Calif, Parks, 1929: "Driving through Wawona, famous living tunnel tree of Yosemite's Mariposa Grove" Keystone View Co., stereograph by Peabody, KU91759
Calif. Museum of Photography, UC/Riverside (909 787-4787)

Introduction of Wood

1) Wood may have an "image problem" for being low tech. Remember that the paper mill and board mills are very sophisticated. The worst property of wood is that it is common, so we feel comfortable → dangerous approach…

2) The fears of shortage of timber can be considerable

Introduction of Wood

- 2) De Havilland built the Mosquito bomber with wood. It was extremely successful. During WW II 7,781 bombers were built. Over 5,000 wooden gliders were built in England for the invasion of Normandy in 1944.

3) Recent bad jobs in condos have damaged the reputation of wood.

4) Wood was critical for Venice and San Francisco

Introduction of Wood

- 5) Wood is a survival. Example: wood coming out of the El Capitan

- 6) Wood is biodegradable, which may be good, however we are not into disposable houses, so we need to be careful preserving and protecting.

Introduction of Wood

- 7) Low energy to produce. The downside is that it requires more labor intensive during construction.

General Information

- Trees are the oldest of all living beings.
- In California pines are 4,000 – 5,000 old.

Classification

- Softwood:
- Conifers which may have scale-like (cedar wood) or needle-like leaves (pines)
- Hardwood:
- Broad leaf trees (oak)

Classification -- biological

- Angiosperm (from the Greek, angeion: vessel, sperma: seed).
- The seeds are inside the containers (fruits): hardwood

Classification

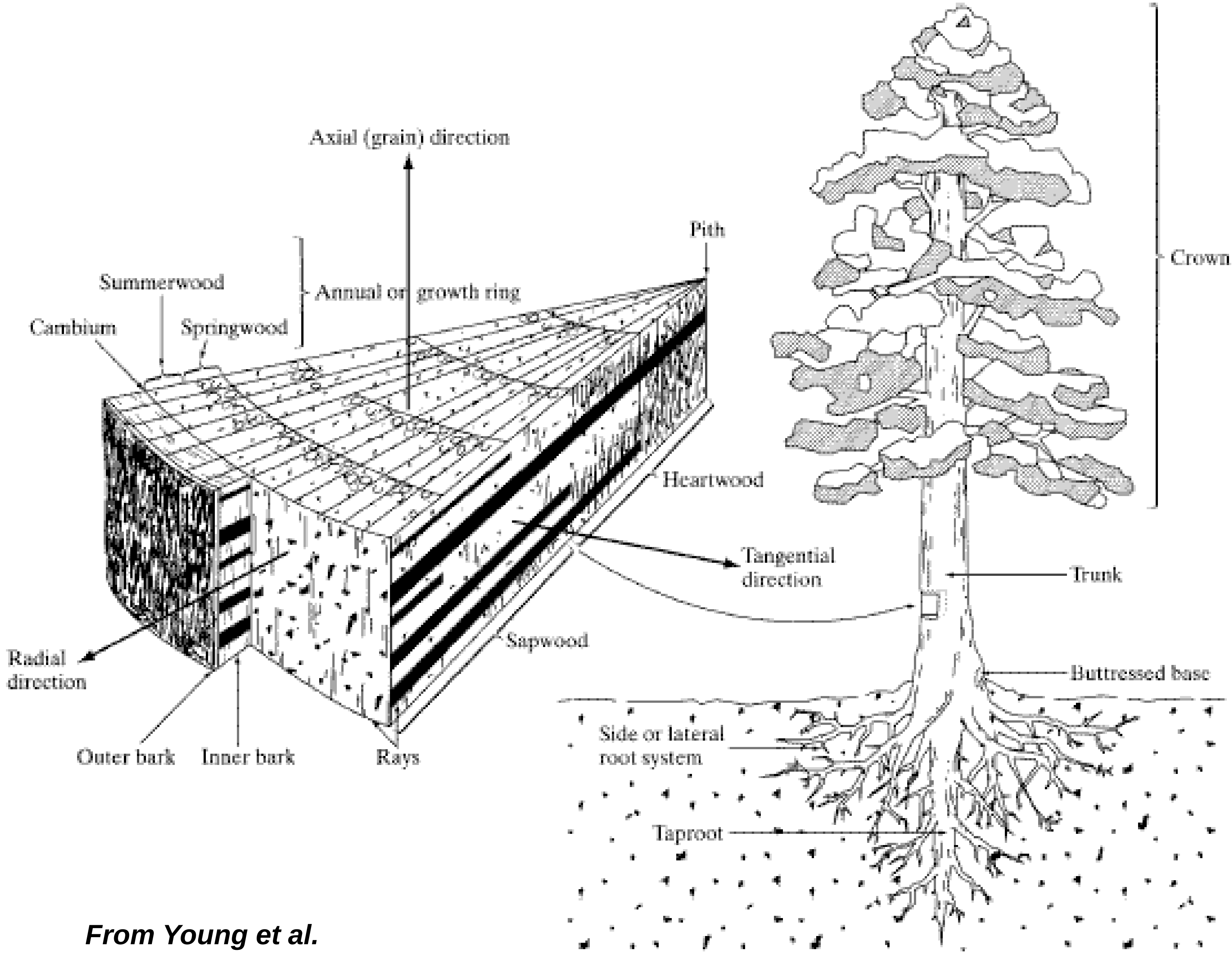
- Gynmosperms (from the Greek, gymmos: naked, sperm: seed).
- Seeds are in the open space of cones. Gynmosperms are more primitive than Angiosperms.
- They include all conifers: cedar, redwood, juniper, cypress, fir and pine, as well as the giant sequoias.
- Softwoods such as pine and fir are used for paper, lumber, plywood.

Definition of Directions in Wood

The shape of a tree stem closely resembles a long slender cone.

Many important features of wood can be traced back to the original tree from which it was cut.

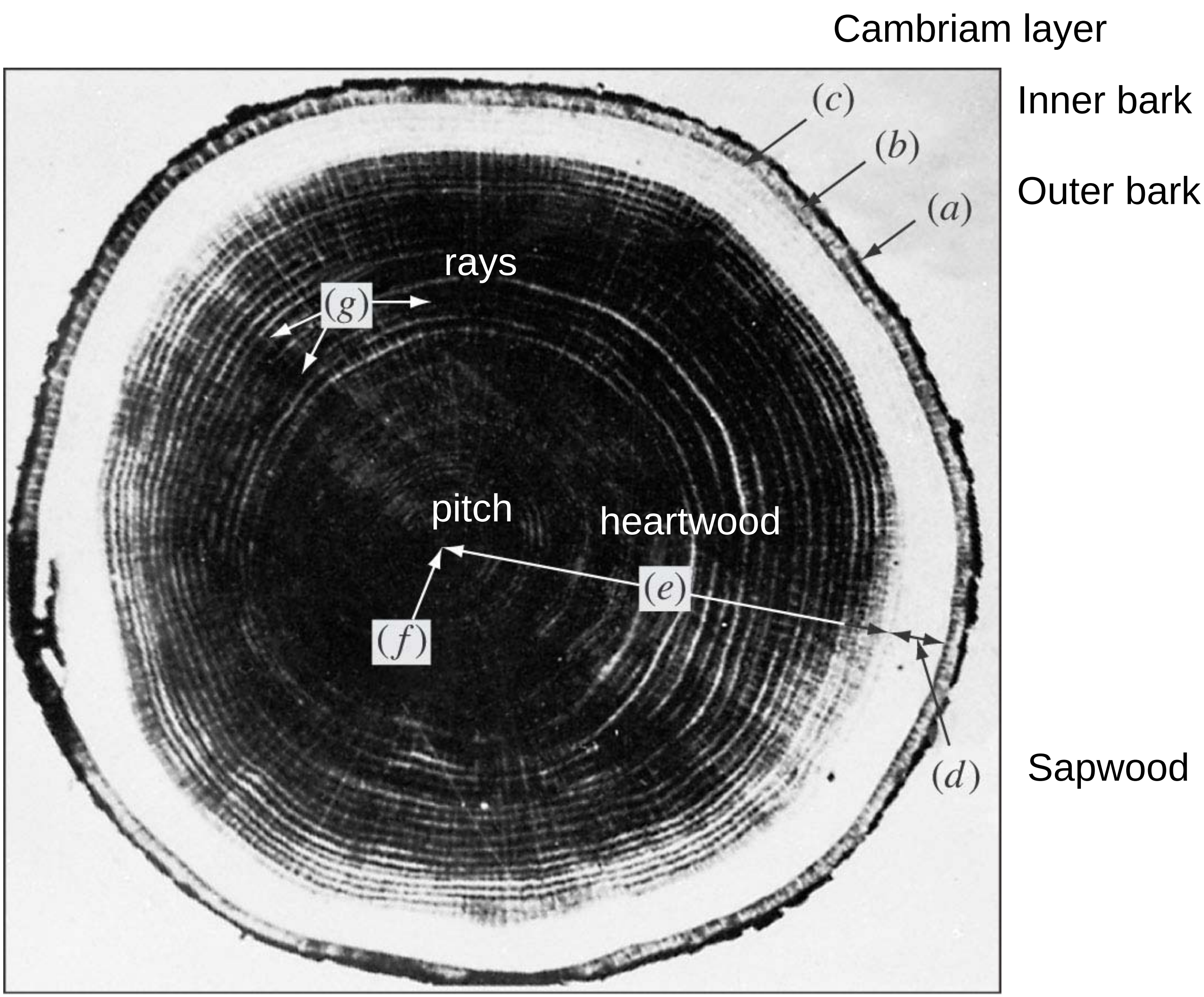
The schematic diagrams show some of these features. Make special note of the directions which are shown next.



From Young et al.

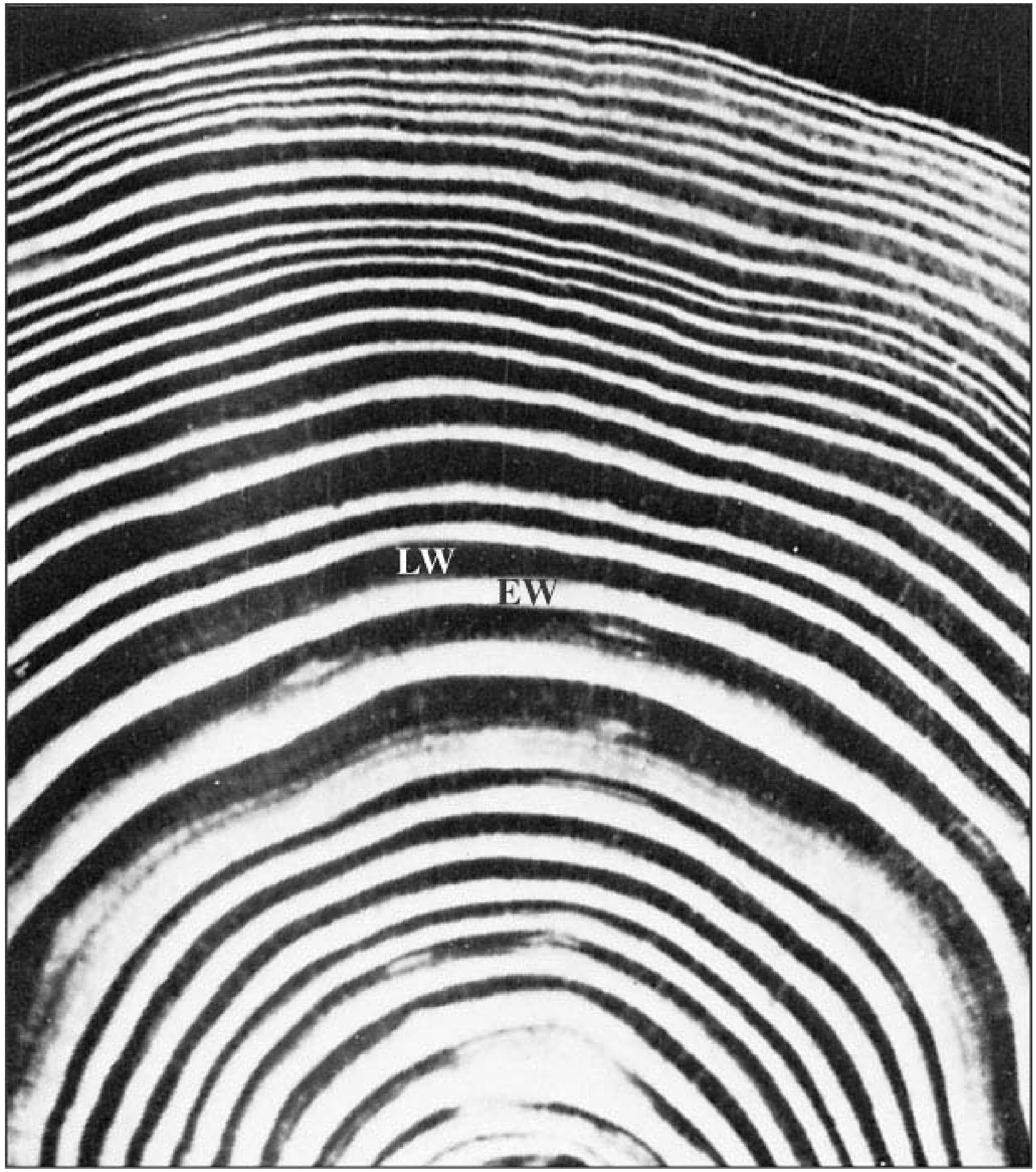
Definitions

- Sapwood conducts moisture, minerals, oxygen, and nitrogen.
- As the tree grows in diameter, the sapwood cells cease their conductive function and form the inactive heartwood.
- Mineral deposits, gums and resins in the heartwood gives a darker color than the sapwood.


Cambriam layer
Inner bark
Outer bark
(c)
(b)
(a)
rays
(g)
pitch
heartwood
(e)
(f)
(d)
Sapwood

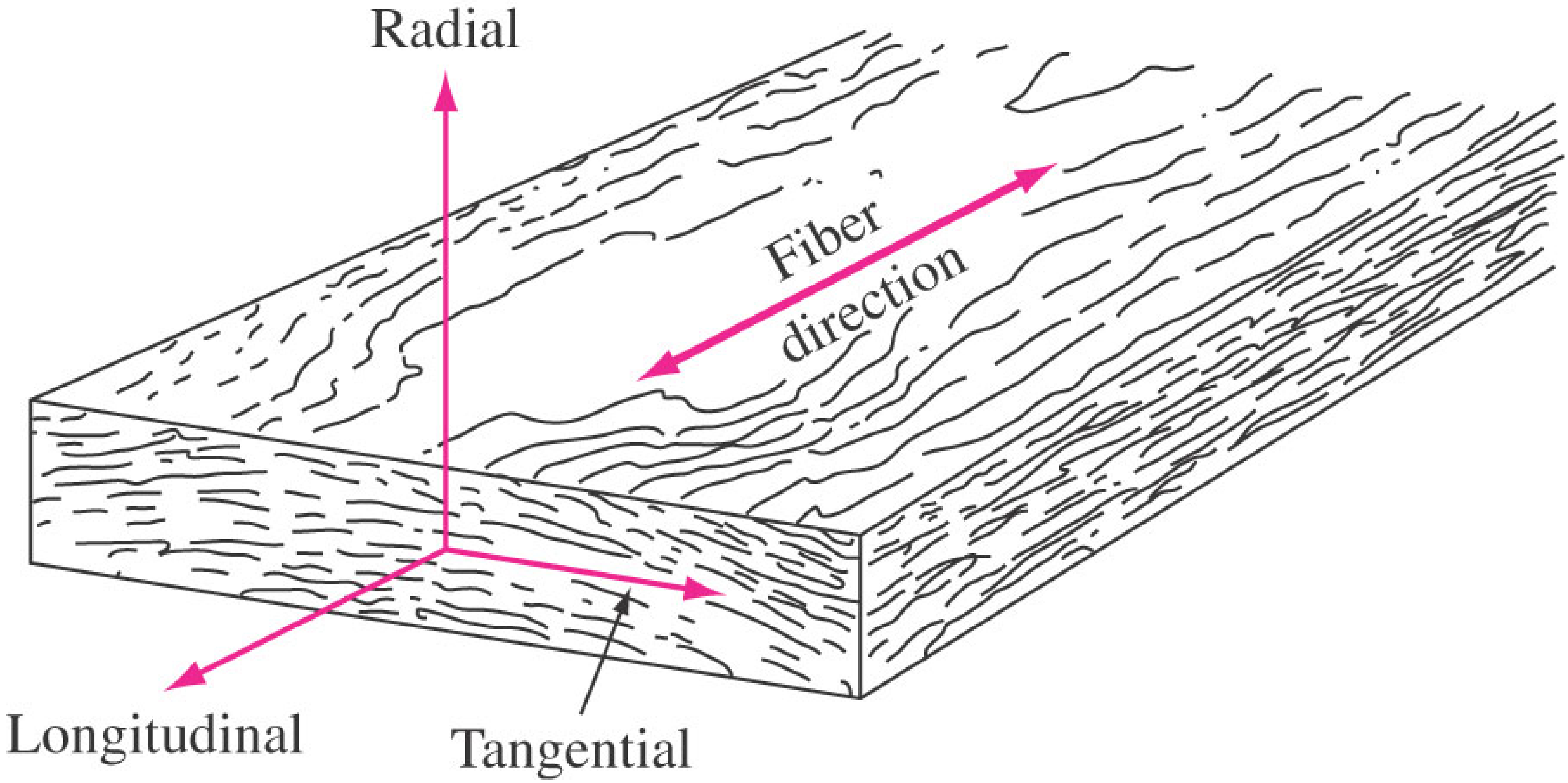
Late wood

Early wood



Directions of Wood

- Longitudinal direction: parallel to the long axis of the stem.
- Radial direction: perpendicular to both the growth rings and the long axis of the stem
- Tangential direction: tangent to the growth rings.



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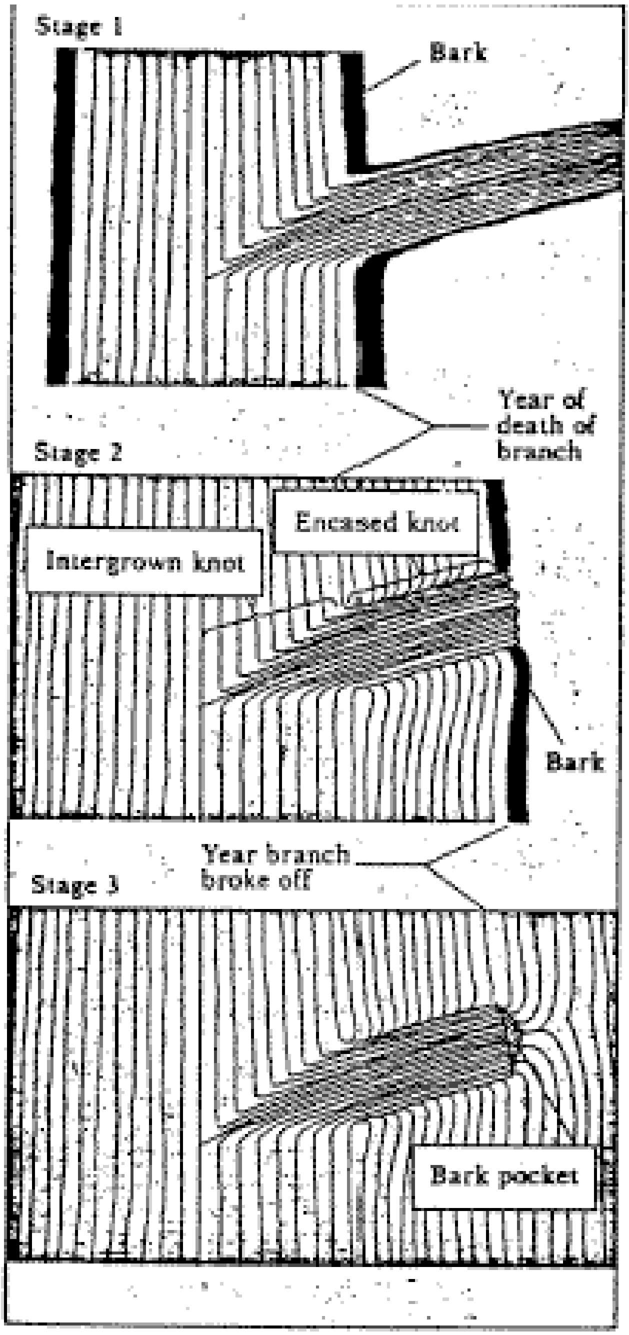
Growth

- A tree is dormant during the winter months and in the spring the cambrium layer forms thin-walled cells with large cavities (spring wood). In the summer months, cell walls increase in thickness and size of the cavities decrease forming annual growth rings.
- Question: Does it work in the Amazon?

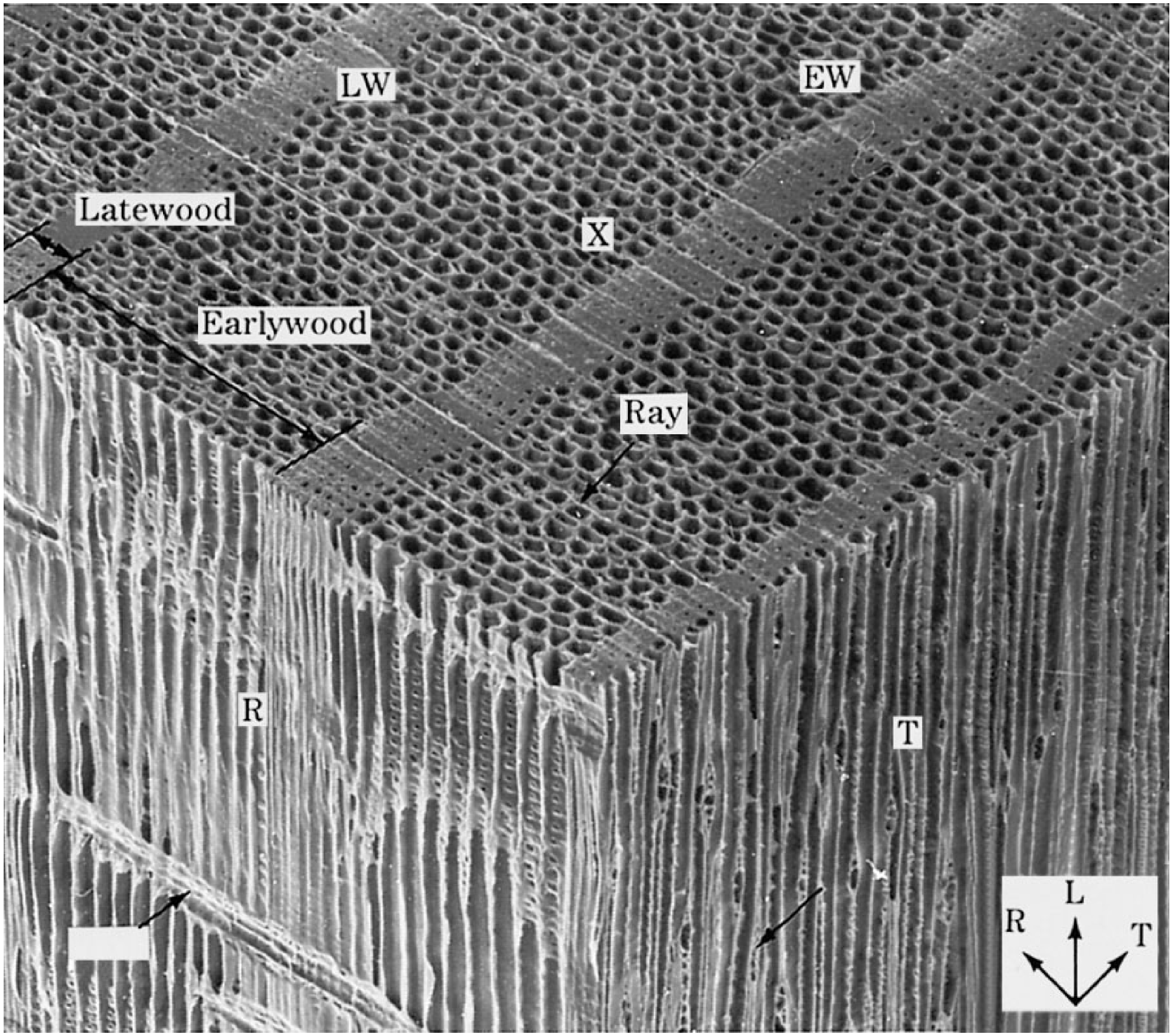
Wood Macrostructure



Microstructure of Softwoods

- A scanning electron micrograph of a softwood specimen is shown next.
- Softwoods consist mainly of long (3 to 5 mm) cells called tracheids which are about 20 to 80 x 10^{-6}m.

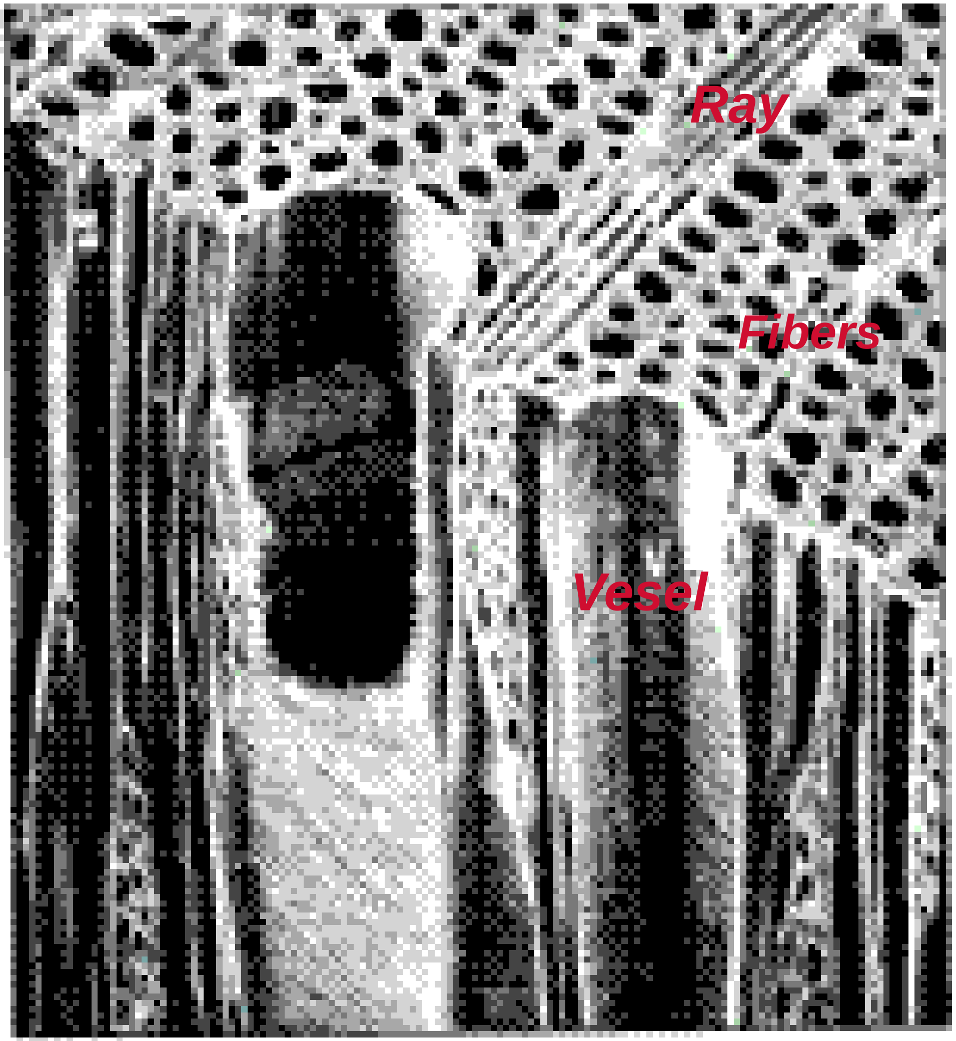
Softwood



Microstructure of Hardwoods

- Hardwoods consist mainly of two kinds of cells: *Wood Fibers* and *Vessel Elements*
  - Wood fibers are elongated cells which are similar to tracheids except they are smaller, only 0.7 to 3 mm long and less than 20 x 10^{-6}m in diameter, and they do not serve for fluid transport in the living tree.
  - The vessel elements do serve for fluid transport in the living tree, and they can have a wide range of sizes.
- A Scanning electron micrograph of a hardwood specimen shows a detail view of wood fibers (F), vessels (V), & rays (R).

Microstructure of Hardwoods



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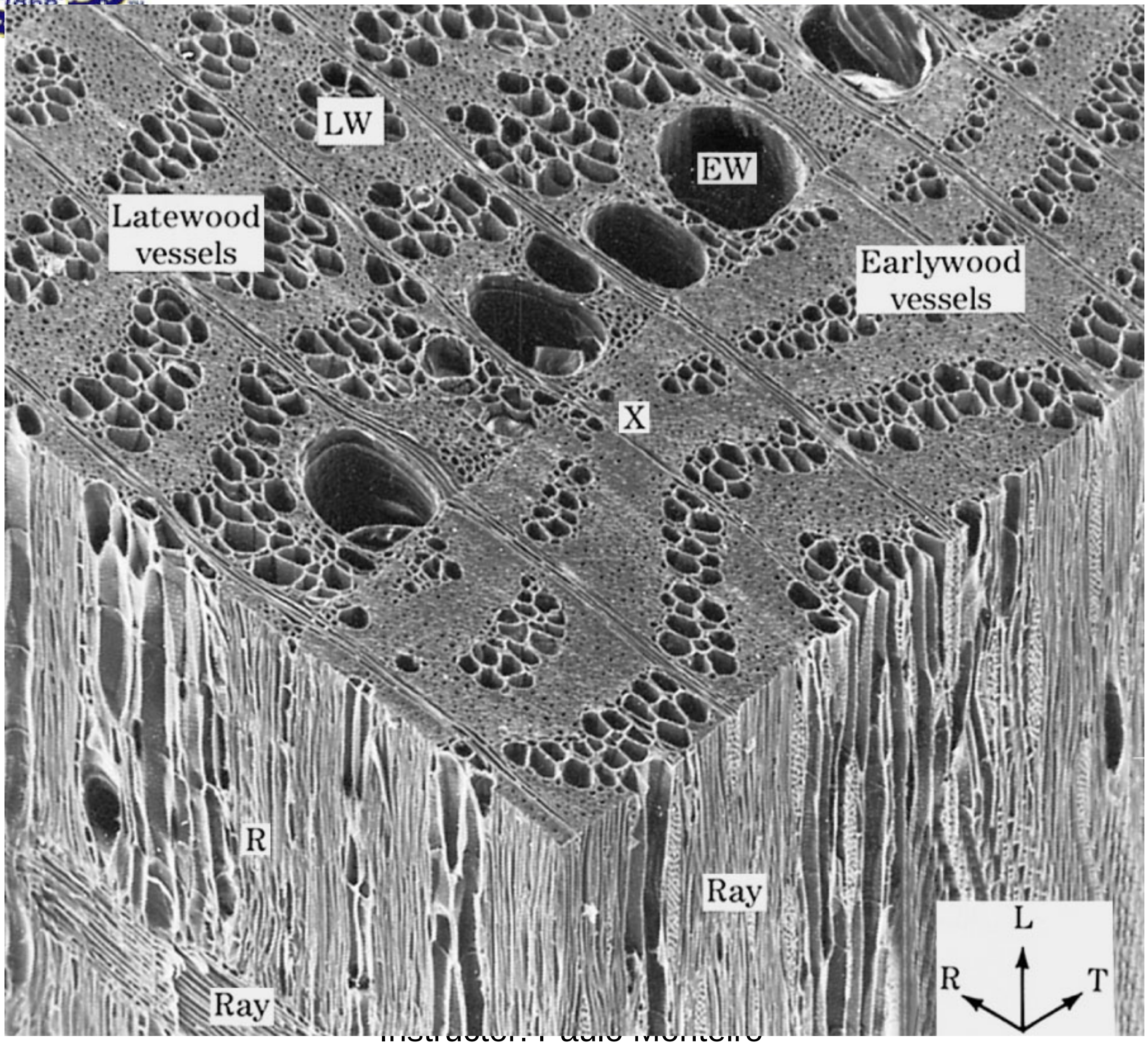
Porous Hardwood



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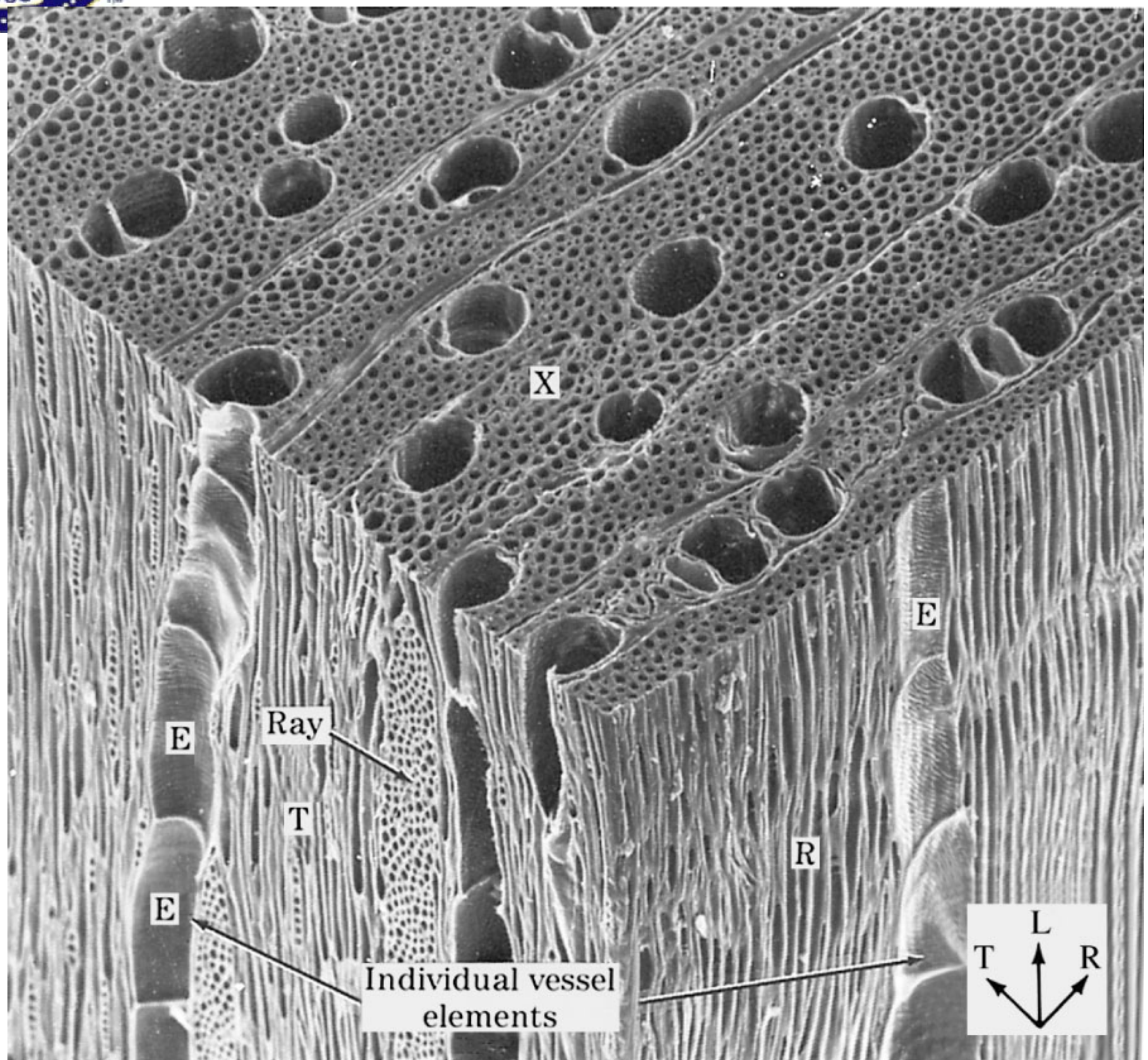
Diffuse Porous Hardwood



A Bundle of Straws Model for Wood

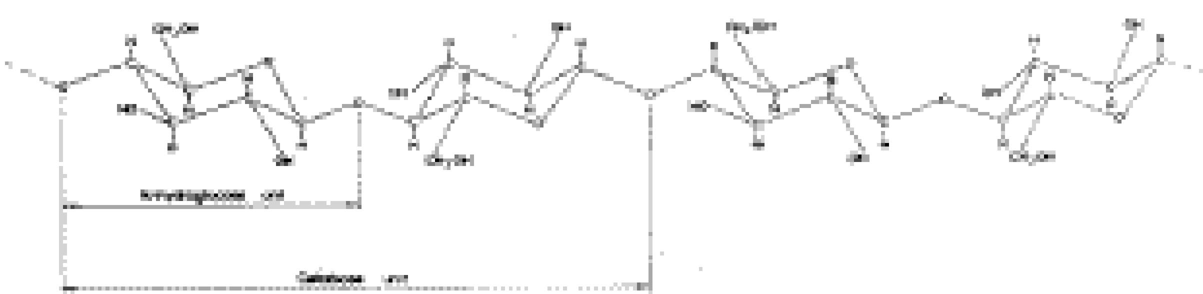
- Both hardwood and softwood can be viewed as a bundle of thin-walled tubes, (such as drinking straws)

Chemical Constituents of Wood

- Wood contains three major chemical constituents: cellulose, hemicellulose, & lignin.
  - Cellulose constitutes about 40 to 50% of wood & it is responsible for most wood properties.
  - Cellulose is a linear polymer with 5,000 to 10,000 mers in one molecule.
  - In wood cellulose forms bundles which are called "microfibrils".

The Crystal Structure of Cellulose

- Many of the important properties of wood are related to the crystalline nature of much of the cellulose in wood.
- Two unit cells of the crystal structure of cellulose are shown at the right.
- Notice that the flat molecules fit together in a regular fashion in their long chain direction parallel to each other. This is typical of other man-made polymers such as polyethylene & polypropylene.



Wood-Moisture Relations

- Moisture content: Wood is a hygroscopic material, i.e., it will absorb water vapor from the atmosphere.
- Moisture content in wood is expressed as a percentage of ovendry weight. A moisture content of 50% means that there are 50 parts of water to 100 parts of dry wood substance by weight.

Water in Wood

- Water may be held in wood in two ways: (1) *bound water*, & (2) *free water.*
- Bound water is held within the cell walls by adsorption force.
  - It is generally believed that bound water is not in the crystalline regions of the cell wall, but is adsorbed in the amorphous regions.
  - This has important implications for the volume changes associated with moisture changes.
- Free water is not held by any forces and is situated in the cell cavities know as *lumin*.

Fiber Saturation Point

- The moisture content at which the cell wall is saturated with bound water & at which no free water is present is called the *fiber saturation point*, (FSP).
- The FSP varies from species to species, but it averages about 28% moisture content.
- Addition or removal of water *below the FSP* has a pronounced effect on practically all wood properties.
- Addition or removal of water *above the FSP* has a almost no effect on any wood properties.

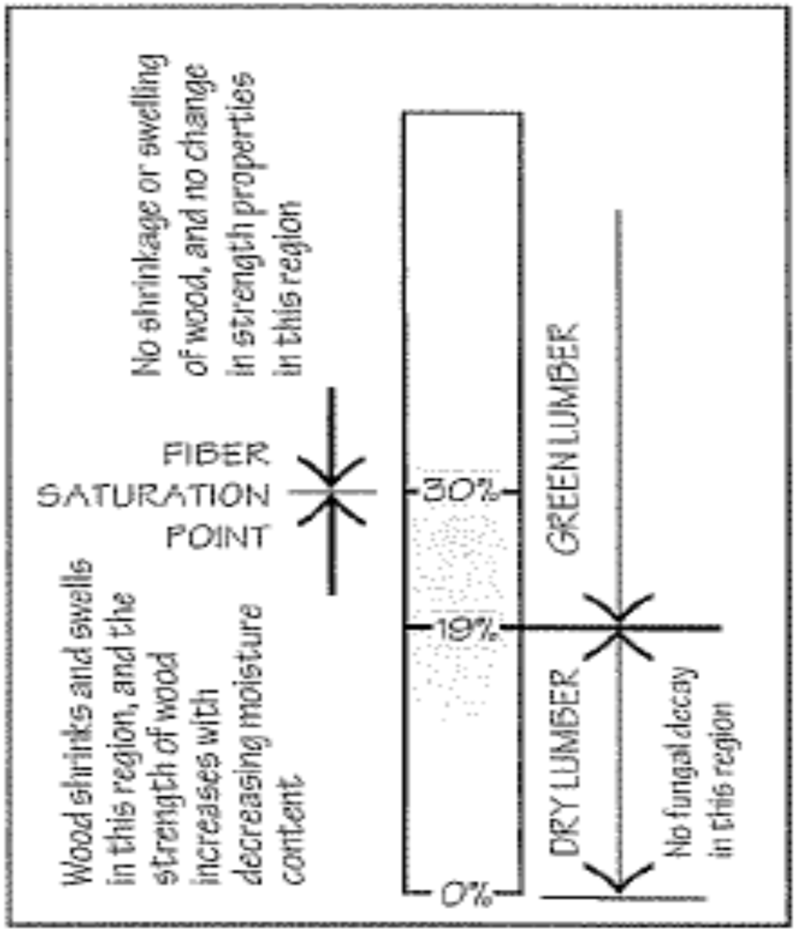
Shrinkage & Swelling of Wood

- The variation of shrinkage between different directions can be attributed to the microstructure of wood.
- The latewood cells dominate shrinkage since they absorb much more water and in the tangential direction there is an unbroken alignment of latewood.

Shrinkage & Distortion of Lumber

- The greater shrinkage in the tangential direction causes distortion in lumber with different orientations.

Green and Dry Lumber



- Green Lumber: moisture content greater than 19%
- Dry Lumber: moisture content less than 19%

Lumber Seasoning

- Air seasoning: lumber dries naturally. Piles of lumber are stacked in a way that air can circulate freely. The process can take months.
- Kiln seasoning: Warm air circulates through the pieces of lumber

Mechanical Properties of Wood

- The strength of wood is highly dependent upon direction:
  - Tensile strength values in longitudinal:radial:tangential directions on average are in the ratio of 20:1.5:1.
- The variation of strength between different directions can be attributed to the fine structure of the wood cells.

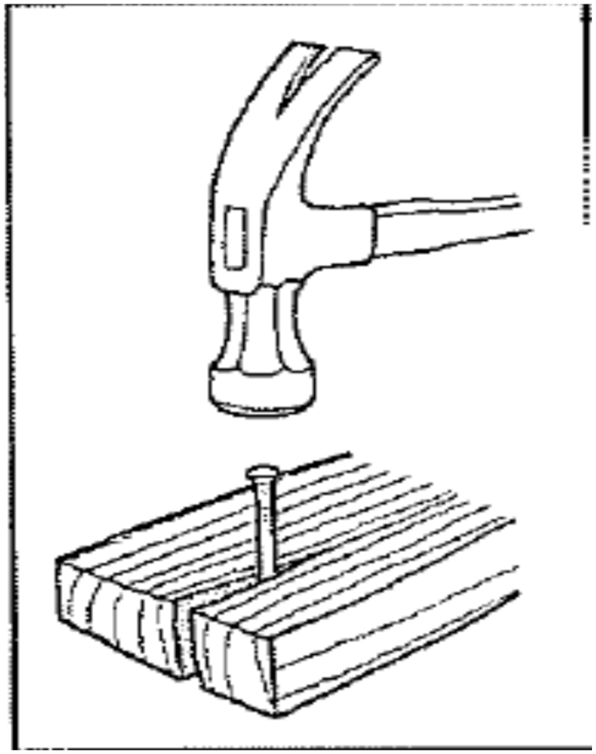
Effects of Moisture on the Strength of Wood

- The strength of wood is constant above the fiber saturation point.
- Below the fiber saturation the strength of wood increases with decreasing moisture content. This can be related to where the water is absorbed in the microstructure.

Comparison with other materials

material	E/density	Tensile/density	Compressive/d
wood	20-30	120-170	60-90
Mild steel	26	30	30
Aluminum	25	180	130
concrete	15	3	30

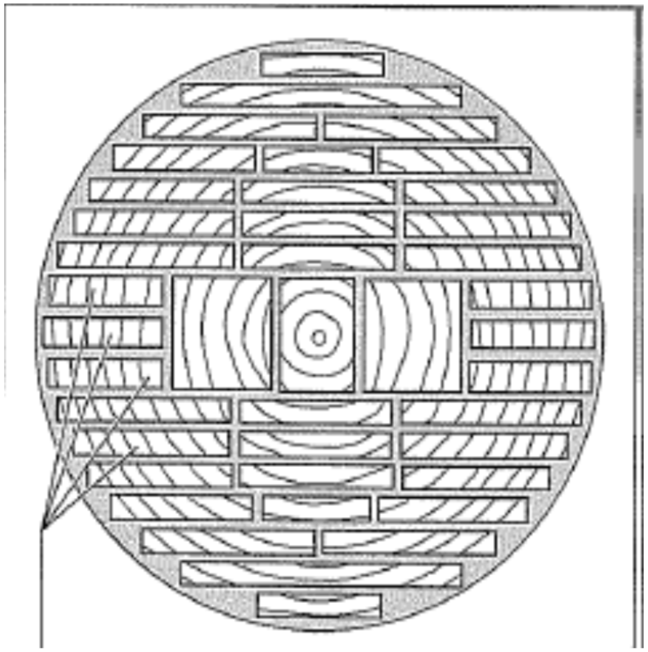
Mechanical Behavior



Nails close to the end splits lumber easily because of the weak bond between the fibers. (Image from Mehta et al.)

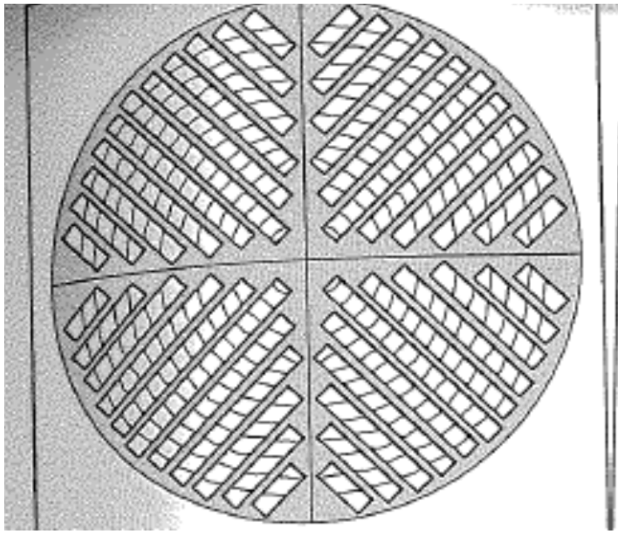
Sawing Lumber

- Flat (or plain) sawing



Sawing Lumber

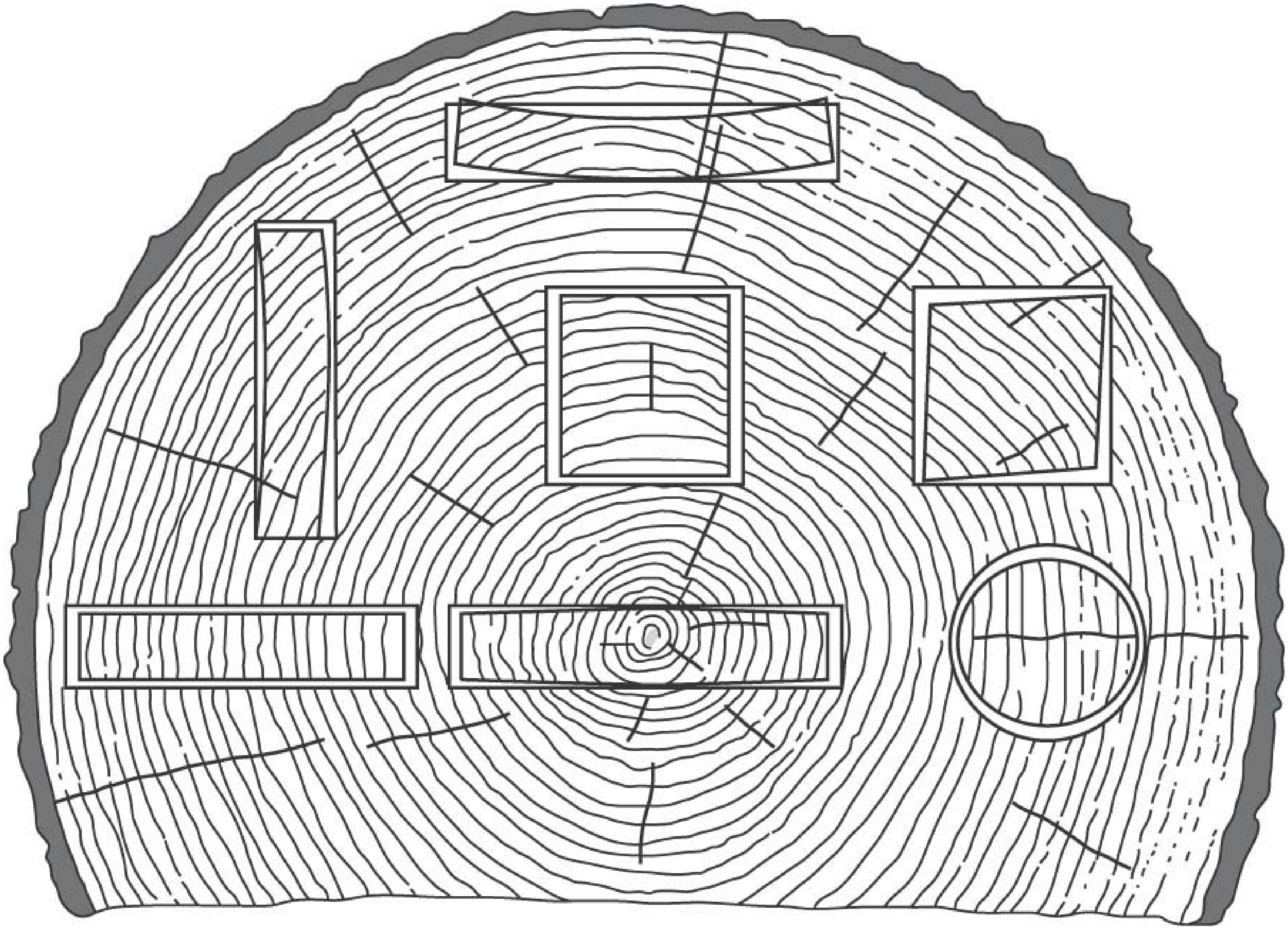
- Radial (quarter) sawing



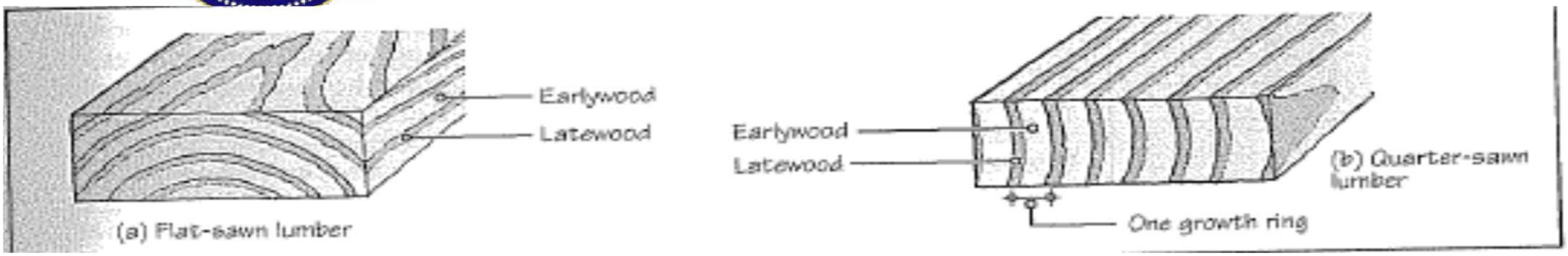
Processing-Related Defects

- Drying
- Warp
- Surface checks, end-splits
- Collapse
- Stain

Differences:



Reason



- Radial saw is more dimensionally stable.
- Radial saw has latewood more uniformly distribute so it has improved abrasion resistance.
- High-grade finish floors often require radial sawn lumber (from Mehta et al.)

Softwood Lumber Classification

- Board lumber: thickness less than 2 in
- Dimension lumber: Thickness 2in to 4in
- Timber: Thickness 5in or greater

Dimension Lumber

- Used in most structural application for buildings. Most popular sizes: 2x4, 2x6, 2x8, 2x10, and 2x12.
- Available in lengths of 8ft, 10 ft, 12 ft, etc. The maximum length is 28 ft.

Nominal and Actual Dimensions

- In North America, the cross section of a softwood is specified by its nominal dimensions.
- For instance a 2x4 lumber piece has a nominal dimension of 2in x 4in but an actual dimension of 1 ½ in x 3 ½ in

Nominal and actual sizes of lumber

Nominal size	Actual size (in)
1	3/4
2	1 ½
3	2 ½
4	3 ½
5	4 ½
6	5 ½
8	7 ¼
10	9 ¼
12	11 ¼

Board Foot Measure

- Softwood lumber is sold by volume.
- Unusual unit of volume: board foot (bd ft)
- One board foot is the volume of a 1inx1ftx1ft (ie, 1 ft^3 = 12 bd ft)

Glulam members

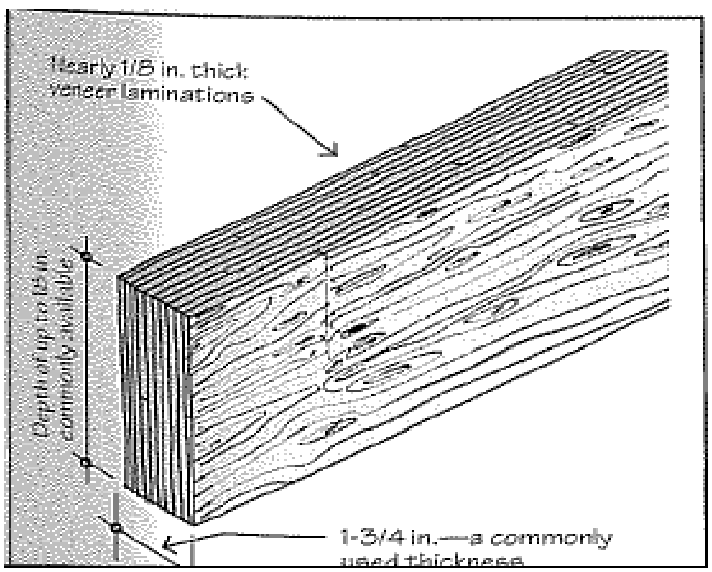
- Glue-laminated wood (glulam) is made from individual lengths of dimension lumber that are glued together to form a large cross section.

From:
http://www.apawood.org/pablog/index.cfm/2006/6/28/Glulam-comes-in-a-range-of-appearances

From:
http://www.lamwood.com/Glulam_Trusses_and_Decking.jpg

Structural Composite Lumber

- Laminated veneer lumber (LVL) is made by gluing together dried wood veneers.
- The grain runs in the same direction (note the difference with plywood where the veneers are cross grained.



From Mehta et al.

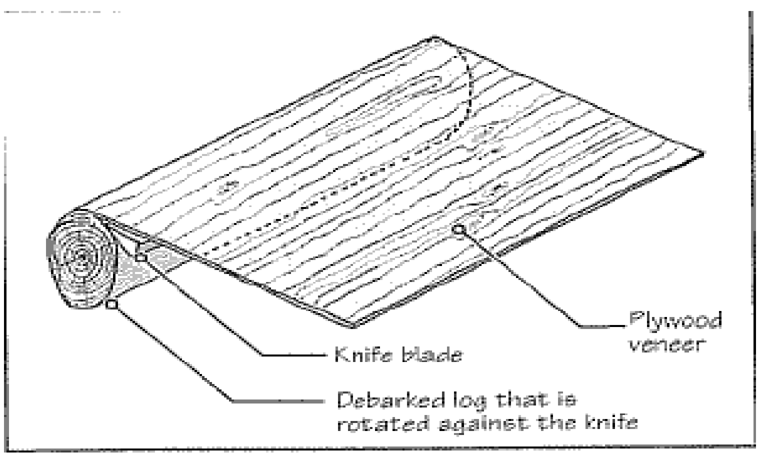
Laminated veneer lumber

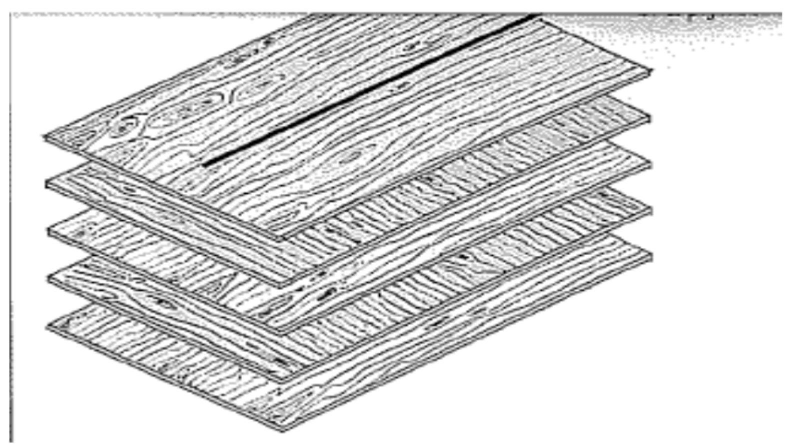
From:
http://www.plymart.com/default.aspx?id=137

From:
http://www.lowes.com/lowes/lkn?action=howTo&p=CommLib/englum.html

Plywood Panels

- Made by gluing wood veneers under heat and pressure.
- The veneers are glued such that the grain direction in each veneer is oriented at right angle to the grain of the next veneer





From: Mehta et al.

Oriented Strandboard Panels (OSB)

- Made with wood strands
- Alternate layers of strands are oriented at right angles to each other
- The several layers are glued under heat and pressure.
- Used only for structural applications (panels cannot be stained or painted). Also OSB panels cannot be treated with preservatives.

Oriented Strandboard Panels

From: http://www.cwc.ca/NR/rdonlyres/F6074ABC-2FD8-4CBE-A1DE-1AEE5197559E/0/OSB.pdf

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Non-structural panels

- Particle Board
- Hardboard
- Medium density siding
- Fiberboard
- Medium density fiber board
- Decorative plywood

BIOLOGICAL EFFECTS ON WOOD

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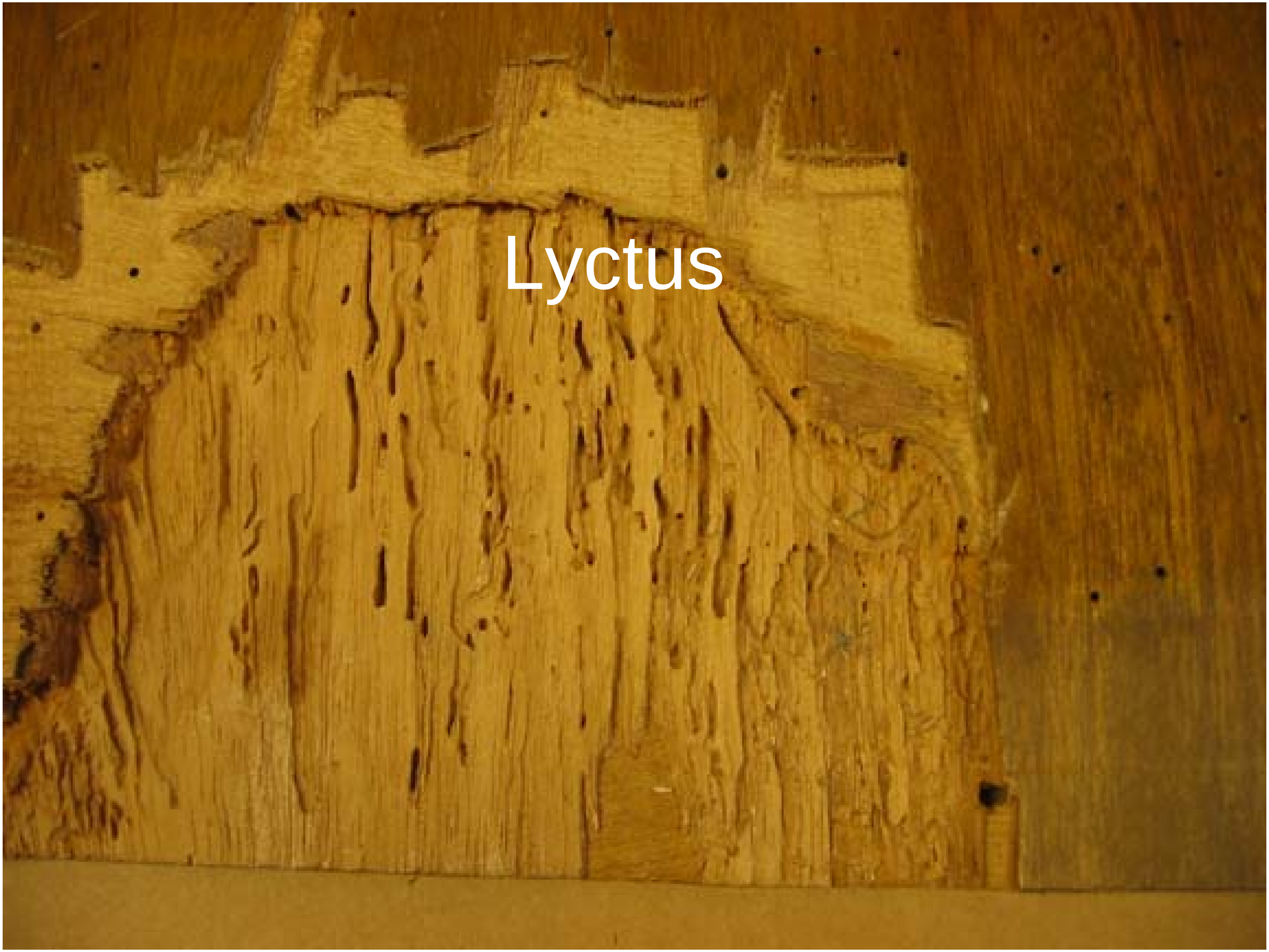
Instructor: Paulo Monteiro

Types of insects that cause deterioration of wood

carpenter ants,
beetles, and
termites

Carpenter ants prefer higher moisture content and softer wood that has begun to decay while powderpost beetles prefer low moisture content in both softwoods and hardwoods.

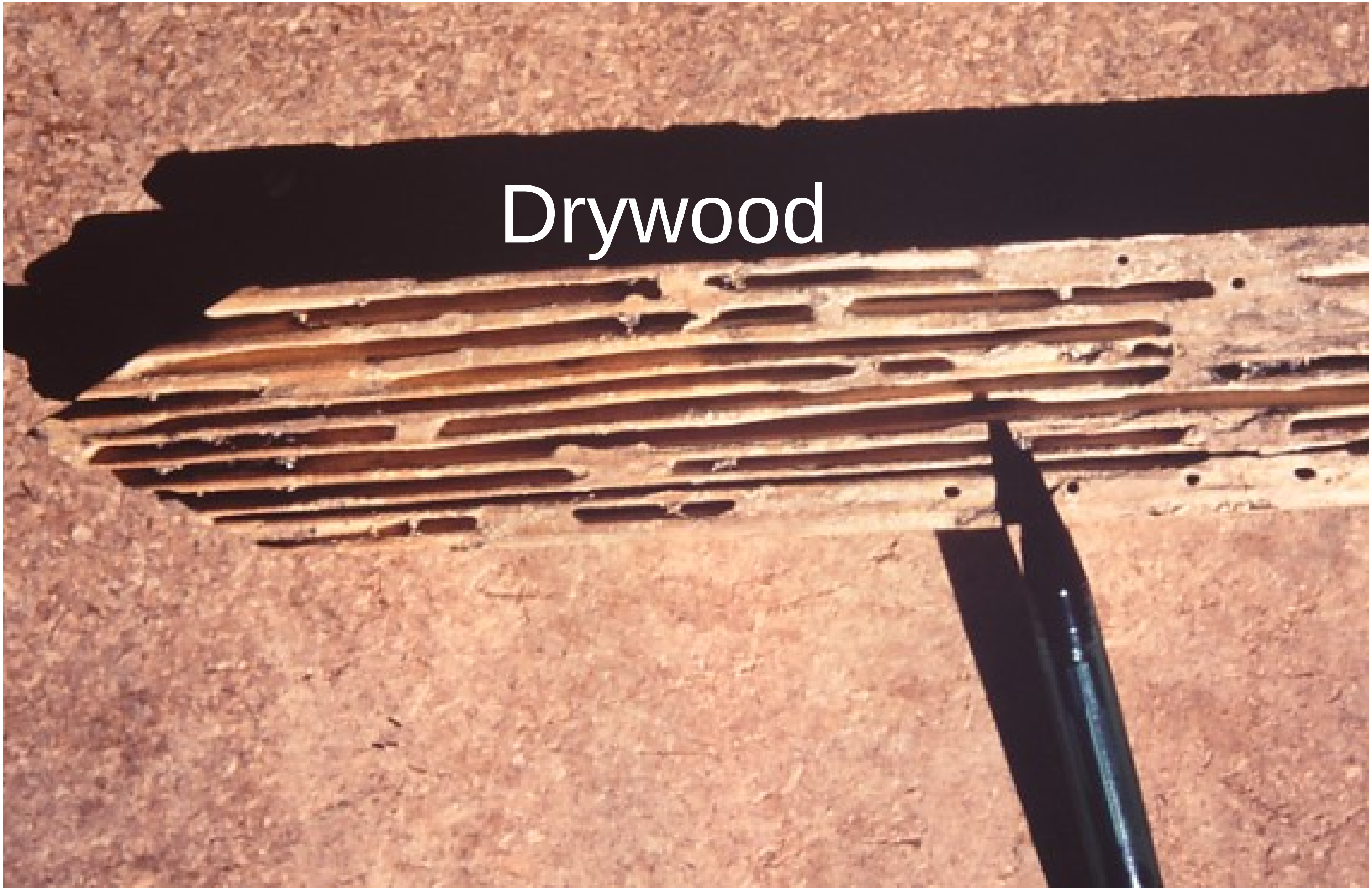

Powderpost Beetle


Lyctus

Deterioration by Insects

- Termites have the following caste system: reproductives, workers, and soldiers
- Subterranean termites build nest 2.5-3 m below the ground. Typical of tropical/subtropical regions
- Formosan termites occur in southern and coastal states
- Drywood termites can be found in tropical and coastal regions of warm temperature zones


Drywood termite


Drywood

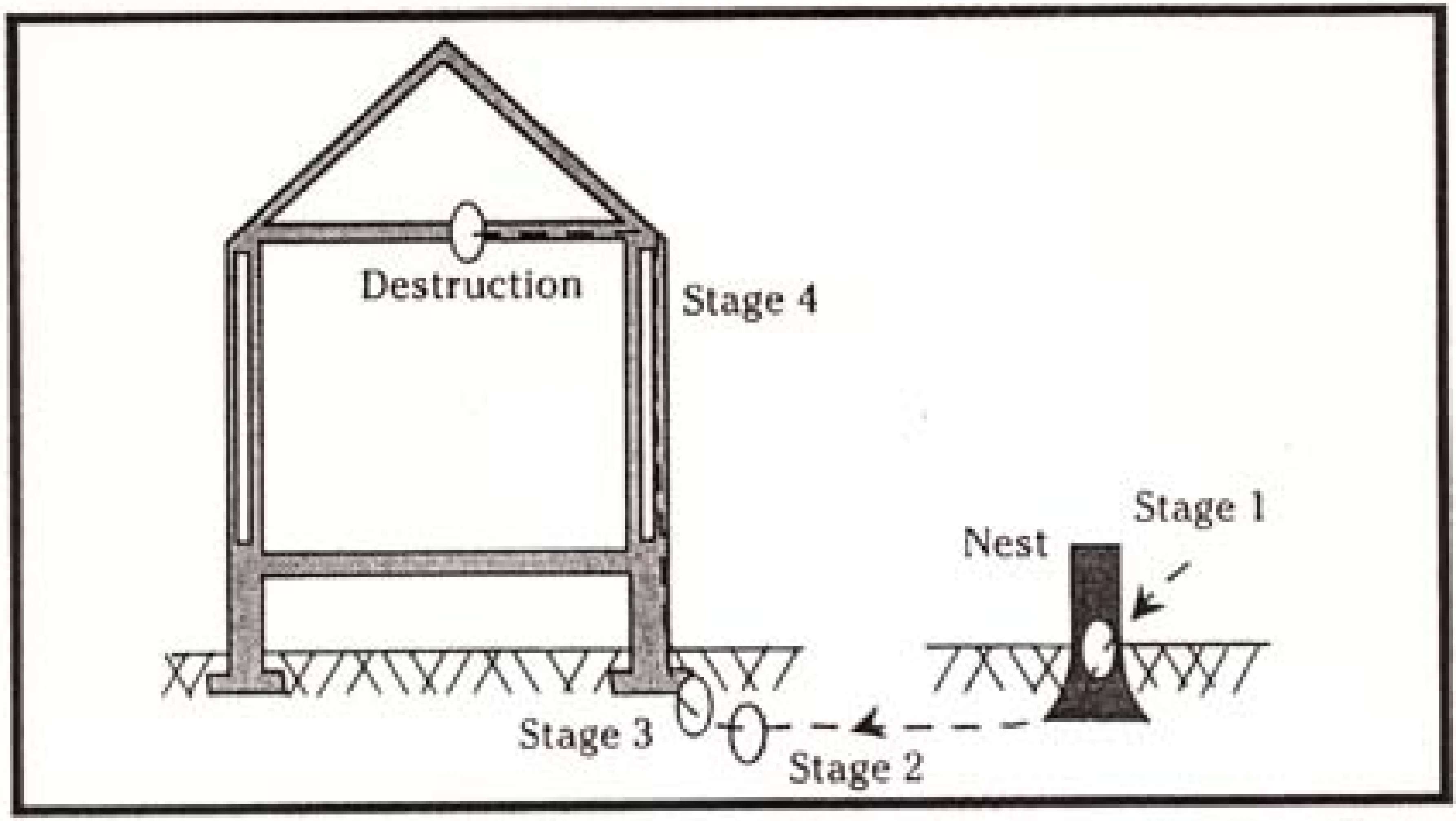
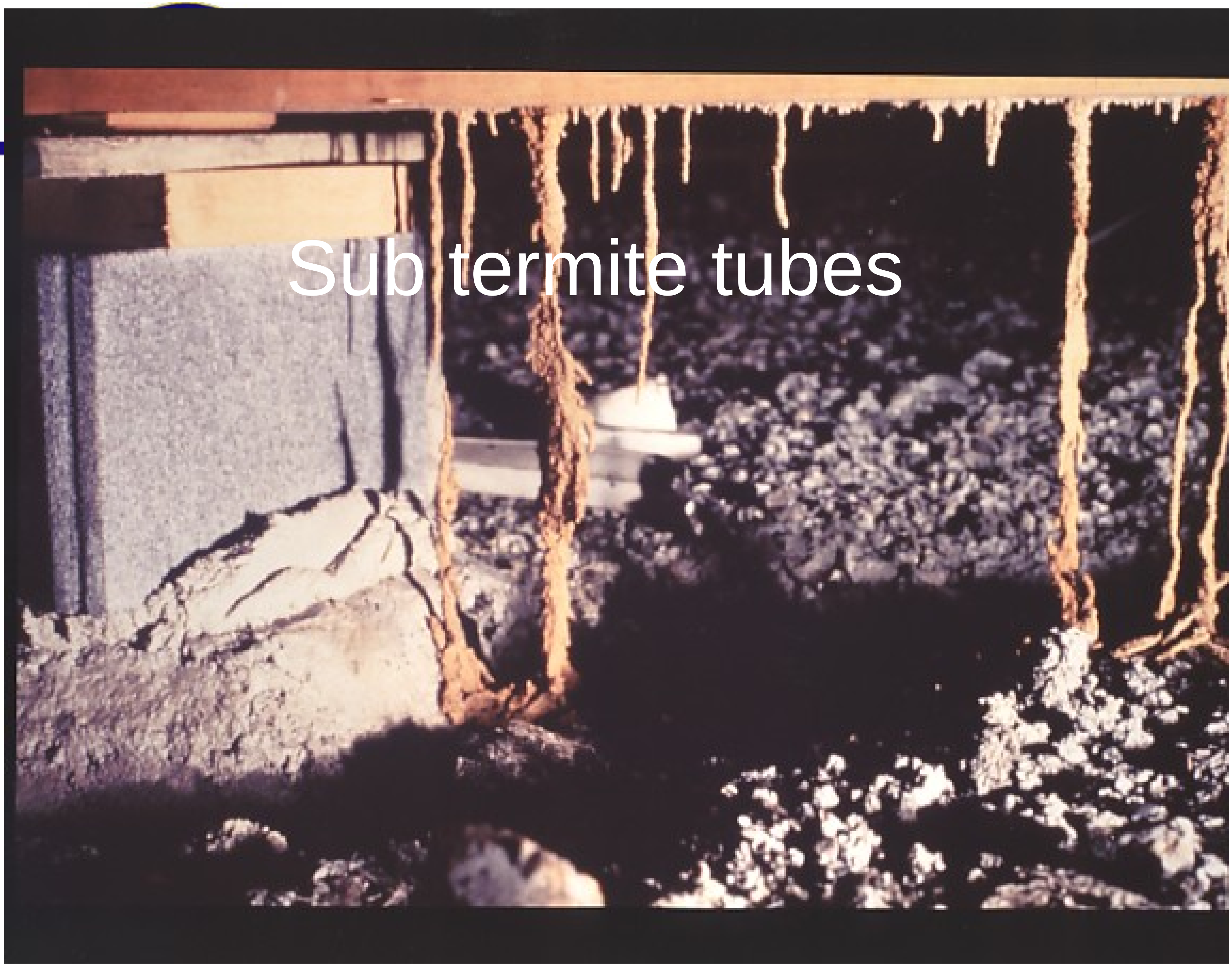


Figure 11. Illustration of the four time events of termite attack.


Sub termite tubes

Rot

- Timber rot is caused by fungi that live parasitically on cellulose because they have no chlorophyll.
- Rots cannot live if the moisture content of wood is below 18%.
- Fungi needs: air, water, food, favorable temperature.

Effects of fungi on wood

- Two groups: a) wood-destroying and b) wood staining and molds
- Requirements: Food, moisture, temperature, pH
- Types of decay: white rot, brown rot, soft rot, dry rot
- Stages of decay: incipient, intermediate, advanced

Sapstain and Molds

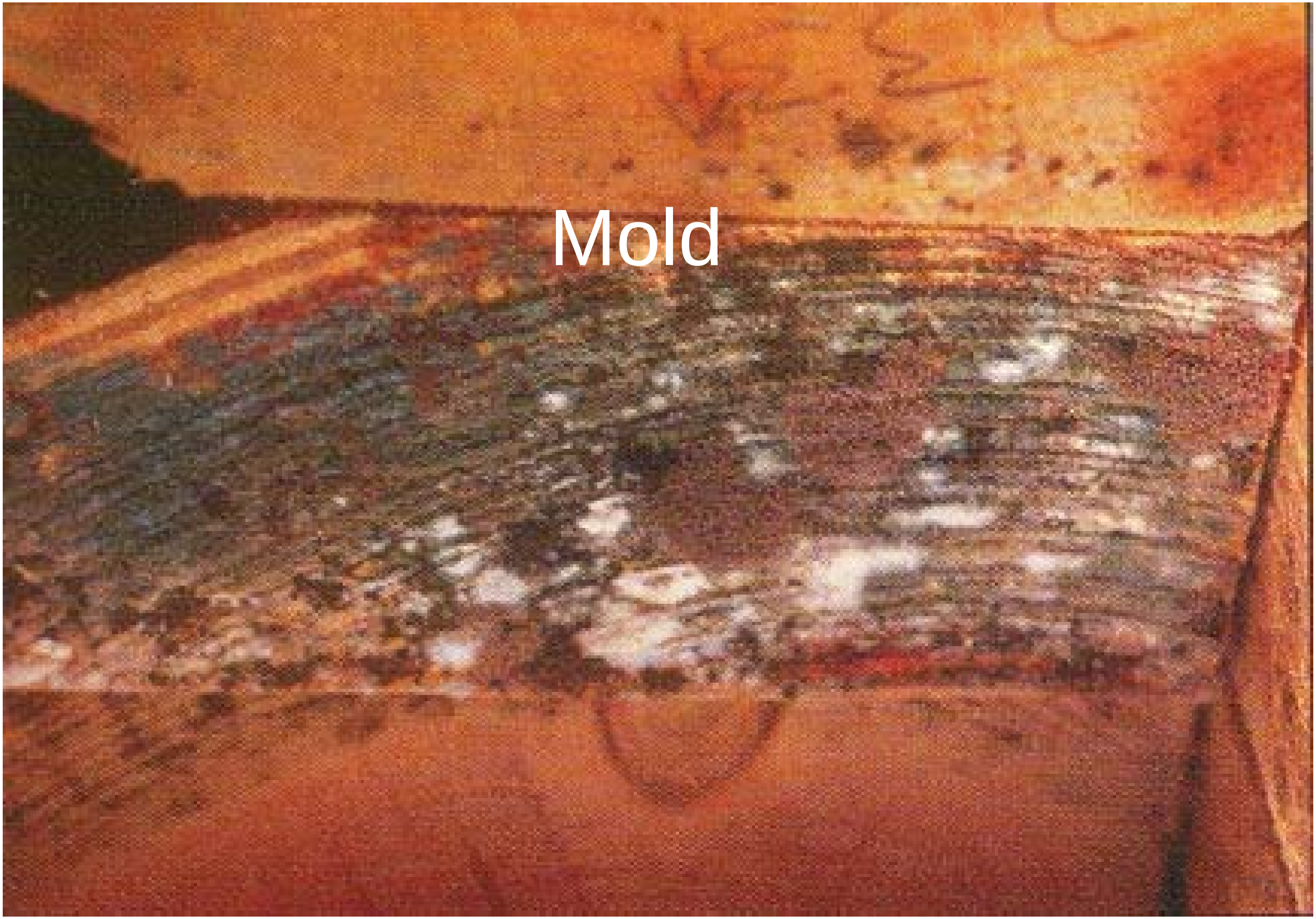
- Molds
  - Wide variation in color
  - Minimal strength effects
  - Usually on sapwood only

Sapstain

Do not attack cell wall

Blue (dark)

Usually on sapwood only


Mold

Staining fungi--log

Mycelium

Dry rot fungus

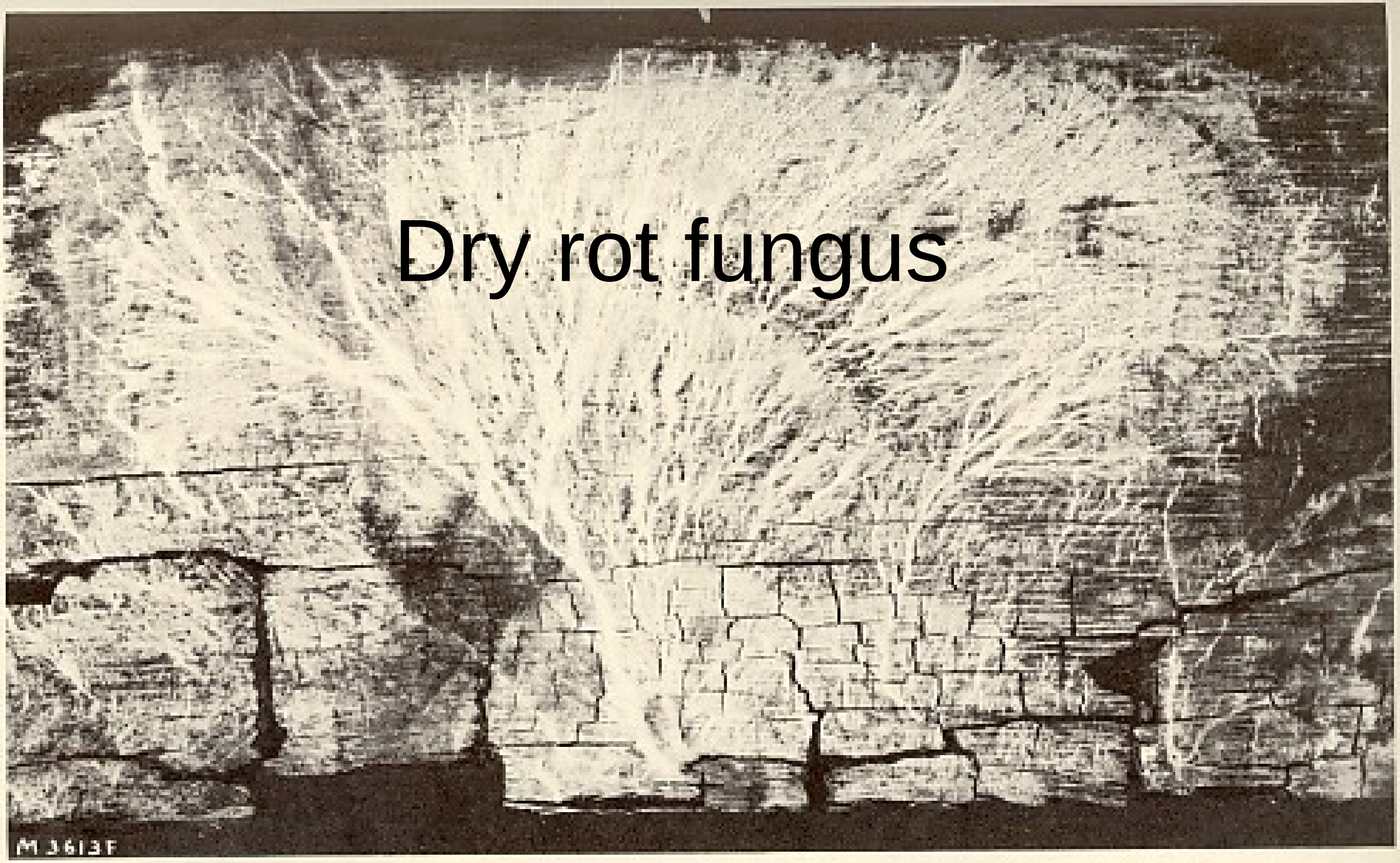


Figure 2.2. Water-conducting strands (rhizomorphs) of *Poria incrassata* terminating in a mycelial "fan." This fungus appears to attack dry wood but in fact wets the wood first, by transporting water from an external source, usually the ground. (Courtesy U.S. Forest Products Laboratory, Madison, Wis.)

Some questions

1) A piece of wood containing moisture weights 205g, and after oven drying to a constant weight, it weights 110g. What is the percent moisture content?

2) (205-110)/110 = 86.4%

3) A piece of wood contains 18% moisture. What must its weight have been before oven dry if it has a constant weight of 140g after drying?

4) (X-140)/140=0.18 → x= 165.2g

Questions

- 1)What is the reason for the high strength of wood in the longitudinal direction of the tree as compared to the transverse direction?
- Longitudinal direction → covalent bonds of cellulose microfibrils
- Transverse direction → Hydrogen bonds

- 2) What are the subrings of the annual growth rings of trees?
- Earlywood (spring)
- Latewood (summer)