Lucien F. Trueb

Pflanzliche Naturstoffe

Wie Pflanzenprodukte unseren Alltag prägen

Borntraeger

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Natural Plant Products

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Plant materials in everyday life

With 89 coloured figures

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Preface

The seeds for this book were planted in my early childhood. Being naturally curious, I asked a lot of questions about the origin and nature of the materials I encountered in everyday life, such as paper, wood, fabrics, rubber, candle wax, paint etc. I noticed very soon that the answers I got from my parents and other adults were mere excuses, and they did not really know. Even worse, they did not want to know and thought my questions were simply inappropriate. The one good advice I got in the process was that I would have to study chemistry if I really wanted to know about "things". Many years later this is exactly what I did.

During my undergraduate years, two things struck me. Synthetic materials such as plastics, glass, metal alloys and ceramics are all over the place. Yet, we still heavily depend on natural products of mostly vegetal origin. Without the materials given us by plants such as wood, fibers, elastomers, hydrocolloids, alcohols, oils, waxes, resins and energy carriers, our everyday life not only would be a lot less comfortable, but downright impossible. Man has actually eliminated his former dependence on just two items: plant dyes and plant tanning agents.

As a student, I was fascinated by the fact that nature has a very limited fantasy when it comes to the molecules it uses. This is the result of a kind of Darwinian selection in the realm of biochemistry. Four nucleotides suffice for the genetic code of all living beings. Just some twenty amino acids are needed to build the thousands of proteins that are needed for making the biosphere tick. Plants owe their mechanical properties and a very efficient means to store energy mostly to glucose and a handful of other simple sugars. Despite a frightening chemical complexity and remarkable stability, the biosphere relies on a very limited set of building blocks that often are endlessly repeated.

Everybody knows that we fully rely on nature for food and to some extent for drugs. Libraries are full of books on those two subjects, this why they were purposely left out here. My intention was to inform the reader about the many non-food, non-drug plant products on which our quality of life and even our survival heavily depend.

In 2015, Borntraeger in Stuttgart (Germany) published my book on natural plant products ("Pflanzliche Naturstoffe", which included the semi-synthetic plant products such as cellophane, celluloid, rayon etc.), in German. At that time I suggested an English version. The condition was that I would not just merely translate the original, but rewrite it, taking into account a remark made by several reviewers. They thought that a lot of interesting details had been left out in quite a few of the plant products I had endeavored to describe. I took this remark very seriously and re-researched every single item in the book, some of them in the field, but mostly on the base of the quoted literature and the indispensable Wikipedia. Thus, the number of pages grew by about 20 percent, which included quite a few new pictures. So this English edition is essentially a new book.

A reader in Germany recently wrote that he presides an organization devoted to the revival of the old dye plants in Europe. It was too late to integrate this information in the text; at any rate, this certainly is a fascinating hobby, but at most a small niche market for enthusiasts.

Ebmatingen-Zurich, 2018

Lucien F. Trueb

1. Materials

1.1 Wood – a Renewable Material

The very distant ancestors of modern man were already experts at fashioning and using wood. Humanoids as well as their cousins, the apes, routinely used sticks and branches to threaten or fight their rivals and enemies. Apes also use them as hunting implements or as tools for getting food. For example, they use slender twigs from which the leaves were carefully removed for "fishing" delicious tasting termites from their nests. Long before the stone age and long afterwards, wood was the universal material. The much studied stone age tools and weapons of prehistoric man almost invariably comprised a wooden handle or shaft.

1.1.1 Wood as the Archetype of Matter

Among the cultural and technical highlights of the Fertile Crescent civilizations in North Africa and the Middle East, one must mention a perfect mastery in working wood. Wooden houses, furniture, carriages, household implements, tools and weapons were routine, so were lathe-turned objects as well as admirable figures and statues. In addition to that, wood was the universal source of energy for cooking, heating and illumination. Starting with the copper and bronze ages, charcoal made of wood was the only reduction agent of early metallurgy. The ashes left after burning wood contain 25 to 40 percent potassium oxide (K_2O) and are an excellent fertilizer. However, from the Middle Ages on, wood ashes were mostly used for making glass, soap and – most importantly – potassium salpeter, one of the key ingredients of gunpowder.

Today, wood is more important than ever, both technically and economically. The most important wood products are beams, boards, engineered wood products, wood chips, cellulose and paper. Wood pellets being a renewable source of thermal energy, are rapidly gaining importance for heating purposes. An important application of wood is the fabrication of pencils: it dates back to 1545. The shaft protecting the graphite pencil lead almost invariably consists of the light, medium-hard wood of the California cedar. It is available as $3/16^{th}$ of an inch thick boards.

By a wide margin, wood is the most important natural product. As we have seen, its importance was so great even in the earliest phases of man's development, that it became the epitome of matter in its most general sense. The Spanish word "Madera" stands for both wood and matter. The expression for matter is related to it in many Indo-European languages.

Wood has its drawbacks too, as it burns easily; furthermore, under normal climate conditions, wood is decomposed by bacteria and fungi within a few tens or at most hundreds of years. The only ways to preserve it in the long term is to store it under near-absolutely dry conditions or under water under anaerobic conditions. In Egyptian tombs, thousands of years old sarcophagi and wooden implements were found to be in good condition. In more Northern latitudes, the poles used for anchoring the houses of pile dwellers in the ground were preserved thanks to their being constantly immersed in oxygen-poor water. Radiometric C-14 dating showed that those poles are up to 7000 years old. Due to the fact that the spacing of year-rings reflects the climatic conditions during the growth-phase of a tree, wood bears its own, extremely accurate chronology and climate archive. Dendrochronology is even used for correcting the C-14 scale, as the latter often yields erroneous results due to the variable activity of the sun that influences the rate of formation of the carbon isotope ^{14}C.

1.1.2 A Natural Composite Material

Wood is defined as the structural tissue located under the bark of trees and shrubs. Plants use their wood as a support structure and as a transport medium for water and nutrients. More particularly, the sugars that are photosynthesized in the chlorophyll-rich leaves are transported to the roots by the outermost part of the wooden tissue. Cell walls use them to produce cellulose fibers and the lower-molecular hemicellulose.

Those polysaccharides are transformed into wood by incorporating lignin, a three-

dimensional network of phenylpropanol units (mainly coniferyl alcohol) with the properties of a plastic. The cellulose fibers that are strong in tension are combined with lignin that is strong in compression. Wood therefore is a natural composite material consisting of 60 to 80 percent cellulose and 20 to 40 percent lignin. It can be compared to glass-fiber reinforced plastic, the cellulose playing the role of the glass fibers while lignin is substituted for the polymer mass.

It may sound paradoxical that a perfectly healthy tree mostly consists of dead tissue. As a rule, only the leaves, buds, blossoms and the cell-layer located under the bark – the so-called vascular cambium – consist of living cells. The outermost layer of the cambium is located under the bark and is called phloem; its function is to transport the sugars photosynthesized by the leaves all the way to the roots. On the other hand, water with dissolved minerals is transported from the roots to the leaves by the xylem, the innermost layer of the cambium.

The outer surface of the vascular cambium keeps forming new layers of phloem, while the inner surface forms new layers of xylem. This causes the diameter of the stem or branch to grow, forcing the bark to expand, often under cracking. The inner part of the stem is dead and may consist of strong and dense heartwood. The latter often contains tannins, dyes, resins and inorganic salts that prevent rotting.

Commercially important tree species such as maple, birch, alder, spruce, beech and pine form little heartwood while lindentree, poplar and willow form none at all. The latter species tend to rot from the inside out, becoming hollow and fragile as they age. This type of wood is soft and very easy to work, but its strength, hardness and durability are much inferior to that of tree species forming heartwood, such as oak, larch, mahogany, rosewood, false acacia, teak, elm and walnut.

Each tree species is characterized by specific microanatomical features, thanks to which it can be unambiguously identified. For example, the so-called ring pores may be distributed homogenously in the wood tissue or massed around the year rings. The rays that are arranged perpendicularly to the year rings are also important for species identification. The core is found in the very center of the tree trunk while the living, outer zone is protected from the bark by the inner bark or bast. The bark itself consists of dead bast cells and cork cells.

Sawing tree trunks for the production of beams and boards generates sawdust. This used to be an important thermal insulator. In the 19th century for example, ice blocks cut on frozen lakes in Norway were packed in sawdust and shipped all the way to Southern Europe and the United States as a refrigerant. The same was done in Switzerland with ice from Alpine glaciers that was ordered by Paris restaurants before the age of refrigerators and ice machines. Today, sawdust is used as a filler in wood cement boards and low density fiberboard. It also serves as a fuel: in the vicinity of big saw mills in Scandinavia, sawdust power plants supply heat and electricity to the neighborhood communities.

1.2 Modern Forestry

The Northern part of the Earth's Northern hemisphere with Fennoscandia (Scandinavia, Finland and the Kola Peninsula, the Baltic Republics and European Russia), Eastern Russia, Siberia and North America (Alaska, Northern Canada, the Arctic islands, Labrador, Newfoundland) is covered with giant forests. They absorb huge quantities of carbon dioxide, which slows down the concentration increase of climatically active gases due to the burning of fossil fuels. The world's wood inventory is estimated to be around 1 trillion (1000 billion) tons, the yearly growth being 10 billion tons. This corresponds to about 11 billion cubic meters per year, 3.6 billion cubic meters being harvested. This leaves a net inventory rise of 7.4 billion cubic meters per year, but only a fraction of that can be harvested at an acceptable cost

1.3 The Taiga-Forest of Fennoscandia

Since the early days of the 20th century, management of the Scandinavian forests has dramatically changed. Those forests are now

recognized as ecosystems with an amazing biodiversity. They may be harvested, but with great care and prudence. Accordingly, Nordic forest management is organized for the long term, as the cycle of planting to harvesting lasts about one hundred years.

The Fennoscandian woods mostly consist of dense growths of pine, spruce and birch. Interesting enough, some 80 percent of the original wooded areas were shaped by fire. Those forests burned about once every hundred years without any serious consequences. In the course of millions of years, forest animals and plants had adapted to forest fires that were usually set by lightning. For example, pines protect themselves with a thick, nearly fireproof bark. Branches start at a great height so that the flames cannot reach them. Fires thus mostly destroy undergrowth and forest litter – good riddance!

A very different type of forest grew along rivers and on the shores of Fennoscandian lakes. There, the dominating species was spruce that could reach an age of 200 to 300 years. In those areas, the ground was covered with wet moss, so that a fire locally lit by lightning did not have much of a chance of propagating. For this reason, fires were quite rare in such forests: they formed a very stable ecosystem with a flora needing undisturbed growth conditions.

But once or twice per millennium a devastating fire broke out in a riverside forest: it was a disaster from which the forest and its rich flora and fauna were very slow to recover. One may compare this kind of disaster with today's large area clear-cutting, but there is a difference. Nowadays, every fifth tree is spared: it protects the soil and produces seed for the next generation of trees that will spring up quite by itself, without any human help. After all, trees predate humans by hundreds of millions of years. They managed quite well without us.

1.3.1 Semi-Natural Forests

The Scandinavian forests have been exploited ever since man permanently settled the land after the ice of the last glaciation had retreated. Wood was needed for construction, furniture and as a source of heat and light. This did not hurt the forests as long as the human population density was quite low. But starting with the late Middle Ages, ever larger quantities of wood were needed for naval construction and for the production of tar, charcoal and ashes. Once the really old and big trees had been cut, ever smaller ones were harvested. For this reason, trees that are significantly older than one hundred years are quite rare in all of Scandinavia.

The first Swedish laws regulating the cropping of forests date back to the early years of the 20th century. They stipulated that every tree that is cut must be replaced by a newly planted one, and that the total harvest must never exceed the yearly growth. After World War II, the technology of large area clear-cutting was introduced, replacing the age-old tradition of extracting only the bigger trees. The result was not pretty, but it allowed systematic planting of young, vigorous trees with a selected genome. The result was new, healthy forests in which all the trees have exactly the same age.

Clear-cutting the Scandinavian way is quite friendly to the environment. In areas with an adequate climate with an altitude not surpassing 300 meters, 75 to 120 big and good-looking trees are left per hectare, so their seed may renew the forest. Branches and other refuse are left on the ground as a refuge for small animals and a long-term source of humus. The edges of the cleared areas are left untouched as refuges for plants and animals; the new forest will be colonized from there.

For many decades, enormous efforts were made in Scandinavia to reduce the dead wood as much as possible, in order to eliminate breeding grounds of bark beetles and minimize the spreading of forest fires that were fought most efficiently and limited to small areas. But as it became clear that fire is the forest's friend, the dead wood was left where it was and periodic, controlled burning was introduced. Thanks to this measure, tree-free areas were created that allowed the growth of pioneer plants and young trees: nowadays, new growth exceeds the harvest by 30 percent. Since the beginning of the 20th century, wood

reserves in Scandinavia have doubled and are now of the order of 100 cubic meters of usable wood per hectare.

One of the major aims of Scandinavian forestry is to keep forests as closely as possible in their natural condition while still harvesting them intensely. This means managing the forest as well as the entire environment in which it is embedded, i.e. fauna, flora, fungi, lichens, insects and microorganisms. However, truly virgin forests in the condition man found them when he settled the land are only left in Russia, east of the Ural Mountains. In those areas, the dominating tree species is spruce, but one also finds thick stands of birch and aspen.

1.3.2 Planting and Sowing Trees

For replanted Scandinavian forests, new kinds of pine were bred that develop a dense system of roots in the early stages of their development. The seeds are provided by specially selected and disease-resistant stands of trees. The seedlings are grown in reusable plastic containers filled with peat and polystyrene balls; huge greenhouses allow fast germination and growth.

Planting starts six months after germination. For this purpose, a hole is dug is the ground with a hollow planting stick, then the seedling's root bale is pressed into the hole. It is much more efficient to sow new trees, but it can only be done in May and June. A special kind of wheel was developed for this purpose; while rolling, it presses 2 centimeter deep, pyramid-shaped holes in the ground and deposits a seed grain it its bottom. Those holes are filled in with earth by wind and rain, so the seed grain can germinate. The drawback of this fast and efficient procedure is that the survival rate of the seedlings is only around 10 percent.

1.3.3 Three Thinnings in a Hundred Years

Ten years after planting or sowing, the young trees are thinned out for the first time. This defines the type and quality of the future forest that as a rule consists of spruce, pine and birch. There usually is an excess of birch, as extra seed is brought in by the wind from neighboring, mature birch stands. The first harvest is brought in 30 to 40 years after planting. It is done in order to bring the tree density down to 2000 per hectare; this wood can only be used by the paper industry. The final harvest producing lumber for construction and the furniture industry takes place 90 to 120 years after planting. Only the grandchildren of the present generation will live to see it.

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Global Forest Resources Assessment 2005, FAO Forestry Paper 147, ISBN 92-5-105481-9.

1.4 Forests of Central and Southern Europe

Even though vast areas of Central and Southern Europe are covered by forests, the continent relies on the boreal forests of Scandinavia as a major source of lumber and paper. In terms of tree species, Scandinavian forests mostly have their original composition with only 1 or 2 pine species, while in Central and Southern Europe a mix of 1 to 2 coniferous and 2 to 3 species of broadleaf, deciduous trees is typical. Mixed forests with 4 to 6 species of trees are found in Italy and the Eastern European countries. Those mixed forests have been replaced in some areas by plantations of fast-growing conifers. Furthermore, new species were introduced, mostly from North America.

In the group of introduced species, the most important coniferous trees are Norway spruce (*Picea abies*), a European species that was widely propagated in Northern and central Europe, Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii*), Western hemlock (*Tsuga heterophylla*) as well as several pine and larch species. Among the introduced broadleaf species one must mention the Red oak (*Quercus rubra*), the False acacia or Robinia (*Robinia pseudoacacia*) and the poplar (*Populus* spp.). In Northern Spain and Portugal, several Eucalyptus species (*Eucalyptus* spp.) from Australia were introduced success-

fully – maybe too successfully. At any rate, great efforts are now being made to eradicate them and reintroduce original, native trees.

The diversity of North American tree-species is amazing – there are hundreds of them – while Europe is quite poor in that respect. The reason is the combined effects of the Ice Age (that lasted from about 800,000 b.p. to 10,000 b.p. with many warm intervals) and the topography. As the ice advanced in North America, bringing colder climates to Southern latitudes, the Northern tree species were free to shift southwards; they came back North when the ice retreated.

The situation was quite different in Europe, as the formidable East-West barrier of the Alps gave the trees no chance to retreat further South: they were trapped at the foot of the Alps. Little over 10 000 years ago, the Swiss Plateau was covered with 3000 meters of ice! Under those conditions many species, particularly the cold-sensitive ones disappeared; only relatively few cold-tolerant species such as birch, beech and conifers were left to recolonize the area after the ice had gone.

Central Europe is densely populated by man and this had a considerable impact on the forests. In order to make room for agriculture, flat areas were mostly cleared; in hilly areas, the tree cover was left only on the hilltops. Yet, forests still cover 46% of the European land area, which means over 1 billion hectares, 80% of which are located in the Russian Federation. The forest cover is quite uneven further West, large forested areas are concentrated in Southern France, Northern and Northwestern Spain, the Alpine regions, the center of the old Yugoslav Federation, the Carpathians, the Black Sea coast of Turkey and the Caucasus. Beech and oak play an important role in the Mediterranean area. On 4 to 5% of the forested area, the typical mix of deciduous and coniferous trees was replaced by plantations of fast-growing conifers yielding low-cost paper pulp and construction material.

1.5 North American Forests

After the supercontinent Pangaea broke up some 200 million years ago and the Atlantic Ocean gradually widened, germ plasm exchange between Europe plus Western Africa and the newly formed Americas became more and more difficult and eventually ceased altogether, the distance from shore to shore having become too great. From then on, tree species evolved on their own on both sides of the Atlantic, eventually developing into separate but closely related species.

At the time Columbus discovered the Americas, not one European tree species was found on the Western side of the Atlantic, and vice versa. Of course this has changed since the 16th century, as American tree species were brought by man to the Old World while some European species gained footholds in the Americas. There was a report some years ago of a West-African species that was found as a native tree in South America. This was never unambiguously confirmed but is not impossible. Rafting of viable seeds on tree trunks over considerable distances has happened in other places. And indeed: the shortest route across the Atlantic is between Brazil and West Africa. If the rafting hypothesis is correct, the probability of it happening there is optimal. The direction was from West to East, as the prevailing winds blow that way.

North America is a huge continent with an area of over 24.7 million square kilometers extending from Arctic Alaska all the way to tropical Mexico. Accordingly, the tree flora is very rich and diversified, quite aside from the fact that it was not significantly affected by the Ice Ages, as explained above. The classification of Young and Giese lists eight different North American forest types: Boreal-Coniferous, Northern Hardwood, Central Broad Leaved, Oak-Pine Southern, Tropical, Bottomland Hardwood, Rocky Mountain and Pacific Coast.

The Boreal or Northern Coniferous Forest extends from the Alaska timberline in the Northwest to Newfoundland in the East. The Rocky Mountain Forest complex follows both slopes of the Rocky Mountains from Western Canada all the way to Southern Mexico; south of the Mexican border it splits into an Eastern and a Western branch. Within California, the Sierra Nevada forms a separate biome and forest complex. The Pacific Coast Forest starts in

Alaska, hugging the Pacific coast into Central California with island-like extensions to Baja California. The Great Basin, Mojave, Sonoran and Chihuahuan deserts, i.e. the area stretching from southern California to Western Texas are home to the Southwest Dry Forest Complex.

The Eastern third of North America with its moderate climate supports a great diversity of forests that is classified as the Eastern Deciduous Forest System. It is subdivided in various ways. From the Great Lakes area to the New England coast we encounter the Northern Hardwood Forest that melts into the Central Broad Leaf Forest south of the Great Lakes to (roughly) the Northern boundary of Alabama, Mississippi and the western boundary of Georgia. A wide ribbon encompassing the Southern Atlantic states, the eastern Gulf States and Florida forms the Southern Oak-Pine Forest region. The southern tip of Florida as well as southern Mexico is the realm of the Tropical Forest. The Bottomland Broad Leaved Forest forms a kind of island extending from the Louisiana coast halfway up to the Great Lakes.

The **Boreal Coniferous Forest** extends transcontinentally from Alaska to Newfoundland, the North shore of Lake Superior being its Southern border. It has many things in common with the Fennoscandia Forest in Europe. Both areas are characterized by a cold climate, plenty of snow and a very short growing season just encompassing the three summer months. The so-called Northern treeline is not clearly defined: tree cover just peters out at high latitudes, the remaining trees being ever smaller and distorted by the wind and heavy loads of snow. The last fingers of tree vegetation jutting out North into the tundra follow river valleys and are populated by willows (*Salix* spp.) and alders (*Alnus* spp.).

Many lakes and bogs left by retreating ice-age glaciers were filled with sphagnum moss the decay of which generates acidic water. Only Black spruce (*Picea mariana*) and Eastern larch (*Larix larciana*) are adapted to such soils. Several alder species are found on the shores of lakes and rivers. White spruce *(Picea glauca)* intermixed with balsam fir (*Abies balsamifera*), birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) occupy the drier areas. Jack pine (*Pinus banksiana*) and lodgepole pine (*Pinus contorta*) grow on poor soils and are specially adapted to survive forest fires: their cones release seeds only if they are strongly heated.

The **Rocky Mountain forest complex** extends in a broad swash from Alaska and Western Canada Southwards into Southern Mexico. Tree species distribution is controlled by latitude and elevation; the higher both of them get, the lower the temperatures; elevation alone causes increasing precipitation. Due to the prevailing West to East wind system, the Western slopes of the Rockies get considerably more precipitations than the Eastern part. The timberline is strongly affected by latitude: it lies around 3800 meters in the Southern Rockies and gets as low as 600 meters in Northern Alaska.

One finds at least seven different forest subtypes in the Rocky Mountains. The **Pinyon-Juniper Woodland** occupies arid slopes; it is the domain of less than 6 meters tall, two-needle pinyon pines (*Pinus edulis*), junipers (*Juniperus* spp.) and Ponderosa pine (*Pinus ponderosa)* interspersed or alternating with Gambel oak (*Quercus gambellii*) and mountain mahogany (*Cercocarpus montanus).*

The **Ponderosa Pine Forest** characterizes the transition zone between dry and moist areas at altitudes between 1300 and 2600 meters. The drought-resistant Ponderosa pine often forms clumps and reaches a height of 50 meters. At lower altitudes it is accompanied by juniper and Gambel oak; at higher altitudes one also finds aspen, Lodgepole pine and Douglas fir.

Quaking aspen (*Populus tremuloides*) that resemble birch but actually belong to the poplar genus, are found in protected stands at elevations between 1800 and 3800 meters, forming **Aspen Grove Forests**. The individual stands are often formed by clones growing from the same root system. Stands of over 50 hectares are found, they are the world's largest single organisms. The stalks of the leaves are very thin, which makes them "tremble" in the slightest wind gust. The leaves turn a beautiful golden-yellow in the fall. The Quaking aspen

The Bristlecone Pine, the World's Oldest Organism

Among the world's long-lived trees, the bristlecone pine (*Pinus aristata* var. *longaeva*) does not have the longest life expectation, but it is by far the oldest presently living above-ground organism. The species owes its name to the sharp prickles characterizing the female cones. The record-breaking specimen is 5064 years old; its age-rival called "Methuselah" is 4846 years old. At the time those trees sprouted, the pyramids were built in Egypt. Both of them were found in the Inyo National Forest, North of Death Valley National Park in California at an altitude of over 3000 meters. Only rangers know the location, as tourists would invariably love them to death by cutting off snippets of the wood. But plenty of very old trees can be seen from the accessible trails.

The 5 to 12 meter tall bristlecone pines stand either alone or in small clumps in a very arid, cold high-altitude region where winter snow is the only source of water. The soils consist of highly alkaline, pulverized dolomite or limestone that most other species avoid. Over the centuries, the trees were heavily gnarled and literally eroded by windstorms, hail and fire. Yet they manage to grow living branches, shedding their wax-coated needles only every 30 or 40 years. The tree-trunks are quite thick; due to the proximity of the year-rings the wood is very dense and resists fire. Mechanical damage is repaired with resin that prevents attacks by insects, fungi and microorganism. The roots are widely extended which allows rapid uptake of the sparse water released by melting snow.

The bristlecone pine is of tremendous importance for the dendrochronologist, as its dead tree trunks and specimens living today yielded an uninterrupted sequence of year-rings covering the last 9000 years. This allows a complete reconstruction of the climate history of Southern California during that period as well as an accurate calibration of the C-14 dating method that is subject to variations of the solar wind's proton flux.

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Moore, G. et al. (2008): National Wildlife Federation Field Guide to Trees of North America. Sterling, New York. ISBN 1-4027-3875-7.

is actually the most widely distributed tree in North America.

The **Lodgepole Pine Forest** also includes spruce, fir, Douglas fir and ponderosa pine; it is found at altitudes between 2800 and 3300 meters. The Lodgepole pine is also called twisted pine because of the contorted, bent shape of its Pacific coast variety; furthermore, its needles are twisted too. The tree reaches a height of 40 to 50 meters, its crown is rounded. It was introduced in New Zealand where it is now considered as an invasive species.

The **Spruce-Fir Forest** needs the cool, relatively moist climate that is found at 3000 meters elevation in the Southern Rockies and at lower altitudes further North. Major species are Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*). In the far North they are replaced by white spruce and balsam fir.

The **Subalpine Forest** is found in the Rockies just below timberline and is populated by the gnarled bristlecone pine (*Pinus aristata*) that can reach an age of several thousand years (see above). It is accompanied by the limber pine (*Pinus flexilis*), giving way to subalpine larch (*Larix lyallii*), whitebark pine (*Pinus albicaulis*) and mountain hemlock (*Tsuga mertensiana*) further North.

The **Riparian Forest** section of the Rocky Mountain Complex is located along streams and rivers; it mainly consists of hardwood trees. It is rather patchy and the trees are rarely taller than 10 meters. East of the Rockies, the so-called Plains cottonwood (*Populus del-*

toides ssp. *molinifera*) dominates the scene. On the West side, one finds other species of Cottonwood, particularly the Fremont, Narrowleaf and Black species. Boxelder (*Acer negundo*), Peachleaf willow (*Salix amygdaloides*) and Green ash (*Fraxinus pennsylvanica*) characterize the low elevations. In higher elevations, balsam poplar (*Populus balsamifera)*, quaking Aspen, blue spruce (*Picea pungens*) and white fir (*Abies concolor*) are quite common.

The **Pacific Coastal Forest Complex** grows under particularly favorable conditions, i.e. moderate temperatures due to the proximity of the ocean, ample precipitations (mostly in the winter) and nutrient-rich, volcanic soils. Elevation differences between sea-level and 4600 meters in the Coast Range, the Cascade Mountains and the Sierra Nevada further East foster a wide variety of tree species that are adapted to different temperature and precipitation regimes.

The **Northwestern region** includes Vancouver Island, the Oregon Willamette Valley and Northern California. The forest is of the oak-pine type and is populated by Oregon white oak (*Quercus garryana*), Pacific madrone (*Arbutus menziesii*), Knobcone pine (a variety of the Lodgepole pine) and the coastal variety of Ponderosa pine.

Along rivers, black cottonwood (*Populus trichocarpa*) dominates the **riparian forests**: it reaches a height of 60 meters and a trunk diameter of 3 meters. It grows throughout the entire latitude range of the Pacific Forest complex; the same applies to the Red Alder (*Alnus rubra*) that has the additional advantage of fixing nitrogen in its root nodules. White alder (*Alnus rhombifolia*) replaces red alder in the Southern Cascade Mountains. The Sitka alder (*Alnus viridis* ssp. *sinuata*) is also found there, but at higher elevations. The range of the Oregon ash (*Fraxinus latifolia*) extends from the state of Washington to southern California. This region is also characterized by about thirty species of willow (*Salix* spp.); among them, the Pacific willow (*Salix lucida* ssp. *lasiandra*) reaches a height of 20 meters.

Inland Oregon and Washington are covered with a **Douglas fir forest**. On the West side of the Cascades, it is associated with red alder, Bigleaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). Ponderosa pine, sugar pine (*Pinus lamberiana*), as well as several species of fir, pine and larch are the Douglas fir's associates in dry areas.

The **subalpine forest** in the upper reaches of the Cascade Mountains gets plenty of snow in the winter. The tree population growing there is practically identical with that of the northern Rocky Mountains, the exception being the Yellow cedar (*Chamaecyparis nootkatensis*) that is unique to that region.

The Pacific coast from southern Alaska to southern Oregon is covered by a **spruce-hemlock forest** dominated by Sitka spruce and Western hemlock. Sitka spruce always hugs the Pacific coast within 50 km. It grows to a height of over 60 meters, its trunk diameter can exceed 3 meters. The western red cedar accompanies it; its decay-resistant wood was already used extensively by the native people, mainly for canoes and house construction. The tallest tree in the area is the coastal variety of the Douglas fir, as it can reach a height of 100 meters. The Port-Oreford cedar (*Chamaecyparis lawsonia*) is at least as tall as the Sitka spruce. The understory trees of the spruce-hemlock forest are Pacific yew (*Taxus brevifolia*) and Pacific dogwood (*Cornus nuttallii*).

The **Redwood Forest** just south of the spruce-hemlock forest is one of the major tourist attractions in northern California. Small wonder, as the redwoods (*Sequoia sempervirens)* are the tallest trees anywhere in the world. Fortunately, the remaining stands after fierce logging in the 19th and 20th century are protected by a small, three-part national park some 30 km from the Oregon border One of those trees has been reported to reach a height of 115.5 meters. A tunnel wide enough for cars was drilled into the trunk of another big redwood with no ill effects for many years. However, that tree eventually died, but at least three tunneled redwoods can be driven through (for a fee) on privately owned forest parcels.

One of the unique characteristics of the Pacific Coast forest system (that includes offshore islands) is the presence of endemic

conifers that are found only in limited areas. They are called **closed-cone pine forests** due to the fact that their so-called serotinous cones are coated with wax. The seeds are released by the heat of a forest fire and then fall into the nutrient-rich ash left by burned wood. For quite some time, European foresters emigrated to North America did not understand that the pine forests of the southeast and the coniferous forests in the west are not only adapted to fire but depend on it to rejuvenate themselves. The redwoods in northern California for example would be replaced by competing species without fire. This is why controlled burns are routine in many national parks, national forests as well as in privately owned forests.

The most important species in the closed-cone pine forests are Bishop pine (*Pinus muricata*), Sargent's cypress (*Cupressus sargentii*), Knobcone pine (*Pinus attenuata*), Monterrey pine (*Pinus radiata*), Monterrey cypress (*Cupressus macrocarpa*) and Gowen cypress (*Cupressus goveniana*). The Monterrey pine was found out to be a rapidly growing species adapting itself easily to different environments. This is why it was introduced all over southern California, in Chile and in New Zealand, all places with a mild, Mediterranean climate and mostly winter precipitations. The Coulter pine (*Pinus coulteri*) and the Torrey pine (*Pinus torreyana*) are specific for Southern California. Visitors may be astonished to find blue gum eucalyptus in this region too. Actually, *Eucalyptus globulus* was introduced from Tasmania.

Within the state of California, the **Sierra Nevada Forest Complex** forms an elongated island starting east of the agriculturally very rich Central Valley and ending at the boundary of the Basin and Range Province. The Sierra Nevada is Californian territory, with just a small extension into northwestern Nevada; it roughly follows the western border of Nevada in its 600 km North-South extension. The major peaks of the Sierra are Mount Humphrey near Bishop: it rises to 4300 meters. With 4421 meters, Mount Whitney is the highest peak in the contiguous United States. Within the Sierra Nevada complex, six different forest types can be recognized as one proceeds from low elevations to higher ones.

The **Oak-Pine Woodland** stretches throughout western California and preferably occupies sheltered valleys up to an altitude of 1700 meters. The area is shared by six species of oak: Oregon white oak (*Quercus garryana*), Interior live oak (*Quercus wislizeni*), Coast live oak (*Quercus agrifolia*), blue oak (*Quercus douglasii*), Isolated Engelmann oak (*Quercus engelmannii*) and Valley oak (*Quercus lobata*). They are accompanied by Gray pine (*Pinus sabiniana*), Pacific madrone (*Arbutus menziesii*), California laurel (*Umbellularia californica*, a big hardwood tree), and Incense cedar (*Calocedrus decurrens*, a conifer), all in the northern part of the Sierra Nevada. On the other hand, California buckeye (*Aesculus californica*) and California walnut (*Juglans californica*) are widespread in the south.

The **Sagebrush-Pinyon Forest** is characteristic for the dry eastern slope of the Sierra between 1700 and 2300 meters of altitude. It is populated by the Singleleaf pinyon (*Pinus monophylla*) and California juniper (*Juniperus californica*); both are rather small and shrubby. The sagebrush associated with this type of forest is the fire-adapted *Artemisia tridentata.*

As already mentioned, precipitation is quite high on western mountain slopes, as the prevalent West to East wind system brings moist air from the Pacific that rains itself out as it is forced to rise to the crest of the Sierra. For this reason, relatively big trees can grow at elevations between 800 and 2000 meters on the western side. They form the **Mid-Elevation Pine Forest** with the coastal variety of white fir (*Abies concolor* var. *lowiana*), California black oak (*Quercus kelloggii*), Incense cedar, Sugar pine and Douglas fir. As the moist air sinks on the Eastern side, heating up adiabatically, there is still humidity left at altitudes between 2300 and 2700 meters for the growth of Jeffrey pine (*Pinus jeffreyi*) that is closely related to the Ponderosa pine but is more drought and cold tolerant.

After the redwoods of coastal Northern California, the Giant sequoia (*Sequoiadendron giganteum* – note that the word is one of the rare ones containing all five vowels of

the Latin alphabet) is one of the world's tallest trees. It can reach a height of 100 meters and a trunk diameter of 10 meters. It dominates the **Giant Sequoia Grove** in the Sequoia National Park east of Fresno in the elevation range between 1700 and 2300 meters. With a 30 to 60 centimeter thick bark, it easily resists even strong forest fires; the wax-coated cones only release their seeds if that wax is melted off by fire. The giant sequoia is accompanied by Sugar pine, White fir, Incense cedar and California black oak.

The California red fir (*Abies magnifica*) dominates the **Montane Fir Forest** on both slopes of the Sierra Nevada but in different elevation ranges: 2000 to 2700 meters on the moist west side, 2600 to 3000 meters on the drier east side. It is a stately tree reaching a height of 40 meters; above 2500 meters on both slopes one also finds the Western white pine and the Lodgepole pine, the latter being a pioneering species rapidly growing on burned areas. White fir is found only at low elevations on the western slope. Douglas fir is the dominating species in the northern montane fir forests where Pacific yew (*Taxus brefolia*), Tanoak or Tanbark oak (*Lithocarpus densiflorus*, one of the rare evergreen hardwood trees) and California nutmeg (*Torreya californica*) are associated with it. The latter is not closely related to the true nutmeg; it is an evergreen tree also encountered in the Northern part of the California coastal range and in gardens where it makes a nice ornamental tree.

The highest elevation range of the Sierra up to 3800 meters just below timberline is host to a rugged, open **Subalpine Forest** where the growing season only lasts a couple of months. It is occupied by Mountain hemlock and Western juniper (*Juniperus occidentalis*), a twisted tree reaching an age of 2000 years and a trunk diameter of up to 5 meters. Several species of pine are also found in the subalpine forest: Whitebark, Lodgepole, Limber, Western white and Foxtail (*Pinus balfouriana*) that resembles the extremely long-lived Bristlecone pine described in the section "Rocky Mountain Forest Complex".

The **Southwest Dry Forest Complex** occupies the area between California, Western Texas and Central Mexico. This is a series of deserts: Great Basin, Mojave, Sonora and Chihuahua. Next to grasses, the sparse vegetation consists of drought-resistant shrubs and cacti. Trees can only grow along watercourses and at higher elevations, watercourses being an euphemism for snow meltwater, intermittent rivers or springs, flashfloods and runoff from thunderstorms. Only extremely drought-resistant tree species with deep taproots can survive under such conditions.

The **Riparian and Canyon Forest** consists of hardwood trees such as California sycamore (*Platanus racemosa*) and California walnut giving way to the equivalent Arizona species further east. The only conifer is the Arizona cypress (*Cupressus arizonica*); in such forests that follow watercourses (often intermittent, so-called arroyos) and canyon bottoms, one also finds Fremont cottonwood (*Populus fremontii*), Narrowleaf cottonwood (*Populus angustifolia*), Canyon maple (*Acer grandidentatum*) as well as several species of ash, willow, alder and oak. The drier sites are home to honey mesquite (*Prosopis glandulosa*), Catclaw acacia (*Acacia greggii*), Blue paloverde (*Parkinsonia florida*), yellow paloverde (*Parkinsonia microphylla*) and Desert ironwood (*Olneya tesota*).

The water supply is considerable better in the **Lower Rio Grande Forest**. The region is only semiarid with a relatively big river flowing through it, even though much of its water is diverted for irrigation; furthermore, annual precipitation is more than 60 centimeters. The most important tree species are the Montezuma bald cypress (*Taxodium mucronatum*), Cedar elm (*Ulmus crassifolia*), Sandpaper tree (*Ehretia anacua*), Jerusalem thorn (*Parkinsonia aculeata*) and Sabal palm (*Sabal texana*).

The rather dry upland forests consist of Ashe juniper (also called Mexican cedar; it is classified as *Juniperus ashei*). The characteristic oak species are Texas live oak, (*Quercus fusiformis*), Lacey oak (*Quercus laceyi*), Texas red oak (*Quercus texana*), Bastard oak (*Quercus sinuata*) and Post oak (*Quercus stellata*). Among the leguminous species one finds Texas ebony (*Ebenopsis ebano*), Honey mesquite, Catclaw acacia, Sweet acacia (*Aca-*

cia farnesiana), guajillo (*Acacia berlandieri*) and Great leadtree (*Leucaena pulverulenta*).

Thanks to their relatively cool and moist climate, the Santa Catalina mountains in the Tucson (Arizona) area and the Chiricahua mountains in southeastern New Mexico are home to pine forests above the elevation of 2200 meters. They are called **Sky Island Forests** due to their geographical separation from each other. Many species that are common in the Rocky Mountain forests as well as in Mexico are found on those islands. Typical Mexican species are Chihuahua pine (*Pinus leyophila*), Apache pine (*Pinus engelmannii*), Southwestern white pine (*Pinus strobiformis*) and Arizona pine (*Pinus arizonica*). At still higher elevations, Douglas fir, Corkbark fir, Engelmann spruce, Limber pine, Lodgepole pine and Quaking aspen take over.

The Sierra Madre Occidental is the southern continuation of the North American cordillera; it is parallel to the Pacific Coast of Mexico. The dry northern part is the location of the **Madrean Foothill Forest**. At lower elevations, between 1550 and 2700 meters, it is dominated by the Mexican pinyon (*Pinus cembroides*), Arizona pine, Chihuahua pine, alligator juniper and no less than 112 species of oak, the most important of which are Arizona white oak (*Quercus arizonica*), Silverleaf oak (*Quercus hypoleucoides*) and Mexican blue oak (*Quercus oblongifolia*). At higher altitude, above about 2700 meters, one finds the Apache pine, the Mexican white pine (*Pinus ayacahuite*), inland Douglas fir and ponderosa pine; sheltered sites are occupied by Arizona cypress.

Another type of Madrean Foothill Forest is found on the foothills of the Sierra Madre Oriental, the mountain range beginning in Texas as the Davis and Guadalupe Ranges. It is cut by the Rio Grande and continues in eastern Mexico through Nuevo Leon, Tamaulipas, San Luis Potosi, Querétaro, Hidalgo and northern Puebla. The dominating tree species are Mexican pinyon, Weeping juniper (*Juniperus flaccida*), Texas madrone (*Arbutus xalapensis*), Gray oak (*Quercus grisea*) and Mohr oak (*Quercus mohriana*). Other endemic species are Nelson pine (*Pinus nelsonii*), Mexican weeping pine (*Pinus patula*), Pince pine (*Pinus pinceana*) and Gregg pine (*Pinus greggii*). The Mexican Plateau with an average elevation of 1100 meters lies between the two Sierra Madres that are linked by the Eje Volcanico Central in Northern Puebla. This is the northern end-point of most tropical, deciduous tree species that are widespread further south.

The **Eastern Deciduous Forest** covers the eastern third of the United States and stretches west from Florida to Central Texas, north to Minnesota and east to Maine. Forestry scientists and engineers specializing in this vast area have to cope with one of the most highly diversified forest systems in the world with hundreds of species. Deciduous hardwood trees dominate the scene, but many species of conifers are quite widespread and are important locally. The situation is further complicated by a long history of land use, e.g., clearing for agriculture, grazing, selective cutting, recolonization by late generation forests, fire suppression as well as the introduction of exotic species, insects and diseases. All these factors had important effects on forest composition. One example: in the early decades of the 20th century, the chestnut blight practically eliminated the once dominant American chestnut (*Castanea dentata*); it was mostly replaced by oak.

Within the eastern deciduous forest, eight general subtypes are found: they are described in the rest of this chapter. However, the tropical forests in southern Mexico, Guatemala, Belize and the southernmost tip of Florida will be left out due to their minor economic importance.

The **Northeastern Coniferous Forest** extends from the Canadian Atlantic provinces to the New England and Great Lake states, wherever the conditions for hardwoods are marginal. Black spruce and balsam fir are the dominant species in swamps and bogs, while one finds Jack pine, Red pine (*Pinus resinosa*) and White pine (*Pinus strobus*) in drier environments. In better quality sites, White spruce and Red spruce coexist with Sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*) and Yellow birch (*Betula alleghaniensis*). In such mixed forests, the conifers

were often selectively harvested, the low-value hardwoods being left to proliferate. In such stands, the shade-tolerant spruce form the understory. Dry sandy sites are occupied by Red pine and Jack pine; White pine is characteristic for the well-drained sites, but it has to compete with Red pine, Northern white cedar (*Thuja occidentalis*), various hardwoods, Quaking aspen, Bigtooth aspen (*Populus grandidentata*) and Eastern hemlock.

The **Northern Hardwood Forest**_characterizes the Northeast of Canada and of the United States including part of the Appalachians to the South; it extends west to the Lake States. Even though hardwoods such as Sugar maple, Red maple (*Acer rubrum*), American beech and Yellow beech predominate in those forests, conifers play a significant role. Thus, Eastern hemlock, White pine and spruce are plentiful on moderate quality sites. However, the tree population can form disjunct stands; depending on latitude and elevation. It can be infiltrated with boreal species in the North and more southern species in the South, such as basswood (*Tilia americana*), Yellow poplar, northern red oak (*Quercus rubra*), Black cherry (*Prunus serotina*) and White ash (*Fraxinus americana*). On dry sites one also finds White oak (*Quercus alba*), various hickories (*Carya* spp.), Chestnut oak (*Quercus prinus*), Scarlet oak (*Quercus coccinea*) and pitch pine (*Pinus rigida*). On heavily logged or burned sites, the hardwoods are associated with a pioneer tree population including Quaking aspen, Paper birch (*Betula papyrifera*), Sweet birch (*Betula lenta*), Pin cherry (*Prunus pennsylvanica*) and striped maple (*Acer pennsylvanicum*).

The westernmost areas of the eastern United States are a transition zone between the eastern deciduous forest and the grasslands of the central states. This **Midland Hardwood Forest** includes southern Minnesota, Wisconsin, Michigan, Indiana, Illinois, Arkansas, Oklahoma and central Texas. Due to low precipitations and high evaporation, the forests form islands in the open grassland and mostly consist of oak and hickory species. Among the oaks, one must mention the Red, White, Post (*Quercus stellata*), Black (*Quercus velutina*), Scarlet and Chestnut species. The savannah-type environment favors Bur oak next to elm, hackberry (*Celtis occidentalis*), cottonwood (*Populus deltoides*), beech, sweetgum (*Liquidambar styraciflua*) and Pin oak (*Pinus palustris*). As precipitation increases to the East and North, the density of oaks, hickories, elms, ashes, maples and walnut increases in those directions. The conifers are quite rare; their representatives are the Eastern red cedar (*Juniperus virginiana*) and the introduced Scotch pine (*Pinus sylvestris*). The midland hardwood forest was significantly more extensive before the settlement by white people. They cleared much of it, as the land is ideally suited for growing corn, soybeans, sorghum and wheat.

The **Ozark-Piedmont Forest** covers the Piedmont area that is located between the Atlantic Coastal Plain and the Appalachian Mountains, stretching in a flat arc from New Jersey through south-eastern Pennsylvania, Maryland, central Virginia, central North and South Carolina, Northern Georgia and east-central Alabama. Stretching west is the Ozark region that extends to southern Missouri, northern Alabama and eastern Oklahoma. The forest is of the oak-pine type with Shortleaf pine (*Pinus echinata*), longleaf pine (*Pinus palustris*), Pitch pine (*Pinus rigida*), Virginia pine (*Pinus virginiana*) and Loblolly pine (*Pinus taeda*). The hardwood species are oak and hickory with Scarlet oak, Southern red oak, White oak, Northern red oak, Pignut hickory (*Carya glabra*), Shagbark hickory (*Carya ovata*) mixed with Sweet gum and Red maple. This area was extensively used for agriculture, depleted in essential nutrients and eventually abandoned, which caused it to suffer from severe soil erosion. The forest then recolonized those sites, but its productivity is quite low.

The **Mixed Mesophytic Forest** is geographically defined by southeastern Ohio, western West Virginia, eastern and northeastern Kentucky, east-central Tennessee and the Blue Ridge foothills. High precipitation, moderate temperatures and fertile soils allowed the development of the richest forest in eastern North America. There are hundreds of species of trees and woody shrubs the distribution of which is a function of elevation, orientation,

slope and soil. The greatest species diversity is found in protected valleys; some of the most important species are Yellow poplar, Sugar maple, Basswood, American beech, Yellow buckeye (*Aesculus flava*), White ash, Cucumber tree (*Magnolia acuminata*), Northern red oak, Butternut (*Juglans cinerea*), Black walnut, Chestnut oak, Mockernut hickory (*Carya alba*), Shagback hickory, Pignut hickory, American elm (*Ulmus americana*), Kentucky yellowwood (*Cladrastis kentukea*) and Black Cherry. Conifers are rare and are mostly limited to Shortleaf pine and Eastern red cedar.

The **Bottomland Hardwood Forest** follows the Mississippi upriver from its delta in Louisiana as well as its tributaries north, halfway to the Great Lakes. The alluvial soils often cover floodplains and may be permanently or seasonally flooded. As water is no problem, the productivity is very high; the species diversity rivals that of the mixed mesophytic forest in some areas. Hardwoods dominate the scene, with a strong accent on wet site species such as Swamp chestnut oak (*Quercus michauxii*), Overcup oak (*Quercus lyrata*), Green ash (*Fraxinus pennsylvanica*), Sweetgum, Black willow (*Salix nigra*), Swamp white oak (Quercus *bicolor*), Water hickory (*Carya aquantica*) and Red maple. Among the rare conifers one must mention the deciduous Bald cypress (*Taxodium districhum*), Spruce pine (*Pinus glabra*) and Atlantic white cedar (*Chamaecyparis thyoides*), both of the latter ones being evergreens.

The **Southeastern Pine Forest** comprises a good part of the southern United States including the eastern and southern plains along the Gulf coast to east Texas and north to Arkansas. Pines are the absolutely dominating genus, with Loblolly, Slash (*Pinus elliottii*), Shortleaf, Longleaf and Virginia pine. Loblolly pine is planted on a big scale, but Slash and Longleaf pine are preferred on the Coastal Plain and in Florida. A good part of this forest has replaced abandoned agricultural land. The invasion by hardwoods must be prevented by controlled burning, as all the above-mentioned pine species are fire-dependent.

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1.6 Technically and Economically Important Tree Species

1.6.1 Acacias

Some 1000 species of *Acacia* trees and shrubs are found primarily in Africa, Australia and South America. In many cases the pinnate leaves are accompanied by stipules that develop into thorns. In former days, the bark of the Australian Tanner's acacia was sold to tanners as mimosa bark. The small, ball to cylinder shaped flowers are usually white or yellow, sometimes red. They may form grape shaped or wheat ear shaped bunches. The Australian species are called wattles; they do not have thorns, the seeds need fire for germinating.

Some 90 percent of Gum Arabic or Acacia gum (see chapter 7) are obtained from *Acacia arabica* and other, small species that grow wild in Central and Northern Africa. *Acacia arabica* is also the source of fruit-shells containing tannins; they go by the name of Indian galls. The Umbrella acacias are characteristic for the image of African tree steppes. In former days, the Asian catechu-acacias were the source of the tanning agent catechu (see chapter 8). The ancient Egyptians used Acacia wood for making sarcophagi and statues of

gods. *Acacia homalophylla* is the source of the fragrant Australian myall wood while the dark wood of *Acacia melanoxylon* (blackwood) is used for furniture; it can be nicely polished. Other good timber trees are *Acacia kea* from the Hawaiian Islands and *Acacia heterophylla* from Réunion Island.

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1.6.2 Alder

The alder (*Alnus*) belongs to the birch family (Betulaceae); there are 35 alder species, they are found throughout the North Temperate Zone, i.e. most of Europe, southwest Asia and northern Africa. It has been introduced to North America, South Africa, Australia and New Zealand. A few species extend into Central America and the Andes. The major European species is the black alder (*Alnus glutinosa*) that often has several trunks growing from the same root; it can be up to 30 meters tall. It is characterized by a dark, deeply cracked bark, up to 10 cm long leaves and small, black, cone-like fruit. It grows mostly in peatbogs and swaps. The gray alder (*Alnus incana*) reaches 20 meters and prefers moist mountain locations; its bark is light gray.

Alder trees bear both male and female flowers; the reddish male catkins are up to 10 cm long while the female flowers are upright and much smaller. The fruit resemble conifer cones; they scatter their winged seeds in the spring. Pockets of air allow them to float in water for a full month. Alder wood rates as being quite soft, it is mostly used for paper pulp and fibreboard. However, thanks to its high tannin contents, it is extremely durable in water and lasts many centuries. This is why the piling for the buildings in Venice and several French cathedrals was made of alder trunks.

The roots of the tree live symbiotically with nitrogen-fixing bacteria (*Frankia alni*); this is why it flourishes even in poor soils, humid biotopes and on riverbanks. Alders are pioneer plants: they are first to grow on totally bare soil after the passage of an avalanche. The bark of the tree and its twigs contain up to 20 percent tannic acid that was formerly used by tanners.

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1.6.3 Ash

The genus *Fraxinus* to which the ashes belong is part of the Oleaceae family that also includes the olive tree and the lilac. Anywhere between 45 and 65 species are known in the temperate and subtropical climate zones in Europe, Asia and North America. The common ash (*Fraxinus excelsior*) is quite widespread in Europe, it preferably grows on low ground and in river valleys from Spain to Russia. It can reach a height of 40 meters and an age of 250 years, its bark is greenish gray and relatively smooth. The leaves are pinnate, with generally three to five opposed pairs of leaflets and a terminal leaflet. Most species shed their leaves in the fall, but a few subtropical species are evergreen. Male and female flowers grow on separate trees, the seeds are of the samara or helicopter type, which means that they autorotate and can be carried over considerable distances by the wind.

The European ash species suffer from the so-called ash-dieback that is caused by the fungus *Hymenoscyphus pseudoalbidus*. The disease seems to have originated in Poland and has spread all over Europe. It causes leaf loss and death of the tree-crowns. About 20 percent of the trees seem to be naturally resistant.

The white ash (*Fraxinus americana*) and the Green ash (*Fraxinus pennsylvanica*) electric guitars. In former days, ash wood was used for the construction of carriages, later on for pioneer-airplanes and cars. The British sports