying the groundwork for developments that may determine whether future generations will continue to have the abundance of forest products that we have. (Edward G. Locke)
A new chemical seasoning process eliminates drying checks and splits and adds dimensional stability in these walnut gunstocks.

Scraps from nine species of hardwoods, salvaged from a residue pile, were bonded and glued directly to a concrete subfloor for this office floor at the Forest Products Laboratory.