George Tsoumis
Science and Technology of Wood
Structure, Properties, Utilization

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Prologue

The field of Science and Technology of Wood is very broad. Separate books exist that cover subjects dealt with in only chapters or parts of this book. For example, there are books dealing with anatomical structure, wood–water relationships, mechanical properties, various industrial products (lumber, plywood, particleboard, etc.), and other aspects of wood (and bark). This book, however, is a concise, comprehensive presentation of the *total* subject.

The contents is presented in four parts, and developed into 29 chapters. *Part I* is a discussion of *wood structure*, dealing with macroscopic, physical and microscopic characteristics, chemical composition and ultrastructure, the mechanism of wood formation by trees, variation of structure, and abnormalities in wood.

Part II deals with *properties:* density (specific gravity), hygroscopicity, shrinkage and swelling (dimensional changes), mechanical, thermal, acoustical, and electrical properties, and degradation of wood by bacteria, fungi, insects, and other destructive agents.

Part III is devoted to *utilization* (i.e., to products made by primary processing of wood)—namely, roundwood products, lumber, veneer, plywood, laminated wood, particleboard, fiberboard, and pulp and paper. Additional chapters refer to drying, preservation, adhesion and adhesives.

An *Appendix* includes: (i) a brief discussion of secondary products made by mechanical processing (furniture, etc.), products of chemical utilization, wood as a source of energy, and other forest products (foliage, pine resin, etc.); (ii) a detailed treatment of specific woods (North American, European, and some important tropical species) with regard to identification, geographical source, properties and uses; and (iii) a discussion of bark (including cork) with regard to structure, properties, and utilization.

Part of this book, mainly on anatomical structure and identification, is a revised excerpt of my earlier book *Wood as Raw Material* (Pergamon Press, 1968/1969), and is included here with permission. The total contents of this book represent the expansion of an article entitled "Wood and Wood Products" ("Wood Production" after the 1985 printing), which I originally wrote for the *Encyclopaedia Britannica*.

The contents of this book are universal in application, but some aspects (e.g., grading specifications and lumber dimensions) present differences in various countries (or regions), and it would not be practical to present such detail in this book. The problem is circumvented by demonstrating, for example, the importance of defects in grading (Tables 11-4 and 17-4, Figure 17-25), or by reference to proposals for international standardization of dimensions (Table 17-1). Literature references are cited in the text, and extensive lists are included at the end of each chapter, allowing the reader to seek further specialized information. Measuring units are international (SI) and English.

This book was originally published in Greek (1983), and this is a version of it. My sincerest thanks are due to colleagues for reviewing the re-worked manuscript and for their kind assistance. I am particularly thankful to Dr. F. F. Wangaard (emeritus head, Department of Forest and Wood Sciences, Colorado State University), who encouraged this work, previewed the total manuscript, and offered many constructive suggestions, especially on properties. Other colleagues who previewed and commented on specific chapters are Drs. J. Bodig and H. Schroeder (Colorado State University), E. Biblis (Auburn University, Alabama), T. Amburgey, D. Nicholas, T. Sellers, F. Taylor, and F. Wagner (Mississippi State University), I. Goldstein (North Carolina State University), B. Thunell (Royal Institute of Technology, Stockholm, Sweden), and G. Stegmann (Fraunhofer Institut für Holzforschung, Braunschweig, Germany). I am indebted to all but, of course, the responsibility for the contents belongs to the author.

Fellow scientists, laboratories, companies making equipment or products, and others have contributed artwork (photographs, drawings), and their contributions are acknowedged where they appear in the book. Acknowledgment is also made to publishers for permission to reproduce copyright material. Most reproduced drawings, especially the graphs, have been redrawn. It should also be noted that any mention of specific industrial companies or trademarks is only an acknowledgment of source and not an endorsement.

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Introduction

Wood has served man since he appeared on Earth, and has decisively contributed to his survival and to the development of civilization.[1] Moveover, wood continues to be the raw material for a large number of products even in modern times, although other competitive materials (metals, cement, plastics) are available. The value of wood is preserved in many traditional uses, and grows steadily with its use in new products to meet the increasing needs of man (Figures 1 and 2).

After harvesting in the forest, the wood is converted into a great number of products by sawing, slicing, gluing, chipping, pulping, modification by impregnation with chemicals, or chemical processing. In chemical products, the change is so drastic that their wood origin cannot be recognized. Products of primary industrial processing include poles, posts, lumber, laminated wood, veneer, plywood, particleboard, fiberboard, pulp and paper—and, in turn, these are made into products for final use (furniture, etc.). Products of chemical processing are synthetic fibers, photographic films, explosives, chemicals, and many others.

Wood is also an important fuel material for cooking, heating, and production of steam, which may be utilized as a source of energy. About half of the world's production of wood is used as fuel. With the existing energy problems, wood, as a renewable product of nature, is acquiring a greater importance as fuel.

These multiple services are due to certain advantages: wood is aesthetically unrivaled as a material (3), because it is available in a great variety of colors, textures, and figures; it gives a feeling of "warmth" to touch and sight, which is not possessed by competitive materials; it is very strong mechanically in relation to its weight; it is insulating to heat and electricity, exhibits little thermal contraction and expansion, and has good acoustical properties (utilized in making musical instruments); it does not oxidize (rust) and shows considerable resistance to mild concentrations of acids; it may be easily machined with small consumption of energy; nailing or bonding with metal connectors, as well as gluing, is easily achieved; wood is the main source of cellulose, which is the basis of numerous products; it is found in most parts of the world, and is a renewable resource—in contrast to petroleum, metal ores, and coal, which are gradually but steadily exhausted (4, 8, 11) (Figure 3); it is biodegradable; it is a source of energy (i.e., gives heat by direct burning or produces combustible gases).

Wood has disadvantages as well: it is hygroscopic—holds moisture in contact with liquid water or water vapor; the gain or loss of moisture, within certain limits, results in dimensional changes; it is an anisotropic material—presents differential mechanical strength and differential dimensional changes in different structural directions; it may burn and decay; it has variable structure and properties, because it is a product of biological processes—it is produced by many tree species, and its production is influenced by environmental factors and heredity.

As with any other material, sound knowledge of its advantages and disadvantages is prerequisite to rational utilization of wood.[2] Such knowledge allows for improvement of the

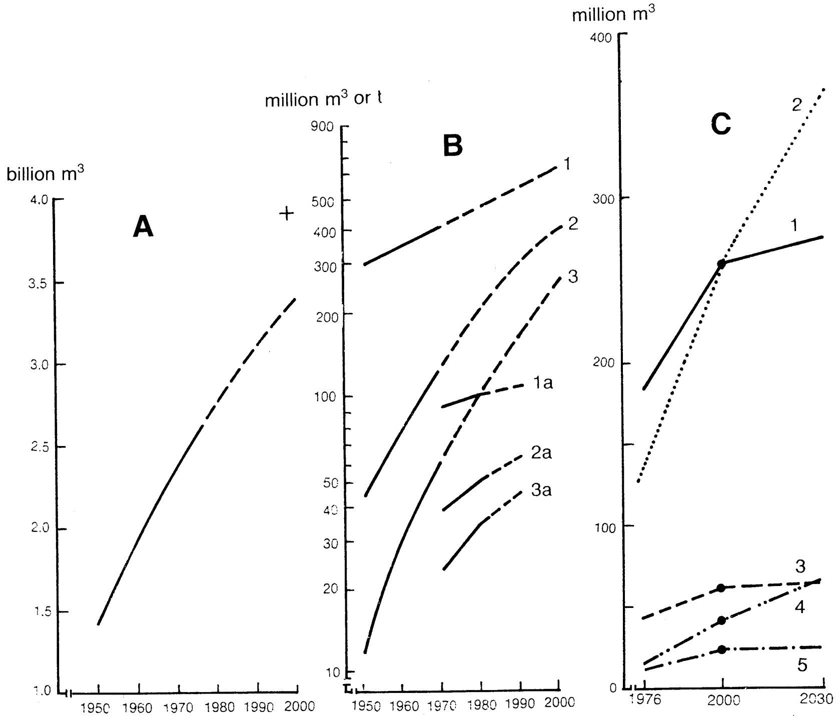

Figure 1. Consumption of wood and wood products with projected demands. (A) World (roundwood). (B) World (1, 2, 3) and Europe (1a, 2a, 3a); 1 and 1a, lumber (m^3); 2 and 2a, paper and paperboard (tons); 3 and 3a, panel products (m^3). (C) U.S.A. (roundwood): 1, sawlogs; 2, pulpwood; 3, veneer logs; 4, fuelwood; 5, other. [Based on data from the following sources: (A) FAO Yearbooks of Forest Products and Ref. 2; + according to Ref. 1; (B) Refs. 6 and 9; (C) Ref. 14.] (1 m^3 = 35.3 ft^3).

quality of wood produced in the forest, better use of the numerous available species, limitation of disadvantages, making products of the best possible quality, and reduction of waste.

The possibility of improved wood quality in the forest is of basic importance and may be realized, within limits, with silvicultural and other measures, such as pruning and spacing of trees, protection from strong winds, microorganisms, and other adverse factors, selection and propagation of genetically superior individuals, and careful harvesting.

With regard to the disadvantages, the following remarks may be made: hygroscopicity and the related dimensional changes may be controlled for practical purposes by proper drying or modification of wood, and thus undesirable effects (checking, warping, etc.) may be avoided; anisotropy is not always a disadvantage (mechanical anisotropy is advantageous in certain types of loading) and, in practice, it may be mitigated in such products as plywood, particleboard, fiberboard, and paper; wood may be protected from fire by impregnation with fire-retardant chemicals and, in the same manner, the durability of wood (i.e., its resistance to insects, fungi, and other destructive agents) may be greatly increased; the variability of wood with regard to anatomical structure and properties, within and between trees and species, may not cause problems if such variability is known and taken into consideration when various products are made. It may be concluded, therefore, that although

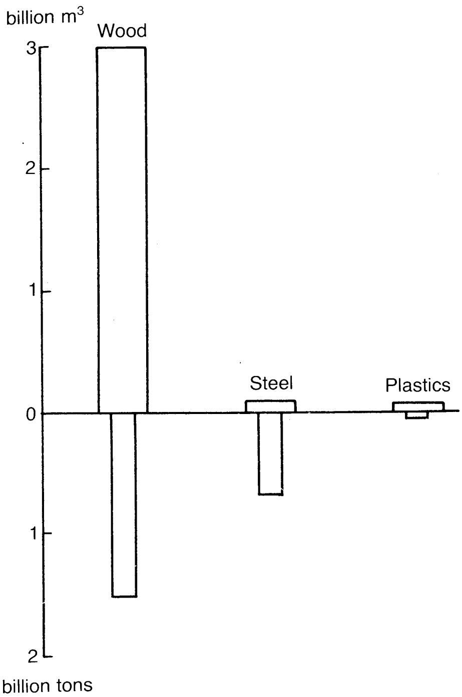

Figure 2. World production of wood, steel, and plastics (1985). (Based on data from FAO and professional societies: schematic presentation after Ref. 10.)

wood has disadvantages, there are possibilities of control in order to ensure the best possible utilization of this precious natural material.

A matter of great concern, both scientific and practical, is that large amounts of wood are usually wasted. It is rather optimistic to say that one third of the volume produced by the trees is finally utilized. Considerable quantities are left in the forest, in the form of logging residues, or form residues during various manufacturing processes. In converting logs to lumber, the residues are on the order of 30–50%. In the pulp and paper industry, 50% or more of the original volume of wood may be wasted. Lignin, a major component of wood, is virtually wasted due to incomplete knowledge of its chemical nature. Problems arise not only from the waste of material, but also from the concurrent pollution of the environment (e.g., water bodies, where residues and chemicals of the pulp and paper industry, if not treated properly, are discharged).

In this area of waste, great efforts are being made and some outstanding successes have been achieved. The best example is the particleboard industry, where residues of sawmills, veneer factories, and logging can be utilized. Current plans include utilizing all the biomass

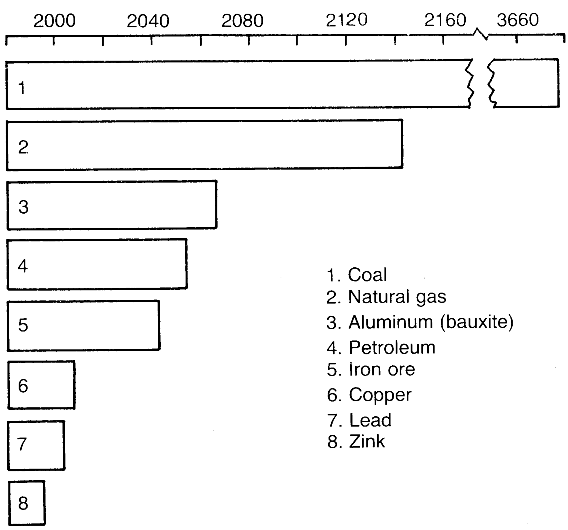

Figure 3. Maximum "life expectancy" of world's resources of raw materials; these estimates are being challenged. (Based on data from Ref. 15.)