18BBO43C- CORE PAPER – V ANATOMY, MICROTECHNIQUES AND WOOD TECHNOLOGY
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Unit – V
Wood Technology: Dendrochronology – Definition, growth rings; classification of wood - heart wood and soft wood; properties of wood - physical, chemical and mechanical; durability of wood - wood seasoning and preservation; commercial wood species of India (Teak and Rose Wood); composite wood: adhesive – types and uses; engineered wood – veneers, ply wood, MDF, particle board

Secondary Growth :

Primary growth produces growth in length and development of lateral appendages. Secondary growth is the formation of secondary tissues from lateral meristems. It increases the diameter of the stem. In woody plants, secondary tissues constitute the bulk of the plant. They take part in providing protection, support and conduction of water and nutrients.

Secondary tissues are formed by two types of lateral meristems, vascular cambium and cork cambium or phellogen. Vascular cambium produces secondary vascular tissues while phellogen forms periderm.

Secondary growth occurs in perennial gymnosperms and dicots such as trees and shrubs. It is also found in the woody stems of some herbs. In such cases, the secondary growth is equivalent to one annual ring, e.g., Sunflower.

A. Formation of Secondary Vascular Tissues:

They are formed by the vascular cambium. Vascular cambium is produced by two types of meristems, fascicular or intra-fascicular and inter-fascicular cambium. Intra-fascicular cambium is a primary meristem which occurs as strips in vascular bundles. Inter-fascicular cambium arises secondarily from the cells of medullary rays which occur at the level of intra-fascicular strips.

These two types of meristematic tissues get connected to form a ring of vascular cambium. Vascular cambium is truly single layered but appears to be a few layers (2-5) in thickness due to presence of its immediate derivatives. Cells of vascular cambium divide periclinally both on the outer and inner sides (bipolar divisions) to form secondary permanent tissues.

The cells of vascular cambium are of two types, elongated spindle-shaped fusiform initials and shorter isodiametric ray initials (Fig. 6.29). Both appear rectangular in T.S. Ray initials give rise to vascular rays.

Fusiform initials divide to form secondary phloem on the outer side and secondary xylem on the inner side (Fig. 6.28 B). With the formation of secondary xylem on the inner side, the vascular cambium moves gradually to the outside by adding new cells.

The phenomenon is called dilation. New ray cells are also added. They form additional rays every year (Fig. 6.28 D). The vascular cambium undergoes two types of divisions— additive (periclinal divisions for formation of secondary tissues) and multiplicative (anticlinal divisions for dilation).

Ray initials produce radial system (= horizontal or transverse system) while fusiform initials form axial system (= vertical system) of secondary vascular tissues.

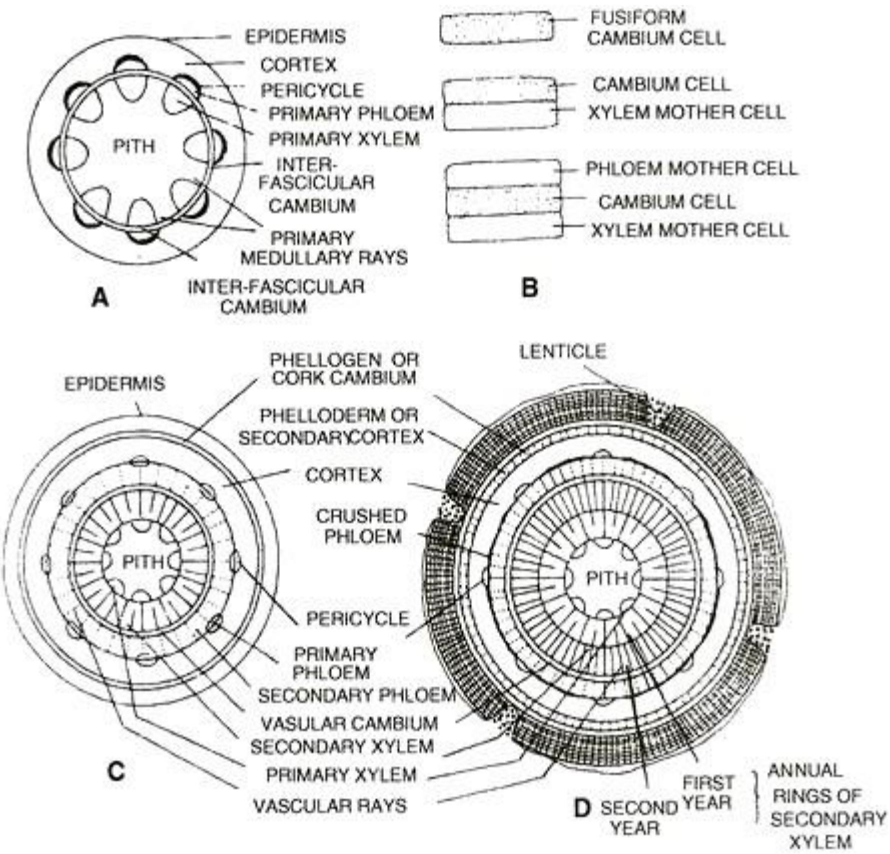

Fig. 6.28. A, complete ring of vascular cambium formed by strips of intrafascicular cambium and inter-fascicular cambium. B, formation of secondary vascular tissue mother cells; C, the beginning of secondary growth (mostly made up of secondary vascular tissues) of dicot stem (diagrammatic); D, two-year stage of secondary growth of a dicot stem.

1. Vascular Rays:

The vascular rays or secondary medullary rays are rows of radially arranged cells which are formed in the secondary vascular tissues. They are a few cells in height.

Depending upon their breadth, the vascular rays are uniseriate (one cell in breadth) or multiseriate (two or more cells in breadth). Vascular rays may be homo-cellular (having one type of cells) or hetero-cellular (with more than one type of cells). The cells of the vascular rays enclose intercellular spaces.

The part of the vascular ray present in the secondary xylem is called wood or xylem ray while the part present in the secondary phloem is known as phloem ray. The vascular rays conduct water and organic food and permit diffusion of gases in the radial direction. Besides, their cells store food.

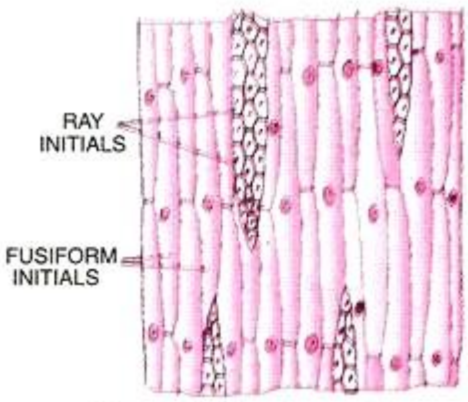

Fig. 6.29. L.S. Vascular cambium showing fusiform and ray initials.

2. Secondary Phloem (Bast):

It forms a narrow circle on the outer side of vascular cambium. Secondary phloem does not grow in thickness because the primary and the older secondary phloem present on the outer side gets crushed with the development of new functional phloem (Fig. 6.28 D). Therefore, rings (annual rings) are not produced in secondary phloem. The crushed or non-functioning phloem may, however, have fibres and sclereids.

Secondary phloem is made up of the same type of cells as are found in the primary phloem (metaphloem)— sieve tubes, companion cells, phloem fibres and phloem parenchyma.

Phloem pairenchyma is of two types— axial phloem parenchyma made up of longitudinally arranged cells and phloem ray parenchyma formed of radially arranged parenchyma cells that constitute the part of the vascular ray present in the phloem.

Elements of secondary phloem show a more regular arrangement. Sieve tubes are comparatively more numerous but are shorter and broader. Sclerenchyma fibres occur either in patches or bands. Sclereids are found in many cases. In such cases secondary phloem is differentiated into soft bast (secondary phloem without fibres) and hard bast (part of phloem with abundant fibres).

3. Secondary Xylem:

It forms the bulk of the stem and is commonly called wood. The secondary xylem consists of vessels, tracheids (both tracheary elements), wood fibres and wood parenchyma.

Wood parenchyma may contain tannins and crystals besides storing food. It is of two types—axial parenchyma cells arranged longitudinally and radial ray parenchyma cells arranged in radial or horizontal fashion. The latter is part of vascular ray present in secondary xylem.

Secondary xylem does not show distinction into protoxylem and meta-xylem elements. Therefore, vessels and tracheids with annular and spiral thickenings are absent. The tracheary elements of secondary xylem are similar to those of meta-xylem of the primary xylem with minor differences. They are comparatively shorter and more thick-walled. Pitted thickenings are more common. Fibres are abundant.

Width of secondary xylem grows with the age of the plant. The primary xylem persists as conical projection on its inner side. Pith may become narrow and ultimately get crushed. The yearly growth of secondary xylem is distinct in the areas which experience two seasons, one favourable spring or rainy season) and the other un-favourable (autumn, winter or dry summer).

In favourable season the temperature is optimum. There is a good sunshine and humidity. At this time the newly formed leaves produce hormones which stimulate cambial activity. The activity decreases and stops towards the approach of un-favourable season. Hence the annual or yearly growth appears in the form of distinct rings which are called annual rings (Fig. 6.30).

Annual rings are formed due to sequence of rapid growth (favourable season, e.g., spring), slow growth (before the onset of un-favourable period, e.g., autumn) and no growth (un-favourable season, e.g., winter). Annual rings are not distinct in tropical areas which do not have long dry periods.

Fig. 6.30. Part of T.S. old stem showing annual rings.

Annual Rings (Growth Rings).

It is the wood formed in a single year. It consists of two types of wood, spring wood and autumn wood (Fig. 6.31). The spring or early wood is much wider than the autumn or late wood. It is lighter in colour and of lower density. Spring wood consists of larger and wider xylem elements.

The autumn or late wood is dark coloured and of higher density. It contains compactly arranged smaller and narrower elements which have comparatively thicker walls. In autumn wood, tracheids and fibres are more abundant than those found in the spring wood.

The transition from spring to autumn wood in an annual ring is gradual but the transition from autumn wood to the spring wood of the next year is sudden. Therefore, each year's growth is quite distinct. The number of annual rings corresponds to the age of that part of the stem. (They can be counted by increment borer).

Besides giving the age of the plant, the annual rings also give some clue about the climatic conditions of the past through which the plant has passed. Dendrochronology is the science of counting and analysing annual growth rings of trees.

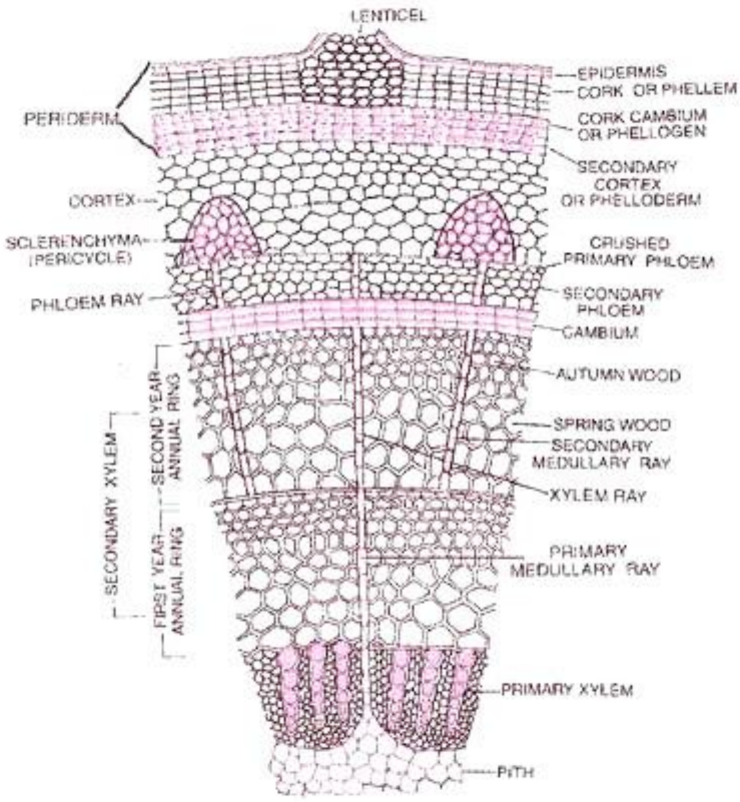

Fig. 6.31. Part of detailed structure of transverse section of two year old dicot stem showing secondary growth.

Softwood and Hardwood:

Softwood is the technical name of gymnosperm wood because it is devoid of vessels. Several of the softwoods are very easy to work with (e.g., Cedrus, Pinus species). However, all of them are not ‘soft’. The softness depends upon the content of fibres and vascular rays. 90-95% of wood is made of tracheids and fibres. Vascular rays constitute 5-10% of the wood.

Hardwood is the name of dicot wood which possesses abundant vessels. Due to the presence of vessels, the hardwoods are also called porous woods. In Cassia fistula and Dalbergia sisso the vessels are comparatively very broad in the spring wood while they are quite narrow in the autumn wood. Such a secondary xylem or wood is called ring porous.

In others (e.g., **Syzygium cumini**) larger sized vessels are distributed throughout spring wood and autumn wood. This type of secondary xylem or wood is known as diffuse porous. Ring porous wood is more advanced than diffuse porous wood as it provides for better translocation when the requirement of the plant is high.

Sapwood and Heartwood:

The wood of the older stems (*Dalbergia, Acacia*) gets differentiated into two zones, the outer light coloured and functional sapwood or alburnum and the inner darker and nonfunctional heartwood or duramen (Fig. 6.33). The tracheids and vessels of the heart wood get plugged by the in growth of the adjacent parenchyma cells into their cavities through the pits. These ingrowths are called tyloses (Fig. 6.32).

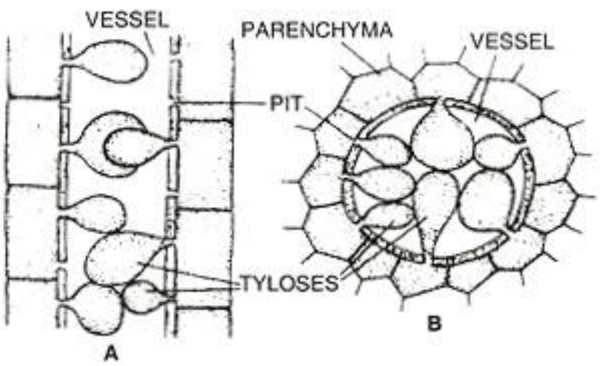

Fig. 6.32. Formation of tyloses in heartwood.
A, L.S. vessel showing tyloses.
B, T.S. vessel showing tyloses.

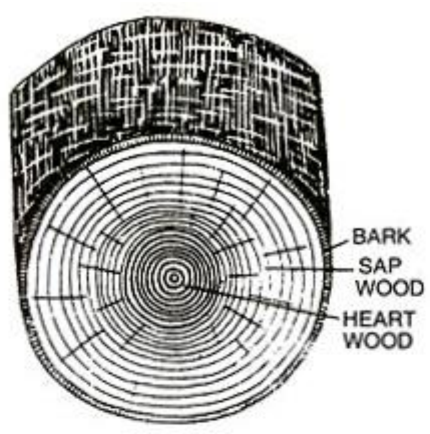

Fig. 6.33. Sapwood and heartwood in T.S. of trunk.

Ultimately, the parenchyma cells become lignified and dead. Various types of plant products like oils, resins, gums, aromatic substances, essential oils and tannins are deposited in the cells of the heartwood. These substances are collectively called extractives. They provide colour to the heartwood. They are also antiseptic. The heartwood is, therefore, stronger and more durable than the sapwood.

It is resistant to attack of insects and microbes. Heart wood is commercial source of Cutch (*Acacia catechu*), Haematoxylin (*Haematoxylon campechianum), Brasilin (Caesalpinia sappan) and Santalin (Pterocarpus santalinus*). Heartwood is, however, liable to be attacked by wood rotting fungi. Hollow tree trunks are due to their activity.

B. Formation of Periderm:

In order to provide for increase in girth and prevent harm on the rupturing of the outer ground tissues due to the formation of secondary vascular tissues, dicot stems produce a cork cambium or phellogen in the outer cortical cells. Rarely it may arise from the epidermis (e.g., Teak, Oleander), hypodermis (e.g., Pear) or phloem parenchyma.

Phellogen cells divide on both the outer side as well as the inner side (bipolar) to form secondary tissues. The secondary tissue produced on the inner side of the phellogen is parenchymatous or collenchymatous. It is called secondary cortex or phelloderm. Its cells show radial arrangement.

Phellogen produces cork or phellem on the outer side. It consists of dead and compactly arranged rectangular cells that possess suberised cell walls. The cork cells contain tannins. Hence, they appear brown or dark brown in colour. The cork cells of some plants are filled with air e.g., *Quercus suber* (Cork Oak or Bottle Cork). The phelloderm, phellogen and phellem together constitute the periderm (Fig. 6.34).

Cork prevents the loss of water by evaporation. It also protects the interior against entry of harmful micro-organisms, mechanical injury and extremes of temperature. Cork is light, compressible, nonreactive and sufficiently resistant to fire.

It is used as stopper for bottles, shock absorption and insulation. At places phellogen produces aerating pores instead of cork. These pores are called lenticels. Each lenticel is filled by a mass of somewhat loosely arranged suberised cells called complementary cells.

Lenticels:
Lenticels are aerating pores in the bark of plants. They appear on the surface of the bark as raised scars containing oval, rounded or oblong depressions (Fig. 6.34 A). They occur in woody trees but not in climbers. Normally they are formed in areas with underlying rays for facilitating gas exchange. Lenticels may occur scattered or form longitudinal rows.

A lenticel is commonly produced beneath a former stomata or stoma of the epidermis. Its margin is raised and is formed by surrounding cork cells. The lenticel is filled up by loosely arranged thin walled rounded and suberised (e.g., Prunus) or un-suberised cells called complementary cells (Fig. 6.34 B).

They enclose intercellular spaces for gaseous exchange. The complementary cells are formed from loosely arranged phellogen cells and division of sub-stomatal parenchyma cells. The suberised nature of complementary cells checks excessive evaporation of water.

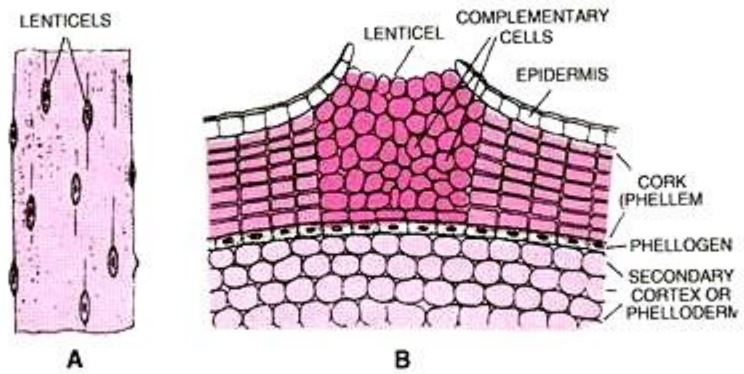

Fig. 6.34. Lenticels. A, external view of lenticels; B, T.S. lenticel.

In temperate plants the lenticels get closed during the winter by the formation of compactly arranged closing cells over the complementary cells.

Bark:
In common language and economic botany, all the dead cells lying outside phellogen are collectively called bark. The outer layers of the bark are being constantly peeled off on account of the formation of new secondary vascular tissues in the interior. The peeling of the

bark may occur in sheets (sheets or ring bark, e.g., Eucalyptus) or in irregular strips (scaly bark).

The scaly bark is formed when the phellogen arises in strips instead of rings, e.g., Acacia (vem. Kikar). Bark formed in early growing season is early or soft bark. The one formed towards end of growing season is late or hard bark.

Bark is insect repellent, decay proof, fire-proof and acts as a heat screen. Commercially it is employed in tanning (e.g., Acacia), drugs (e.g., *Cinchona*— quinine) or as spice (e.g., *Cannamon, vem. Dalchini)*. The cork of *Quercus suber* is employed in the manufacture of bottle stoppers, insulators, floats, sound proofing and linoleum.

Significance of Secondary Growth:

1. Secondary growth adds to the girth of the plant. It provides support to increasing weight of the aerial growth.

2. Secondary growth produces a corky bark around the tree trunk that protects the interior from abrasion, heat, cold and infection.

3. It adds new conducting tissues for replacing old non-functioning ones as well as for meeting increased demand for long distance transport of sap and organic nutrients.

Anomalous Secondary Growth:

It is abnormal type of secondary growth that occurs in some arborescent monocots (e.g., *Dracaena, Yucca, Agave*) and storage roots (e.g., *Beet, Sweet Potato*). In arborescent monocot stems, a secondary cambium grows in hypodermal region. The latter forms conjunctive tissue and patches of meristematic cells. The meristematic patches grow into secondary vascular bundles.

Anomalous vascular bundles also occur in cortex (cortical bundles, e.g., *Nyctanthes*) and pith (e.g., *Boerhaavia*). In storage roots (e.g., Beet), accessory cambial rings appear on the outside of endodermis. They produce less secondary xylem but more secondary phloem. The secondary phloem contains abundant storage parenchyma.

Importance of Secondary Growth:

1. It is a means of replacement of old non-functional tissues with new active tissues.

2. The plants showing secondary growth can grow and live longer as compared to other plants.

3. It provides a fire proof, insect proof and insulating cover around the older plant parts.

4. Commercial cork is a product of secondary growth. It is obtained from *Quercus suber* (Cork Oak).

5. Wood is a very important product of secondary growth. It represents secondary xylem.

The term wood is applied to the secondary xylem regions of gymnosperms and dicotyledonous species. Woods are usually classified in two main groups — the softwoods and the hardwoods. The term softwood is applied to gymnosperm wood, that of hardwood to the dicotyledon wood. The two kinds of wood show basic structural differences, but they are not necessarily distinct in degree of density and hardness.

The gymnospermous wood, particularly of conifers, is relatively simple in structure, simpler than that of most of the dicotyledons. One of its outstanding features is the lack of vessels. The tracheary elements are imperforate and are mainly tracheids. Fiber tracheids may occur in the late wood, but libriform fibers are absent.

The early wood tracheids have circular bordered pits with circular inner apertures. The latewood tracheids have somewhat reduced borders with oval inner apertures. Axial parenchyma may or may not be present, but resin ducts appear as a constant features of coniferous wood. The rays of conifers are mostly one cell wide, occasionally bi-seriate and from 1 to 20 or even to 50 cells high.

In contrary, the wood of dicotyledons is more varied than that of gymnosperms. The wood of the primitively vessel-less dicotyledons is relatively simple, but that of the vessel-containing species is usually complex. Wood of the latter species may have both vessels and tracheids, one or more categories of fibers, axial parenchyma and rays of one or more kinds.

The use of wood for purposes of identification requires a very sound knowledge of wood structure and factors modifying that structure. In general macroscopic, microscopic characteristics of woods along with odor and taste were considered for diagnostic purposes.

For microscopic study of wood three kinds of sectional views of the wood was considered, these include, T.S. view, R.L.S. view, T.L.S. view. Often maceration of wood tissues were also made for detailed diagnosis of the wood.

On the basis of several important diagnostic features the commercial woods may be identified to some extent.

The more important diagnostic features are mentioned here:

(i) Porous and Nonporous Woods:

The presence or absence, and the nature and arrangement of pores, serve as a ready means of classifying woods. The coniferous woods do not possess pores, and are known as nonporous woods, whereas the angiospermic woods possess numerous pores and are termed as porous woods. On the basis of the distribution of pores, the woods may be of two types—ring porous and diffuse porous woods.

In ring porous woods (e.g., ash, elm, oak, etc.) the pores are found to be arranged in concentric circles, the outer and inner portions of which differ with regard to the number and size of the pores. In diffuse porous woods (e.g., beech maple, walnut, etc.) the pores are small and ne

arly of the same size and are found to be scattered uniformly throughout the wood.

(ii) Early Wood and Late Wood:

In temperate regions, every year new wood is formed in a limited growing season, with the result definite growth layers develop, which shows two distinct areas within each layer.

The wood thus formed in the spring is called the spring wood or early wood, and that formed in winter is called the autumn wood or late wood. There is a sharp contrast between the late autumn wood and the early spring wood, and this makes the successive rings distinct.

The growth ring of a single year is called an annual ring and the number of these annual rings gives an indication of the age of tree. Annual rings of successive years may vary greatly in width. Wide rings are formed under favourable conditions of growth of the tree, and narrow ones are formed when conditions are unfavourable.

(iii) Sapwood and Heartwood:

The outer region of the wood which is of lighter colour is known as the sapwood, and this alone is used for conduction of water and salt solutions. The cells of this region are alive and physiologically active. In old trees the central region of the secondary wood is filled up with tannin and other substances which make it hard and durable.

This region is known as the heartwood. It looks black owing to the presence of tannins, oils, gums, resins, etc., in it. The vessels often become plugged with tyloses. The function of the heartwood is no longer conduction of water, but it simply gives mechanical support to the stem. The heartwood usually takes good polish and is used for cabinet work, furniture and other high grade wood-working industries.

(iv) Texture, Grain and Figure:
Texture refers to the relative size and quality of the various woods, while gram refers to their structural arrangement. Figure is applied to the design or pattern which appears on the surface of wood.

(v) Rays:
The rays are made of parenchyma cells that are oriented at right angles to the main axis of the stem. They vary greatly in width, height and arrangement.

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3. Mechanical Properties of Wood:
Wood possesses some important mechanical properties which either alone or in combination, determine its usefulness and suitability for various purposes. These properties may differ in different species. The mechanical properties enable the wood to resist various external forces which tend to change its shape and size and produce deformations.

The important mechanical properties of wood are mentioned here.
A. Strength:
The strength is restricted to the ability to resist certain definite forces which may be termed—crushing strength, tensile strength, shearing strength and cross-breaking strength.

They are as follows:

(i) Crushing Strength:
It is the resistance offered to forces that tend to crush wood.

(ii) Tensile Strength:
It is the resistance to forces that tend to pull wood apart.

(iii) Shearing Strength:
It is resistance to those forces which tend to make the fibres slide past one another.

(iv) Cross-Breaking Strength:
This is the resistance to forces which cause the beams to break, and all the above-mentioned forces are involved.

The strength of wood is the most important property in determining the value of any species for structural purposes. It is a very variable property, and is influenced by the density of the wood, the moisture content, the presence of defects and many other factors.

Suitability figures for eight different properties have been calculated by taking into consideration the various strength functions of both green and seasoned timber as shown in the table.

Suitability	*Strength and other properties of wood*
1. **Weight**	Specific gravity based on weight oven dry and the volume of seasoned timber (approximately 12%) moisture content.
2. **Strength as a beam**	Modulus of rupture and fibre stress as the elastic limit in static bending. Fibre stress at the elastic limit in impact bending.
3. **Stiffiness as a beam**	Modulus of elasticity in static bending. Modulus of elasticity in impact bending.

Suitability	*Strength and other properties of wood*
4. **Suitability as a post**	Maximum crushing strength and strength at the elastic limit in compression parallel to grain. Modulus of elasticity in static bending.
5. **Shock-resisting ability**	Work to maximum load and total work in static bending.
6. **Retention of shape**	Shrinkage green to oven dry in volume and in the radial and tangential directions.
7. **Shear**	Shearing strength in the radial and tangential directions.
8. **Hardness**	Fibre stress at the elastic limit in compression perpendicular to the grain. Radial, tangential and end hardness.

B. Stiffness:
It is the measure of the ability of wood to resist forces that tend to change its shape.

C. Toughness:
It is referred to the ability of wood to absorb a large amount of energy, and so resist repeated, sudden sharp blows or shock.

D. Hardness:
It is the measure of the power of wood to resist indentations, abrasion and wear.

E. Cleavability:
It is an expression of the ease with which wood can be split.

Structure and Utility of Wood:

Sapwood white and small; the heartwood when cut green, has a pleasant and strong aromatic fragrance and a beautiful dark golden yellow colour, which on seasoning soon darkens into brown, mottled with darker streaks. The timber retains its fragrance to a great age, the characteristic odour being apparent whenever a fresh cut is made.

It is moderately hard, exceedingly durable and strong, does not split, crack, warp, shrink or alter its shape when once seasoned; it works easily, takes a good polish.

Teak owes its chief value to its great durability, which is ascribed, probably with justice, to the circumstance that it contains a large quantity of fluid resinous matter which fills up the pores and resists the action of water. (At the Karli caves near Poona the teak-wood-work, two thousand years old, seems perfectly good at the present day).

The many uses of teak are well known. In India it is highly prized for construction, ship building, and for making sleepers and furniture.

Wood is very durable and resistant to fungi. It is used for poles, beams, trusses, columns, roofs, doors, window frames, flooring, planking, panelling, stair cases, and other constructional work. It is one of the best timbers for furniture and cabinet making, wagons and railway carriages.

Due to its better shape-retention ability, teak is popular in marine constructions and is a class by itself for boat and ship-building, particularly for decking. On account of its resistance to chemicals, teak articles are used in chemical industries and for making laboratory bench-tops; suitable for casks and vats for shipping corrosive liquids and for storing vegetable oils, fruit syrups, chutneys, etc.

Teak is employed for sound-boards of musical instruments, keys, etc., and for different grades of plywood. Wood waste in the form of wood-shavings and sawdust is used for chip-boards, fibre-boards and plastic-boards.

Chemical composition

Look at some freshly cut wood under a microscope and you'll see it's made up of cells, like any other plant. The cells are made of three substances called **cellulose** (about 50 percent), **lignin** (which makes up a fifth to a quarter of hardwoods but a quarter to a third of softwoods), and **hemicellulose** (the remainder). Broadly speaking, cellulose is the fibrous bulk of a tree, while lignin is the adhesive that holds the fibers together.

The inner structure of a tree makes wood what it is—what it looks like, how it behaves, and what we can use it for. There are actually hundreds of different species of trees, so making generalizations about something called "wood" isn't always that helpful: balsa wood is different from oak, which isn't quite the same as hazel, which is different again from walnut. Having said that, different types of wood have more in common with one another than with, say, metals, ceramics, and plastics.

Strength

Physically, wood is strong and stiff but, compared to a material like steel, it's also light and flexible. It has another interesting property too. Metals, plastics, and ceramics tend to have a fairly uniform inner structure and that makes them **isotropic**: they behave exactly the same way in all directions. Wood is different due to its annual-ring-and-grain structure. You can usually bend and snap a small, dead, tree branch with your bare hands, but you'll find it almost impossible to stretch or compress the same branch if you try pulling or pushing it in the opposite direction. The same holds when you're cutting wood. If you've ever chopped wood with an axe, you'll know it splits really easily if you slice with the blade along the grain, but it's much harder to chop the opposite way (through the grain). We say wood is **anisotropic**, which means a lump of wood has different properties in different directions.

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That's not just important to someone chopping away in the woodshed: it also matters when you're using wood in construction. Traditional wooden buildings are supported by huge vertical poles that transmit forces down into the ground along their length, parallel to the grain. That's a good way to use wood because it generally has high **compressive strength** (resistance to squeezing) when you load it in the same direction as the grain. Wooden poles are much weaker placed horizontally; they need plenty of support to stop them bending and snapping. That's because they have lower **tensile strength** (resistance to bending or pulling forces across the grain). Not all woods are the same, however. Oak has much higher tensile strength than many other woods, which is why it was traditionally used to make the heavy, horizontal beams in old buildings. Other factors such as how well seasoned (dry) a piece of wood is (as discussed below) and how dense it is also affect its strength.

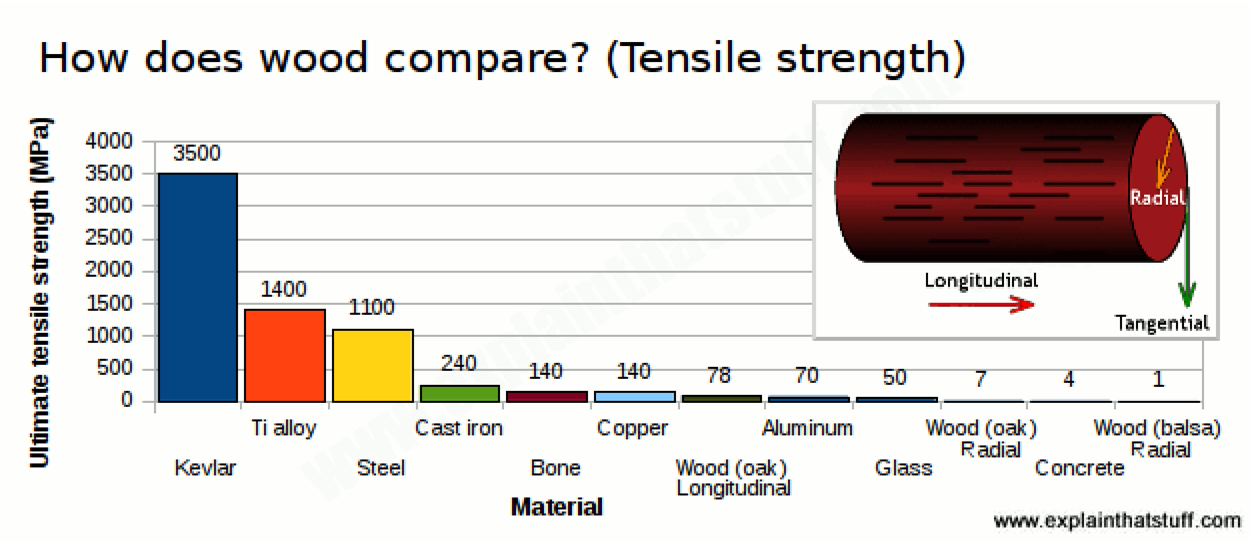

Chart: Wood can be very weak. In tension (for example, stretched horizontally in struts or beams), it's one of the weakest of all common materials. That's why it's more likely to be used in compression (in vertical beams), where it's very much stronger. (Concrete suffers from the same problem, which it's why it's often reinforced with steel.) All woods are different, and vary with atmospheric conditions, but typically they're 10–30 times stronger in the longitudinal direction than in the radial direction (see the inset picture of a tree trunk for an explanation of these terms).

Durability

One of the best things about wood is how long it lasts. Browsing through the daily news, you'll often read that archeologists have unearthed the buried remains of some ancient wooden article—a wooden tool, perhaps, or a simple rowboat or the remnants of a huge building—that are hundreds or even thousands of years old. Providing a wooden object is properly preserved (something else we discuss later), it will easily outlast the person who made it. But just like that person, a wooden object was once a *living* thing—and it's a natural material. Like other natural materials, it's subject to the natural forces of decay through a process known as **rotting**, in which organisms such as fungi and insects such as termites and beetles gradually nibble away the cellulose and lignin and reduce wood to dust and memories.

Photo: Under attack! The big problem with wood is that it's a natural material subject to attack from other natural things, notably fungi and insects. This is what Formosan subterranean termites can do to wood. Photo by Scott Bauer courtesy of US Department of Agriculture/Agricultural Research Service.

Wood and water

Wood has many other interesting characteristics. It's **hygroscopic**, which means that, just like a sponge, it absorbs water and swells up in damp conditions, giving out the water again when the air dries and the temperature rises. If, like mine, your home has wooden windows, you'll probably notice that they open much more easily in summer than in winter, when the damp outdoor conditions make them swell into the frames (not necessarily such a bad thing, since it helps to keep out the cold). Why does wood absorb water? Remember that the trunk of a tree is designed to carry water from the roots to the leaves: it's pretty much a water superhighway. A freshly cut piece of "green" wood typically contains a huge amount of hidden water, making it very difficult to burn as firewood without a great deal of smoking and spitting. Some kinds of wood can soak up several times their own weight of water, which is absorbed inside the wood by the very same structures that transported water from the roots of the tree to the leaves when the tree was a living, growing plant.

Wood and energy

What other properties does wood have? It's a relatively good heat insulator (which comes in handy in building construction), but dry wood does burn quite easily and produces a great deal of heat energy if you heat it up beyond its ignition temperature (the point at which it catches fire, anywhere from around 200–400°C, 400–750°F). Although wood can absorb sound very effectively (another useful property in buildings, where people value sound insulation shutting out their neighbors), wooden objects can also be designed to transmit and amplify sounds—that's how musical instruments work. Wood is generally a poor conductor of electricity but, interestingly, it's piezoelectric (an electric charge will build up on wood if you squeeze it the right way).

Environmentally friendly

Wood was one of the first natural materials people learned to use, and it's never lost its popularity. These days, it's particularly prized for being a natural and environmentally friendly product. Forestry is a rare example of something that has the potential to be completely **sustainable**: in theory, if you plant a new tree for every old tree you cut down, you can go on using wood forever without damaging the planet. In practice, you need to replace like with like and forestry is not automatically sustainable, whatever papermakers like us to believe. A brand new tree has much less ecological value than a mature tree that's hundreds of years old so planting a thousand saplings may be no replacement for felling just a handful of ancient trees. Logging can be hugely environmentally damaging, whether it involves clearcutting a tropical rainforest or selectively felling mature trees in old-growth temperate woodland. Some of the processes and chemicals used in forestry and woodworking are also environmentally damaging; chlorine, used to bleach wood fibers to make paper, can cause water pollution in rivers, for example. But on the positive side, growing trees remove carbon dioxide from the atmosphere and planting more of them is one way to reduce the effects of climate change. Trees also provide important habitats for many other species and help to increase **biodiversity** (the wide range of living organisms on Earth). Practiced the right way, forestry is a good example of how people can live in perfect harmony with the planet.

Using wood

How does wood get from the tree to the roof of your house, your bookshelf, or the chair you're sitting on? It's a longer and more complex journey than you might think that takes in harvesting, seasoning, preserving and other treatment, and cutting. Here's a brief guide.

Harvesting

Photo: Chopping down a longleaf pine is only the start of the fun: now you've got to get it home preferably without damaging the rest of the forest in the process. That's where this skidder machine comes in, lifting up the logs with a hydraulic crane and dragging them away with a powerful diesel engine. Photo by Randy C. Murray courtesy of US Army.

Growing plants for food is called agriculture; growing trees for human use is **silviculture**—and the two things have a great deal in common. Wood is a plant crop that must be harvested just like any other, but the difference is how long trees take to grow, often many years or even decades. How wood is harvested depends on whether trees are growing in plantations (where there are hundreds or thousands of the same species, generally of similar age) or in mature forests (where there's a mixture of different species and trees of widely differing ages).

Planted trees may be grown according to a precise plan and **clear-cut** (the entire forest is felled) when they reach maturity. A drastic approach like that makes sense if the trees are a fast-growing species planted specifically for use as biomass fuel, for example. Individual trees can also be **selectively felled** from mixed forests and either dragged away by machine or animal or even (if it makes economic and environmental sense) hauled upward by helicopter, which avoids damaging other nearby trees. Sometimes trees have their bark and small branches removed in the forest before being hauled away to a lumber yard for further processing, though they can also be removed intact, with the entire processing done offsite. It all depends on the value of the tree, the growing conditions, how far away the lumber yard is, and how easy the tree is to transport. Another interesting form of forestry is called **coppicing**, which involves removing long, thin, low-growing branches from trees such as hazel and willow in a careful and respectful way that does no long-term damage.

Photo: These cottonwood trees might look too spindly for making poles or planks, but they'll not be used for either. They're part of a fast-growing plantation that produces biomass, a type of renewable energy burned in power plants. Biomass is better for the environment because the trees take in as much carbon dioxide when they grow as they give out when they're burned; leaving aside the energy wasted in harvesting and processing, a biomass plant produces no overall carbon dioxide emissions, unlike a traditional power plant fueled by oil or coal. Other "energy crops" include willow, poplar, and eucalyptus. Photo by Warren Gretz courtesy of US DOE/NREL (Department of Energy/National Renewable Energy Laboratory).

Seasoning

A freshly cut tree is a bit like a sponge that comes presoaked in water, so it has to be completely dried out or **seasoned** before it can be used. Dry wood is less likely to rot and decay, it's easier to treat with preservatives and paint, and it's much lighter and easier to transport (typically, half a freshly felled tree's weight may come from water trapped inside). Dry wood is also much stronger and easier to build with (it won't shrink so much) and if a tree is destined for burning as firewood (or an energy crop), it will burn more easily and give out more heat if it's properly dried first. Typically wood is dried either in the open air (which takes anything from a few months to a year) or, if speed is important, in vast heated ovens called kilns (which cuts the drying time to days or weeks). Seasoned wood is still not completely dry: its moisture content varies from about 5–20 percent, depending on the drying method and time.

Preserving and other treatment

In theory, wood might last forever if it weren't attacked by bugs and bacteria; preservatives can greatly extend its life by preventing rot. Different preservatives work in different ways. **Paint**, for example, works like an outer skin that stops fungi and insects penetrating the wood and eating it away, but sunlight and rain make paint crack and flake away, leaving the wood open to attack underneath. **Creosote** (another popular wood preservative) is a strong-smelling, oily brown liquid usually made from coal-tar. Unlike paint, it is a fungicide, insecticide, miticide, and sporicide: in other words, it works by stopping fungi, insects, mites, and spores from eating or growing in the wood.

Photo: A fence before (right) and after (left) treatment with wood preservative.

Different kinds of treatment help to protect and preserve wood in other ways. It's a great irony that wood can be used to build a fine home that will last many decades or burn to the ground in minutes. Wood is so plentiful and burns so well that it has long been one of the world's favorite fuels. That's why fire-protection treatment of wooden building products is so important. Typically, wood is treated with fire retardant chemicals that affect the way it burns if it catches fire, reducing the volatile gases that are given off so it burns more slowly and with greater difficulty.

Cutting

There's a big difference between a tree and the table it might become, even though both are made from exactly the same wood. That difference comes mainly from skillful cutting and woodworking. How much cutting a tree needs depends on the product that's being made. Something like a utility pole or a fence post is not much more than a tree stripped of its branches and heavily treated with preservatives; that's an example of what's called **roundwood**. Trees need a bit more work in the sawmill to turn them into **lumber**, **timber**, or **sawnwood** (the three names are often used interchangeably, though they can be used with more specific meanings). Flat pieces of wood can be made from trees by cutting logs in two different directions. If you cut planks with the saw running in lines parallel to the length of the trunk, you get **plainsawn** (sometimes called flatsawn) wood (with ovals or curves on the biggest flat surface of the wood); if you fell a tree, cut the trunk into quarters, then slice each quarter into parallel planks, you get **quartersawn** wood (with the grain running along the biggest flat surface in broadly parallel stripes).

Photo: Left/above: Plainsawn wood is parallel to the trunk, revealing the annual rings as curves or ovals. Right/below: Quartersawn wood is first quartered and then sawn, revealing a pattern of roughly parallel lines.

See how attractive those patterns look? Not surprisingly, wood that's destined for furniture and other decorative uses has to be cut much more thoughtfully and carefully with regard to what's called its **figure**. This is the way a particular tree is cut to show off the growth patterns it contains in the most attractive way in the final piece of wood. The figure can also depend on which part of a tree is used. Wood cut from near the stump of a tree will sometimes produce a more attractive figure than wood cut from higher up.

Other wood products

Photo: Particle board is made from offcuts of wood stuck together and coated with an attractive veneer or other surface layer (perhaps plastic or a laminate). This is what an Ikea Billy bookcase looks like if you peer round the back. You can see the veneer on the extreme left and a hardwood backing on the right.

Round wood and sawn wood are what you might call natural wood products, because they involve using cut pieces of tree more or less in raw form. There are many other ways of using trees that involve greater amounts of processing. Some woods are very rare and expensive, while others are cheap and plentiful, so a common technique is to apply an outer layer of expensive and attractive wood to a core of cheaper material. **Veneer** is a thin decorative layer applied to cheaper wood made by turning a log against a blade, much like peeling an apple. Using veneer means you can get an attractive wooden finish at much lower cost than by using a solid piece of expensive wood. **Plywood** is made by taking layers of wood (or plies) and gluing them together with an outer coating of veneer. Typically each ply is placed at 90 degrees to the one underneath so the grains alternate. That means a piece of plywood is usually much stronger than a piece of the natural wood from which it's made. **Laminated wood** is a weaker kind of plywood in which the grain of each layer runs in the same direction. **Particle board** (often called **chipboard**) is made by taking the waste chips, flakes, and sawdust from a mill and forcing it under high pressure, with glue, in a mold so it sticks together to make planks and panels. Low-cost and self-assembly furniture is often made this way. **Fiber-board** is similar, but made with wood-pulp fibers instead of wood chips and sawdust. **Hardboard** is a thin sheet of wood made from wood fibers in much the same way.

Not all wood products are immediately recognizable as such. A great deal of the paper and cardboard people use is made by turning cellulose from trees into a fibrous pulp, for example. Lignin (the other main chemical inside wood) also has many uses, including making plastics (such as the celluloid used in old-fashioned photographic film), paints, turpentine, and yeast products.

Commercial Wood Found in India:

I. Rosewood:

Dalbergia latifolia Roxb.; Eng. Indian rosewood; Vema. Kali Shisham; Sanskrit—shishapa; Bengali—sitsal, swetasal; Mamthi-Shisham, siswa', Gujarati—Shissam, kalaruk, Telugu—Cittegi, irgudu- Tamil—Itti, karundorviral, Kannada—todagatti, Malayalam—Itti, colavitti, Oriya—Sisua-, Trade—Indian Rosewood; Family—Papilionaceae.

A large deciduous or nearly evergreen tree with cylindrical, fairly straight bole and full rounded crown, found in the sub-Himalayan tract of Eastern Uttar Pradesh, Bihar, Orissa and central western and southern India. It attains its maximum development in the southern region of western ghats, where trees 130 ft. high up to 20 ft. in girth and 70 ft. clear bole are sometimes found. The minimum exploitable size is 6 ft. girth.

The sapwood is narrow and pale yellowish white in colour, often with a purple tinge. The heartwood ranges in colour from golden brown through shades of light rose, purple with darker streaks, to deep purple with rather distant, nearly black lines, darkening with age. It is fragrant, heavy, narrowly interlocked grained and medium coarse-textured. The timber is stronger and much harder than teak.

Indian rosewood ranks among the first wood for furniture and cabinet work. It is a valuable decorative wood suitable for carving and ornamental ply-boards and veneers. It is useful for pattern-making, calico printing blocks, mathematical instruments and screws.

It is also used for gun carriage wheels, ammunition boxes and army wagons, pulleys, handles, shelves, decorative carriage parts, temple chariots, boat knees, agricultural implements, combs, razor handles and brush backs. Carefully selected and manufactured Indian rosewood ply-boards satisfy aircraft specification.

II. Teak:

Tectona grandis Linn.; Eng. Teak; Hindi—Sagaun; Sanskrit—Saka; Bengali—Segun-, Marathi—sag, sagwan; Gujarati—Telugu—Adaviteeku, teeku; Tamil—Tekkumaram, tekku, Kannada—Jadi, sagwani, Malnyalam—Thekku, tekha; Onya—Singuru-, Assam—Chingjagu; Lepcha—Ripnyot, Family—Verbenaceae.

A large, deciduous tree, indigenous to both peninsulas of India. In Western India it does not extend far beyond the Mhye. In Central India it attains its northern most point in the Jhansi district, and from that point the line of its northern limit continues in a south-east direction to the Mahanadi river in Orissa.

It is found wild in Assam. It is, however, cultivated throughout Bengal, Assam and Sikkim, and in North-West India without difficulty as far as Saharanpur. The forests richest in large timber on the west side of the Peninsula are the Travancore, Anamally, Wynad, South-west Karanataka and North Kanara forests. In the centre of the Peninsula the Godavary forests are most compact and valuable.