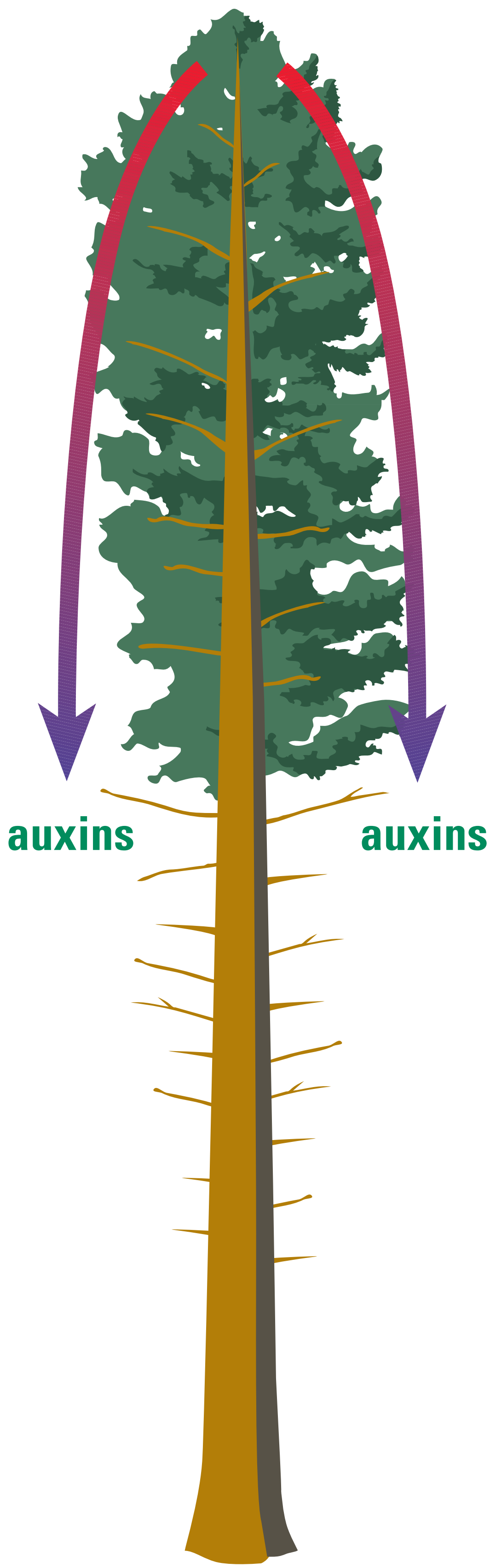
# Wood Quality… Impact on Product Yields, Grades and Values

Forest Practices Branch
Ministry of Forests

Canada
CANADA-BRITISH COLUMBIA
PARTNERSHIP AGREEMENT ON
FOREST RESOURCE DEVELOPMENT:
FRDA II

BC

Forintek Canada Corp.




- Terminal shoot and vigorous last formed portions of the crown foliage produce growth regulating hormones (auxins) and photosynthate.
- Lateral and downward trans-location of auxins to reach lower stem.
- In spring radial growth begins first at the top of the tree and proceeds gradually downward = more EW and wider rings in upper crown region near pith.
- Less EW and smaller rings at the base where rings are far from pith.
- Transition to LW occurs first near the base, farthest from the source of auxin supply and proceeds upward.
- The destiny (and density) of an individual fibre is thus determined by its relative position; its distance from the active live crown region and the time of its formation (season).

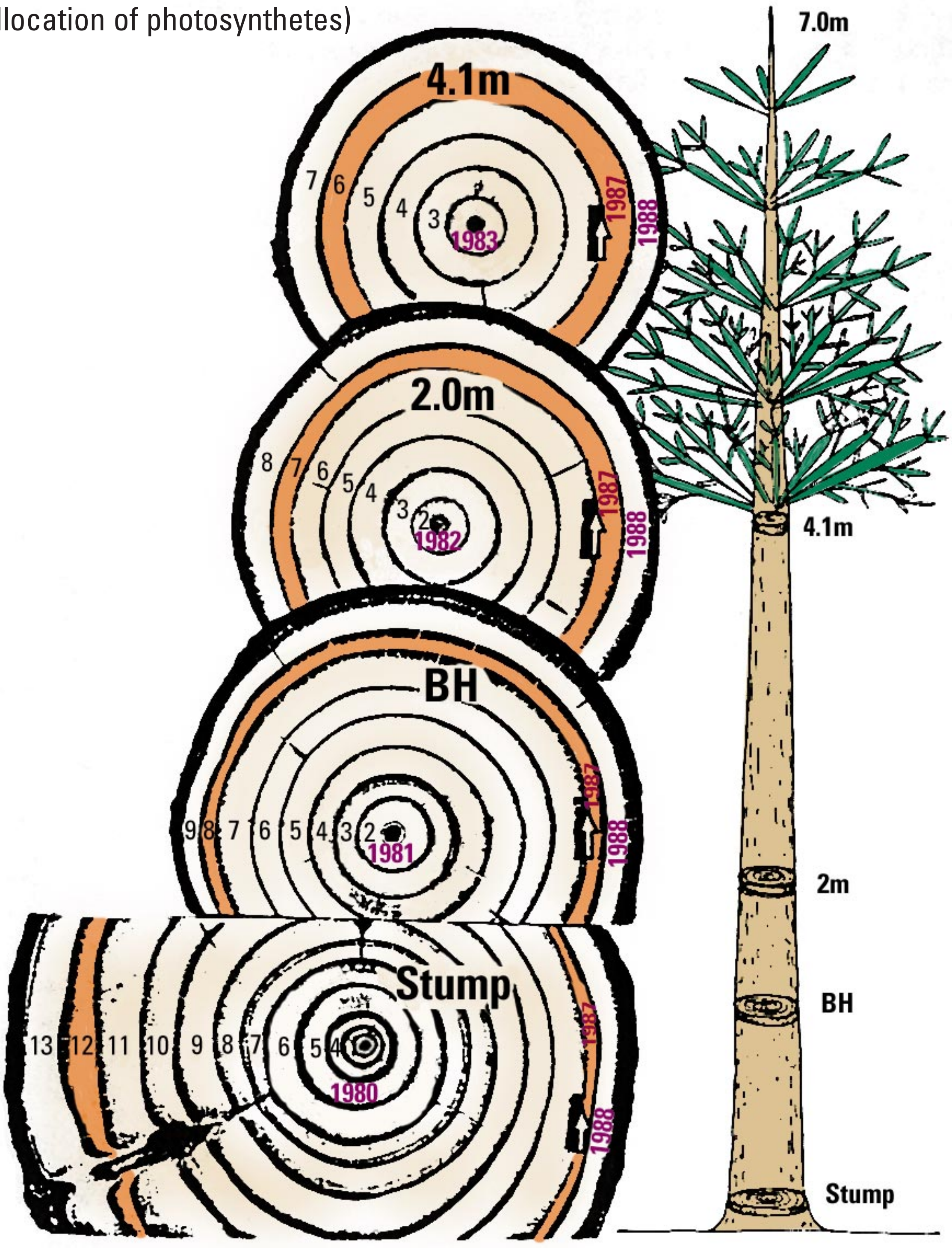
# Overhead 21

In addition to the bullets on this overhead, contrast a fully open-grown tree with a "dog-hair-stand" type of stem with little taper.

To force the right train of thought, ask what is the difference between a 20 year old thinned stem (lying on the ground), and the last 20 years of growth at the top of a 60–80 year old Douglas-fir or lodgepole pine. The discussion should include branch size, height growth, diameter growth, and compression wood formation. The major factor of mortality should be brought into the discussion. Therefore, the top of an older tree will have developed in a more open environment.

# Allometry

(allocation of photosynthetes)



# Overhead 22

Describe **allometry,** or “building block” allocation in a tree. Use this overhead to illustrate the point; the same growth layer, immediately after pruning, gets short changed at the base of the stem. In big and old trees, growing with moisture stress, the trees can have “locally absent rings” and “missing rings” at breast height.

Simplified allometry (energy allocation in order of priority):

No. 1 fine root-hair production (can be up to 40% of the tree’s energy)

No. 2 crown development, including seed production

No. 3 the “leftover” for stemwood production.

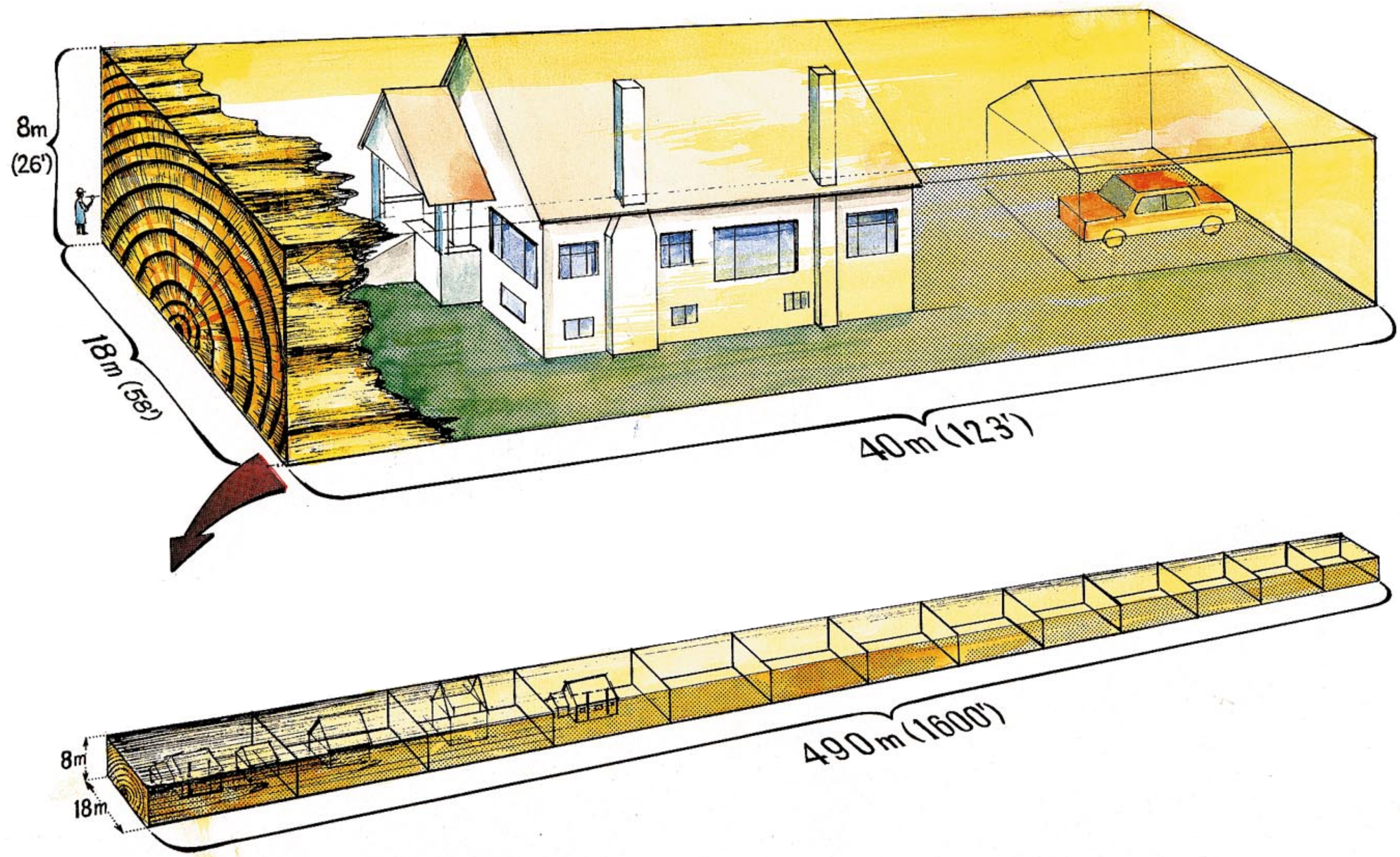
# Overhead 23

Explain the need for magnification when examining wood structure. For example, even with perfect vision, the human eye cannot separate two point objects that are closer together than 0.1 mm; this is our limit of resolution. It just so happens that about 3–4 softwood fibres fit into this 0.1 mm space. For this reason at least a 10× handlens, or preferably a microscope is used in the study of wood structure.

A handful of hollow milkshake straws would give a good approximation (about 94% correct) of wood structure at 200 times magnification. Of course, we would have to introduce plastic coffee stirrers to represent the horizontally aligned rays (now we have a 99.9% true representation of softwood structure).

Remind the class that at this magnification, a complete fibre length would be about 70 cm long, or 100 times of its diameter.

Explain the anisotropic nature of wood because of its structural makeup.

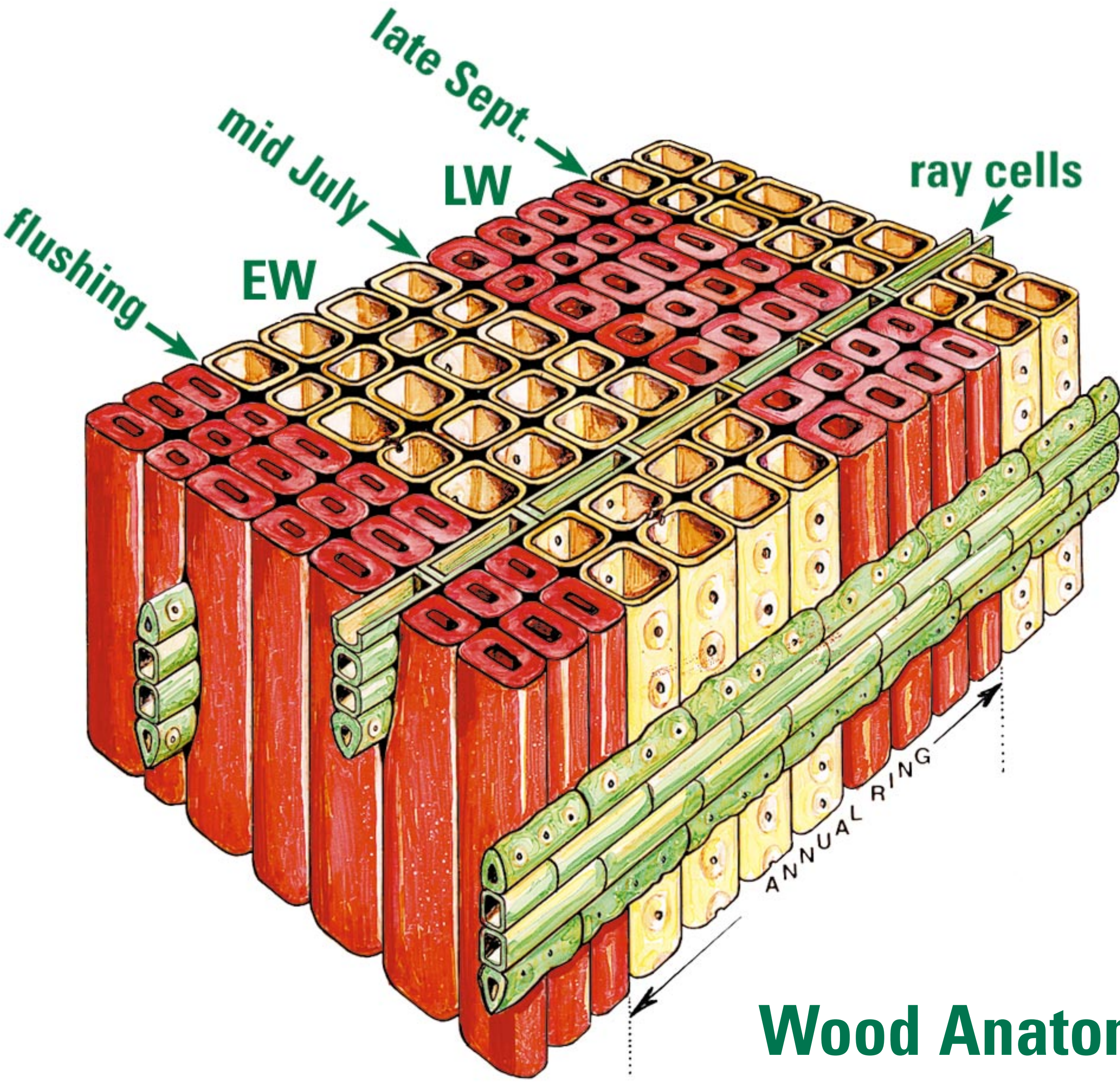

8m
(26')
18m (58')
40m (123')
8m
18m
490m (1600')

# Overhead 24

It would be easy to gloss over the concept of 200× magnification. But we will not. Consider a piece of eight foot long 2 × 4, magnified 200 times: it would be 1600 feet long (490 m), it would be 2.5 stories high (8 m), and 58 feet (18 m) wide.......now fill up 94% of this volume with 70 cm long milkshake straws, and the leftover 6% volume with coffee stirrers. Now you have a good appreciation of wood structure.

For lumber drying, keep in mind that we are trying to remove water from a fibre located in the middle of this 2 × 4; 4 m up from the ground, and 4 m from the top, 9 m in from the sides, and 245 m in from the ends of the board.

The 8' long 2 × 4 will contain on average about 2.5 billion wood fibres (for an average lifespan the human heart beats 2 billion times).



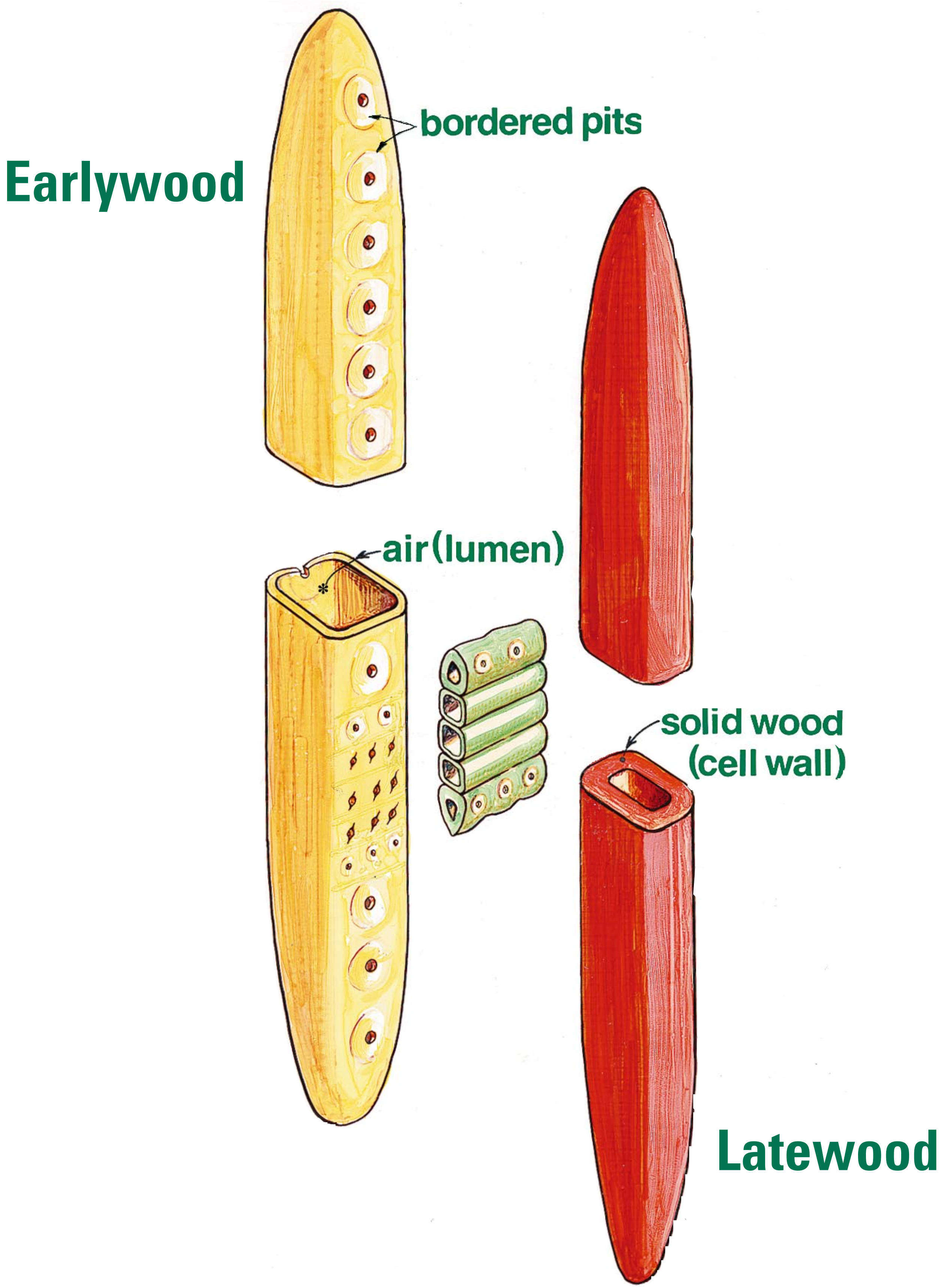

# Wood Anatomy

# Overhead 25

Review annual ring formation. Do a class survey and ask for estimates of **active tree growth**; how many months, out of the 12 month calendar year, do trees actually grow in Butchart Gardens?

Most people tend to confuse photosynthesis with tree growth. In fact, photosynthesis happens every day when temperature is above freezing. For example, during the dormant season (October to March) Sitka spruce seedlings doubled in bone-dry weight in Ireland; although there was cell division photosynthates accumulated in the seedlings' tissues.

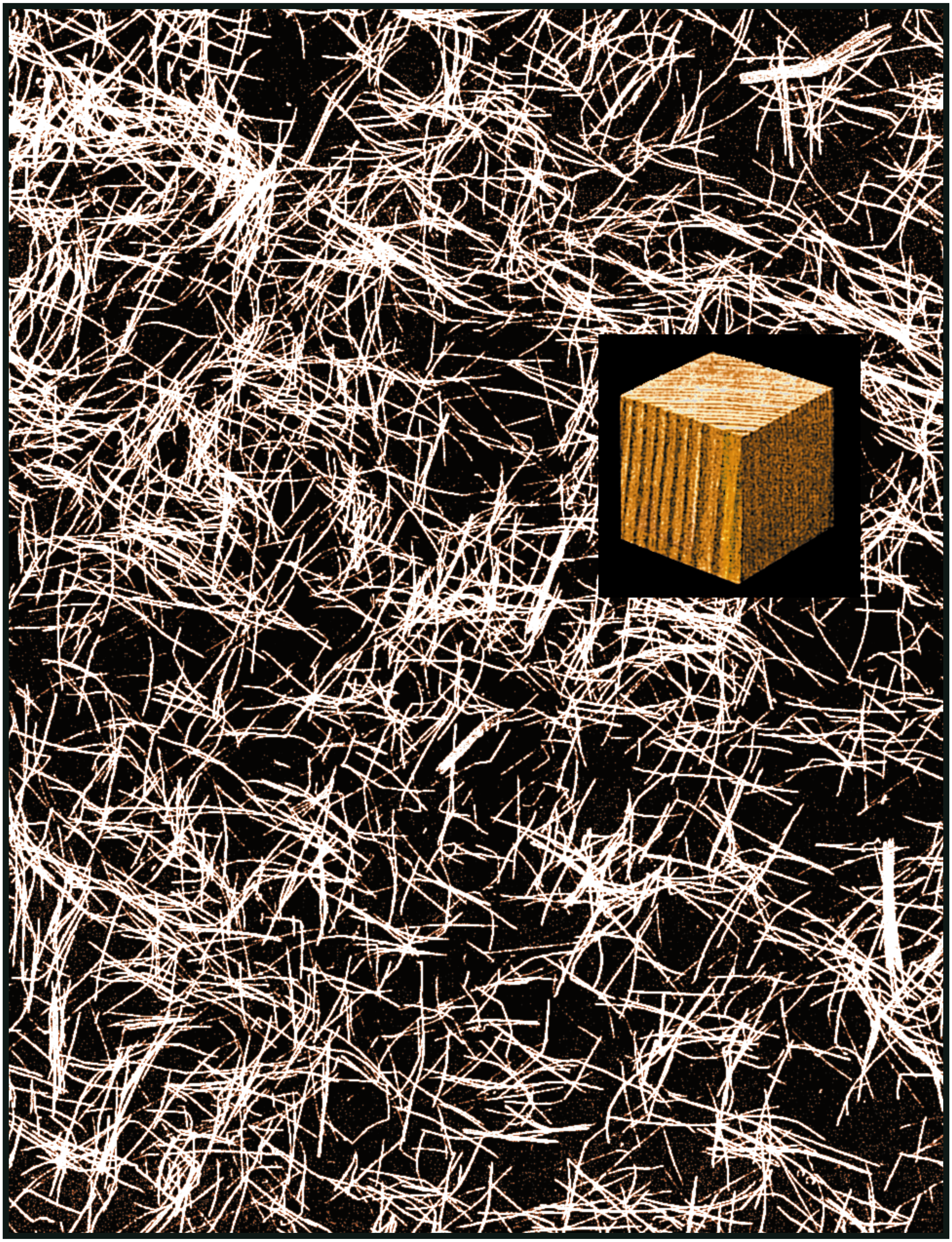
Talk about early wood/late wood (EW/LW) fibre morphology.


Earlywood
bordered pits
air (lumen)
*
solid wood
(cell wall)
Latewood

# Overhead 26

**Introduce fibre models at 4 000× magnification.** Drive home the edge-grain/flat-grain differences at the microscopic level, and conclude with an opinion survey of which face dries faster? Which face performs better when painted? Show examples if possible.

Do the fingernail test for EW/LW on the flat-grain board (more on this later on).

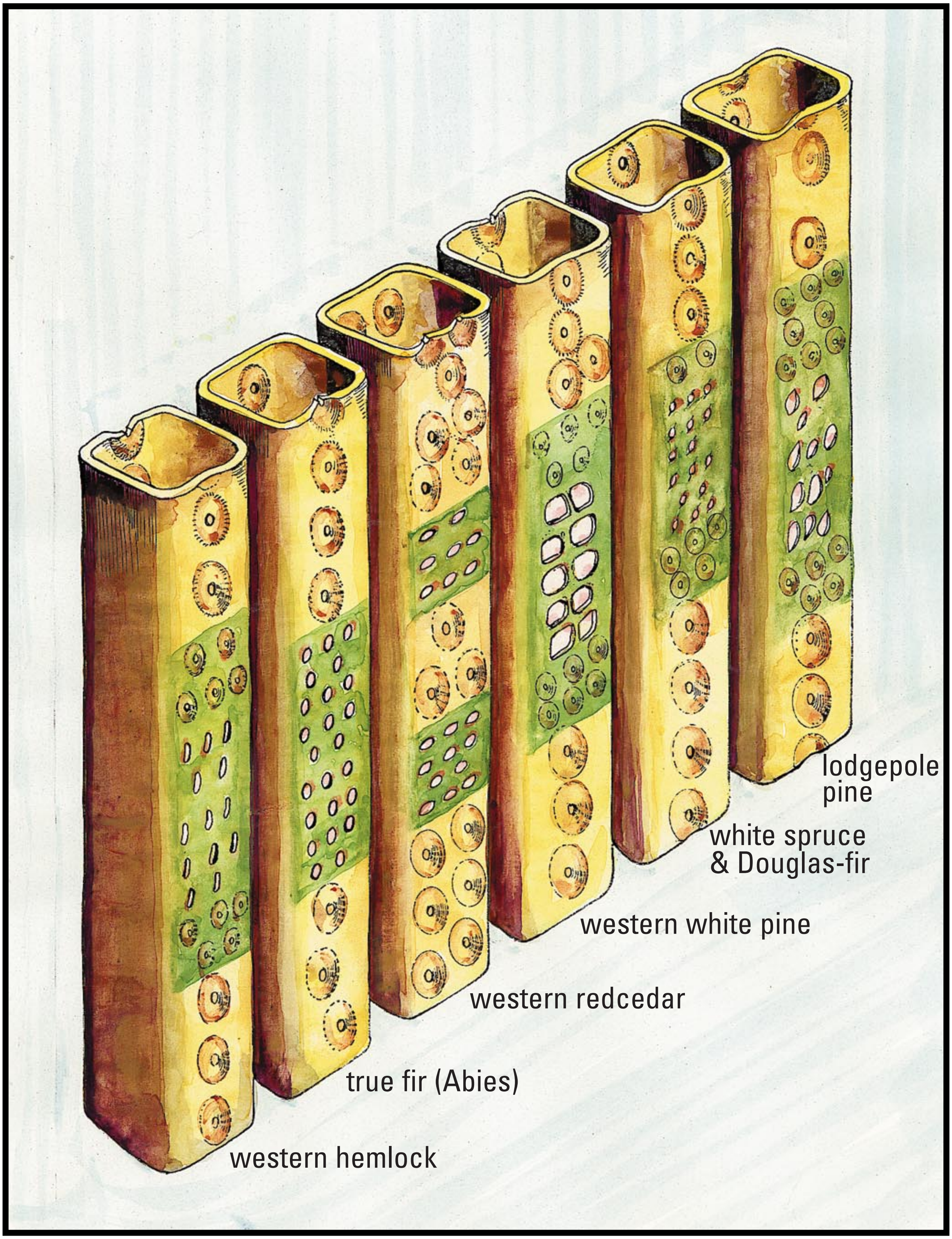


# Overhead 27

Explain the basic concept of chemical pulping; dissolves lignin bond, about 45% yield (lignin, hemicelluse, and extractives are "lost down the drain"). Contrast this with mechanical pulping where yields are about 95%, because the fibre-to-fibre bonding is broken by mechanical action. Therefore, in mechanical pulping the losses are minimal (usually in the form of water solubles and fines).

Tie these concepts back to the 2.5 cm wood cubes, by showing how much heavy shopping bag Kraft pulp can be made from just one cube (45% of its weight, about one half of an 8.5 × 11 in. sheet of paper). Demonstrate with double-ply toilet tissue the mechanical pulp yield from the same cube (about 20–24 squares, or close to 2 m long piece).

- a 2.5 cm softwood cube contains 5 000 000 wood fibres, each about 3.5 mm long.
- if these 5 million wood fibres were laid end-to-end, the total distance spanned would be 17.5 km.


lodgepole pine
white spruce & Douglas-fir
western white pine
western redcedar
true fir (Abies)
western hemlock

# Overhead 28

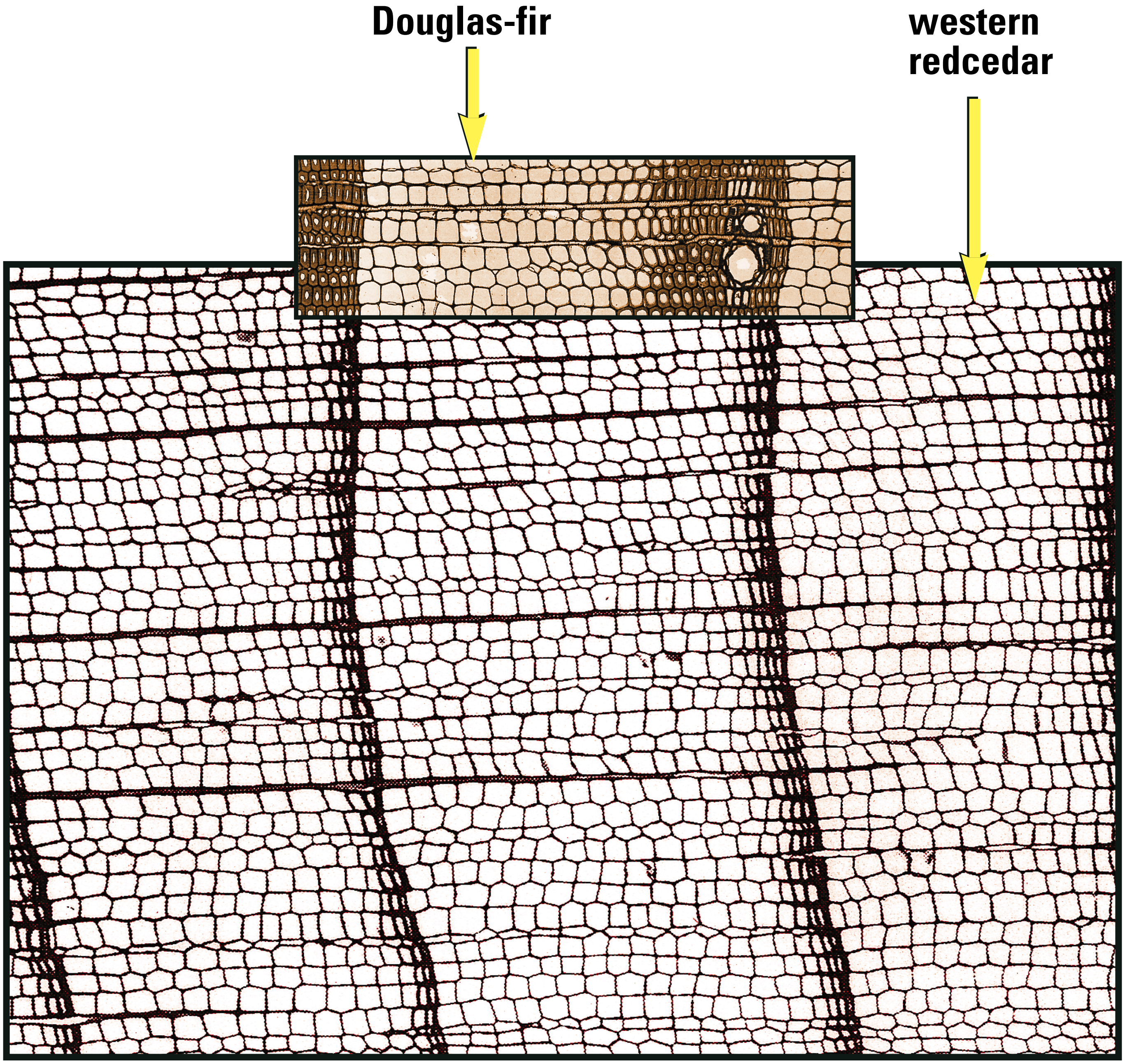
The technique of wood identification is not unlike identifying different makes of cars; that is, by noting their size, shape, proportions and ornaments. With experience it is possible to pinpoint not only the make but the particular year of manufacture.

The ultimate ideal in wood identification is the complete familiarity not only with the diagnostic structures and features, but also with the degree of natural variation to be found in wood from different trees of the same species.

Identification of wood fibres in paper is a challenge even to the seasoned professional. The challenges arise because the anatomical relationships of the cells to one another no longer exist.

The most important thing to remember about species identification of softwood paper fibres is that diagnostic features can be found only on earlywood fibres. Specifically, in the ray-contact areas (crossfields), where the size, shape and the number of ray crossfield pits can be seen. Remember that these features are found exclusively on the radial face (edge-grain) of the cell wall.

**Bullets:** **radial/tangential plane, bordered pit function in sap/heart (show the model at 10 000×), ray-crossfield pits, etc.**

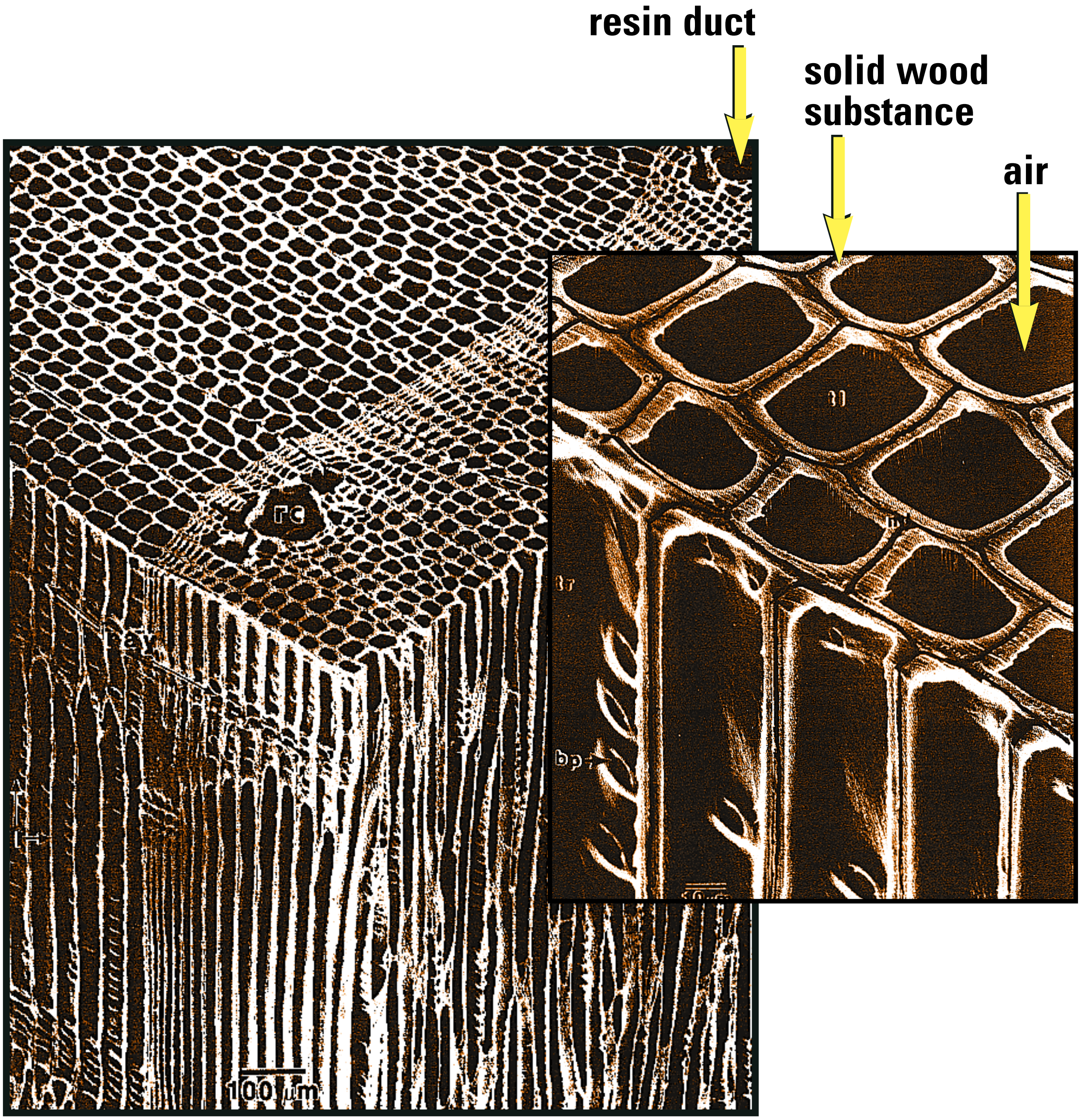

Douglas-fir
western
redcedar

# Overhead 29

The white you see in this cross-section is air. Solid wood substance resides in the black filigree. Heavy horizontal lines are rays, vertical black bands are latewood fibres in this low-density old-growth western redcedar.

Note distance scale:  the 1 mm long black horizontal bar, and the two annual rings bracketed (they are less than 0.5 mm wide). This rate of growth works out to be about 50 rings/inch!

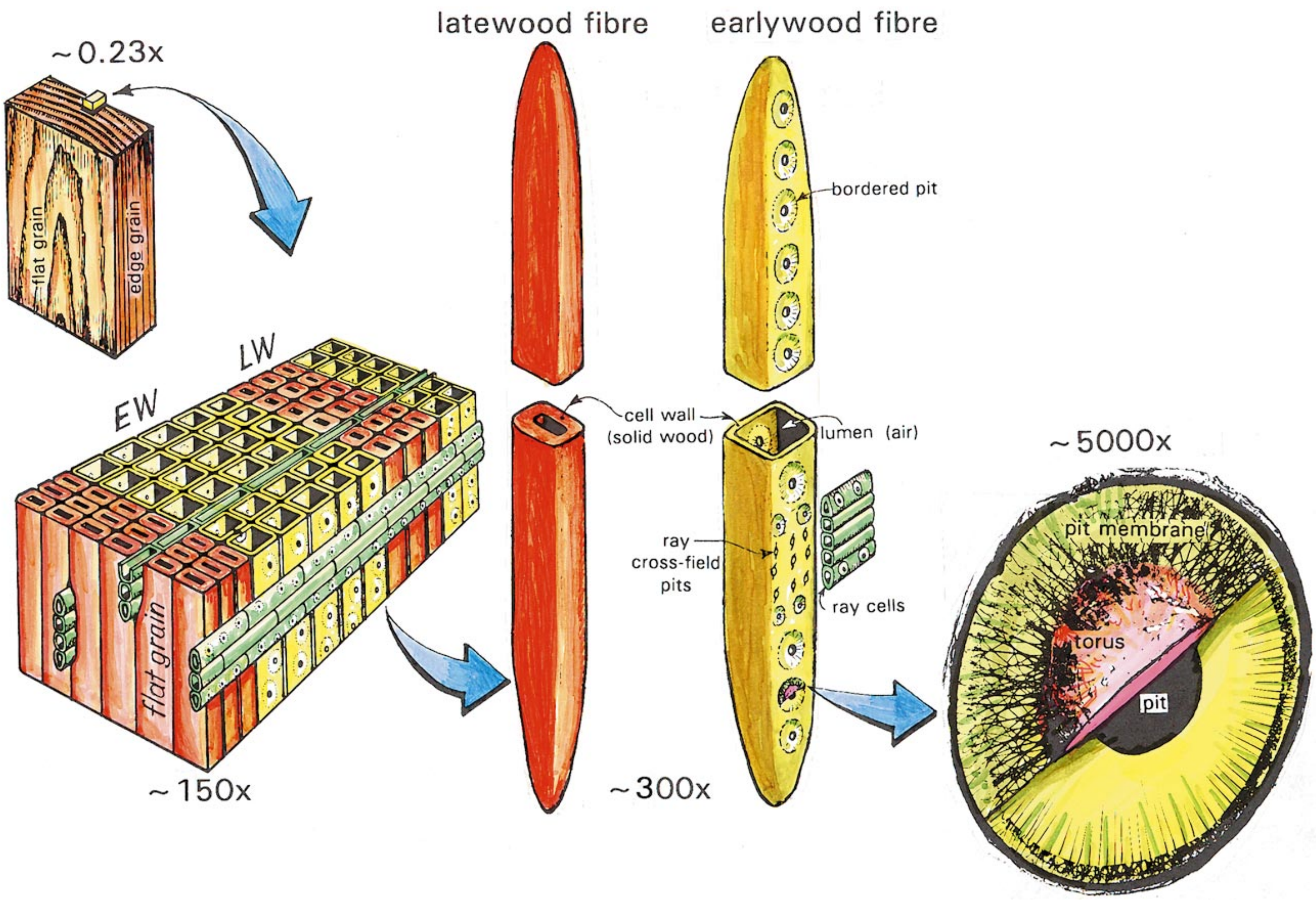
Equally interesting is a small insert in the top of the picture (perhaps this can be revealed at a later time in the discussion, so the viewer is not sidetracked), showing one complete Douglas-fir ring. Draw attention to the similarities and differences (almost identical cell diameters, fibre wall thicknesses; except there is a pair of resin canals, and there is a lot more latewood, with much thicker cell walls).


resin duct
solid wood substance
air
rc
ray
100 µm
tl
tr
bp

# OVERHEAD 30

Describe and summarize the location of solid wood substance, air, middle lamella (the cementing medium that has to be dissolved through pulping). At this stage , demonstrate with wood cube models at various magnifications (150, 200, 1200, 1300, 4000, and 10 000 times).

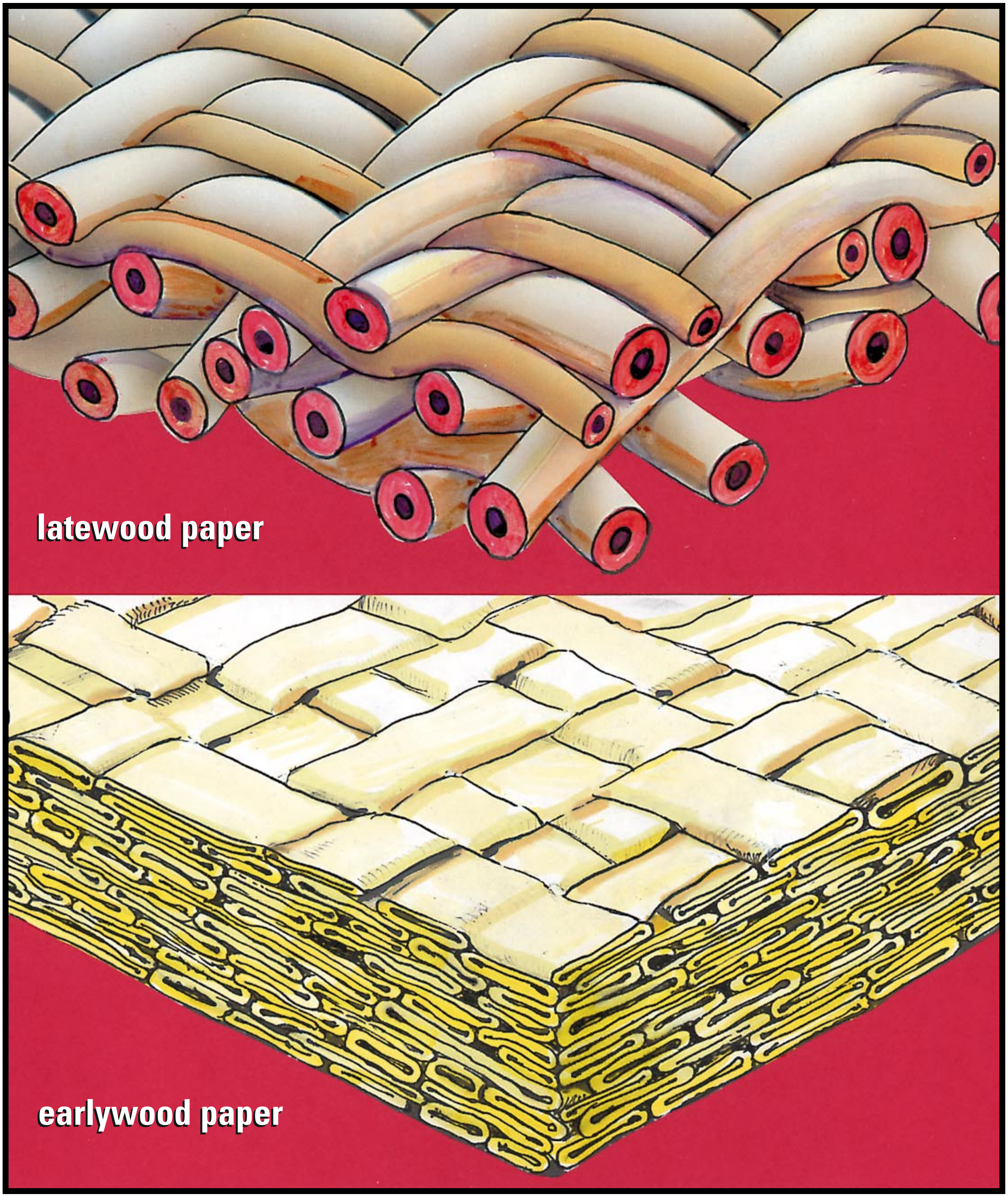
Describe some of the tree species with and without resin canals, and the concept on traumatic resin canals in non-resinous woods.


latewood fibre
earlywood fibre
~0.23x
flat grain
edge grain
bordered pit
LW
EW
cell wall
(solid wood)
lumen (air)
~5000x
ray
cross-field
pits
ray cells
pit membrane
flat grain
torus
pit
~150x
~300x

# Overhead 31

This is the concluding overview of wood structure, both in terms of organization and function. For the solid wood products sector anisotropy is important in terms of appearance, workability and performance.

The usefulness of progressively higher magnification, revealing structural elements was demonstrated through the overheads and various props.


latewood paper
earlywood paper

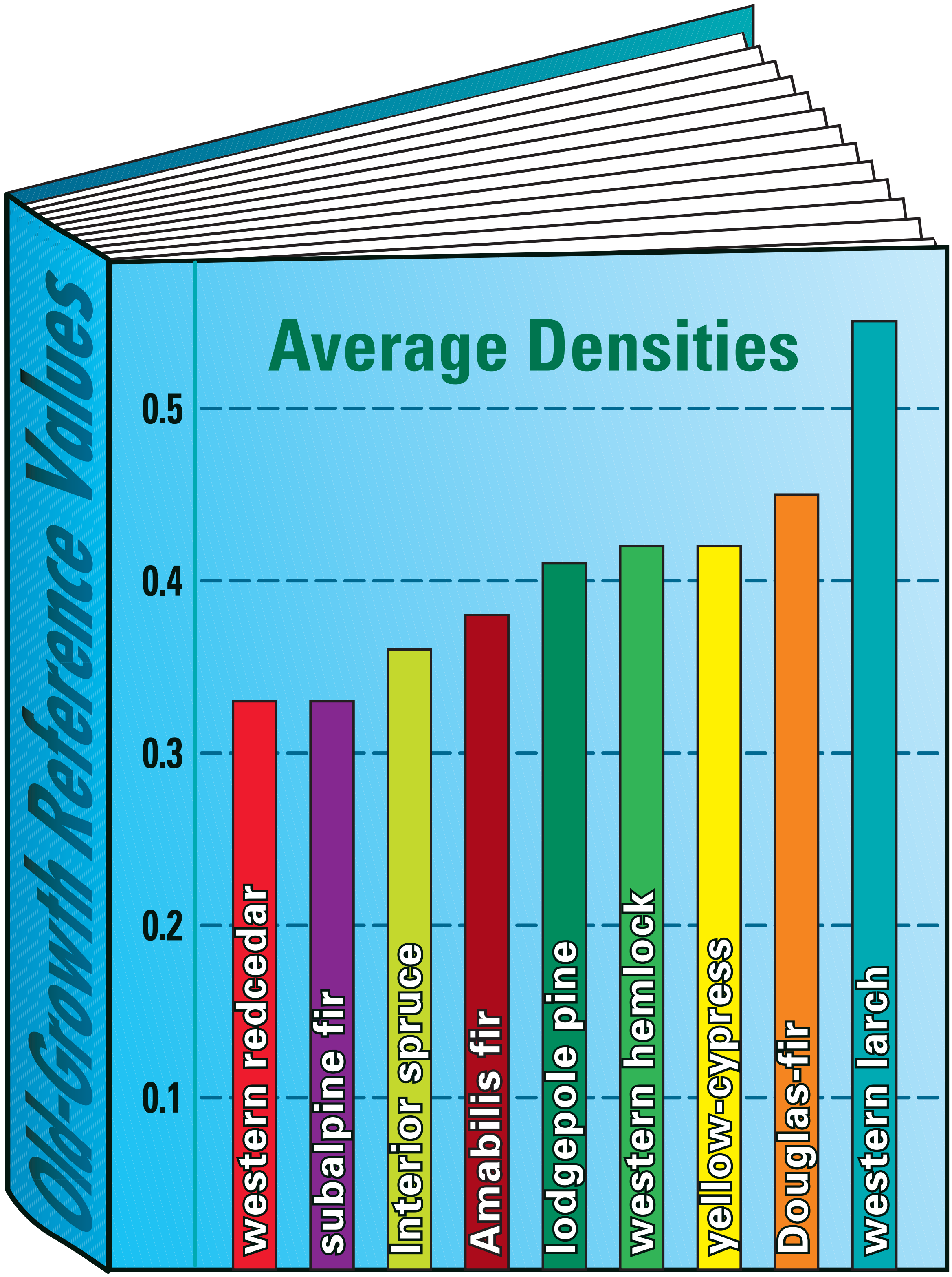
# OVERHEAD 32

Fibre morphology principles are demonstrated here to the paper maker: earlywood fibres collapse to a ribbon-like form, while thick-walled latewood fibres remain rod-like (from the surface of fine printing papers they tend to stick out like the ribs of a starving animal).

As in solid wood products manufacturing, "uniformity" of the fibre furnish is the key to an efficient pulping and papermaking sector. At one time "fibre length" used to be one of the most important quality descriptor, then "weight per unit length" (or fibre coarseness), and today it is "fibre collapsibility".

Sketch out the performance requirements for Kraft paper shopping bags, fine writing and printing papers, and tissue products, and the linkages between wood/fibre quality. Key words are burst, tear, opacity, printability, and absorbance.

Conclude with the "sawlog mentality" in BC, how sawmill waste provides the furnish for pulp and paper (and not old-growth logs from the Clayoquot). Currently, about 90% of the chips come from sawmill waste (slabs, planer shavings, and sawdust), and the other 10% comes from the relatively low-quality pulp logs.


Old-Growth Reference Values
Average Densities
0.5
0.4
0.3
0.2
0.1
western redcedar
subalpine fir
Interior spruce
Amabilis fir
lodgepole pine
western hemlock
yellow-cypress
Douglas-fir
western larch

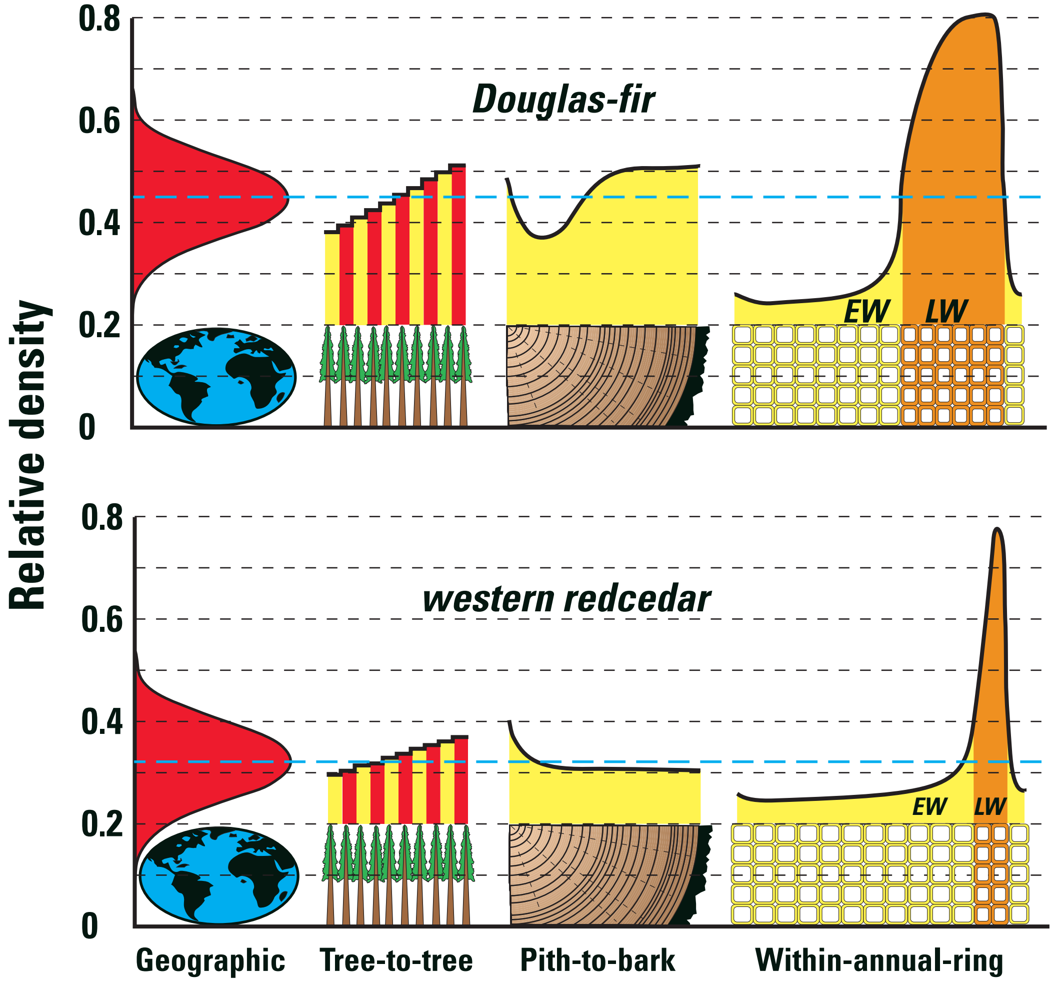
# Overhead 33

Relative density of wood can be viewed from a variety of different perspectives. This overhead shows the "global" average **old-growth** wood density values of some of the important BC softwoods. These are reference values, which were established through density surveys not only in Canada, but in the USA as well.

Provide clarification about terminology: in the metric system the preferred term is **relative density**, a unitless term, NOT TO BE ABBREVIATED. Therefore, the term specific gravity is no longer in vogue. **Basic relative density** means oven-dry weight over green volume.

The reference values shown here come from a Forintek publication, *Conversion Factors for the Forest Products Industry in Western Canada*.

# Global to Microscopic View of Density Distribution in BC Tree Species



# Overhead 34

The best way to discuss this overhead is to cover up 3/4 of it (showing the two globes) and talk about the major differences between Douglas-fir and western redcedar. These two species represent the highest and lowest density softwoods, **0.45** and **0.33**, respectively. **These are old-growth reference values!** One can think of these values as “global” (macroscopic) in nature. The other extreme viewpoint is at the microscopic level, where solid-wood substance basic relative density is 1.1, and lumen (air) is 0. These two limits leave us three intermediate points to discuss:

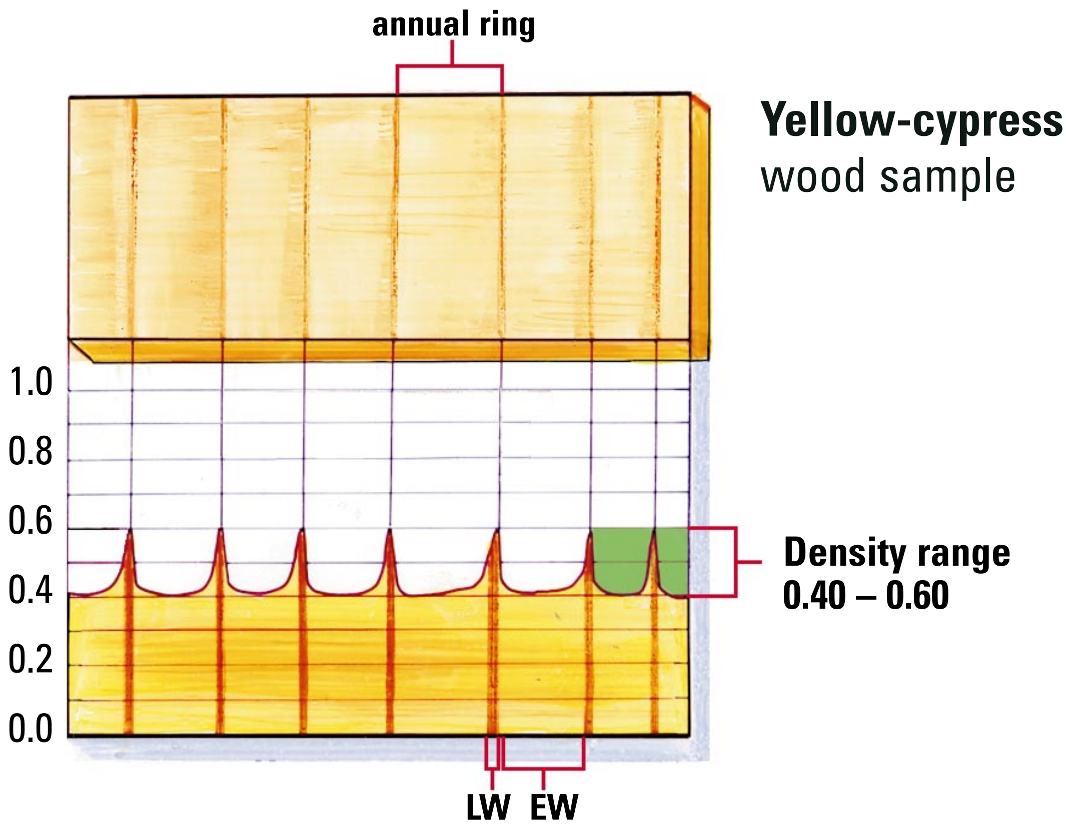
1. **tree-to-tree**
2. **pith-to-bark**
3. **within annual ring density distributions.**

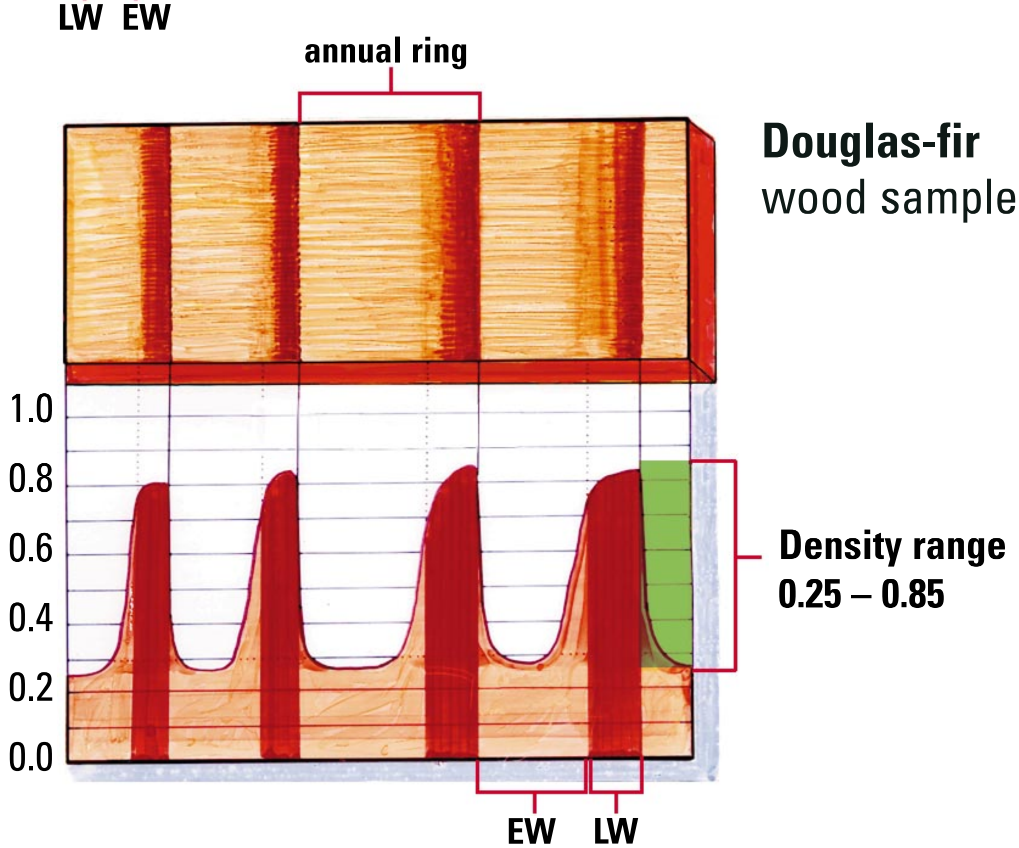
In terms of tree-to-tree density differences (within any one species) the normal coefficient of variation (not to be confused with coeff. of variance!) is 10%. Therefore, in western redcedar and Douglas-fir the normal range in relative density is 0.26–0.40 and 0.36–0.54, respectively. These limits would include 95% of a normally distributed population.

For pith-to-bark density distribution refer to Special Publication SP-34, page 12–14. These two examples in overhead 33 simply represent the most- and least-dense woods.

Within-annual-ring density variation is described in great detail in SP-34. In this overhead the main point to be made is that earlywood and latewood densities are very similar in these vastly different tree species. Ultimately, overall density differences are attributed to differences in latewood content (as was demonstrated in overhead 28).

# Wood Density Variation within Growth Rings



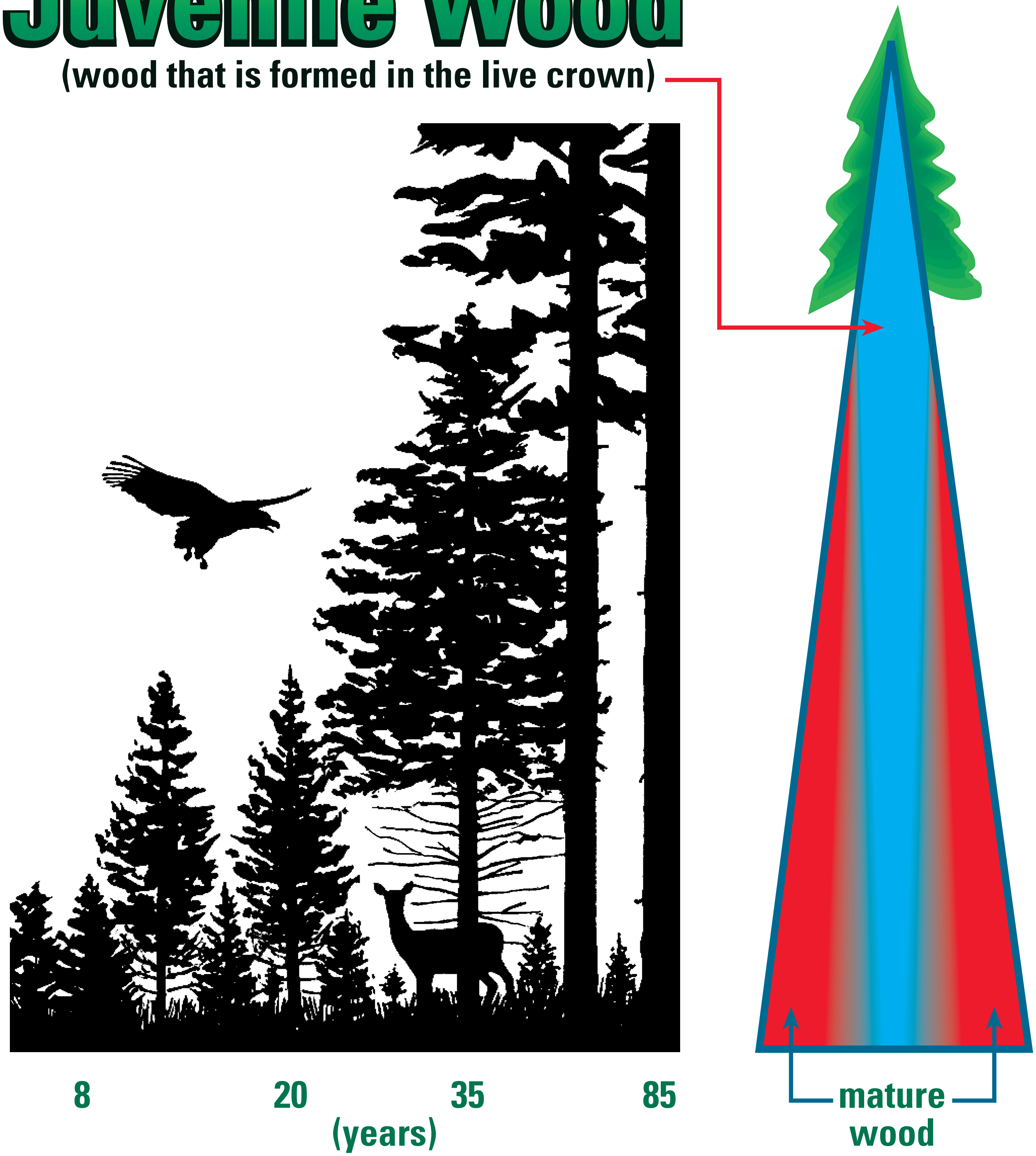
# Overhead 35

Wood density variation within growth rings are to be described in terms of working properties (machinability) and appearance. This is detailed in SP-34 on pages 8 –11.

Show some wood samples with edge- and flat-grain. Draw attention to the lack of grain (not much visual contrast between EW–LW) in yellow-cypress, and to the very “contrasty” Douglas-fir. Invite students to dent the wood with their fingernails. Of course, Douglas-fir latewood will not dent, but earlywood will. In addition, show that yellow-cedar earlywood is tougher than in Douglas-fir.

# Juvenile Wood

(wood that is formed in the live crown)



# Overhead 36

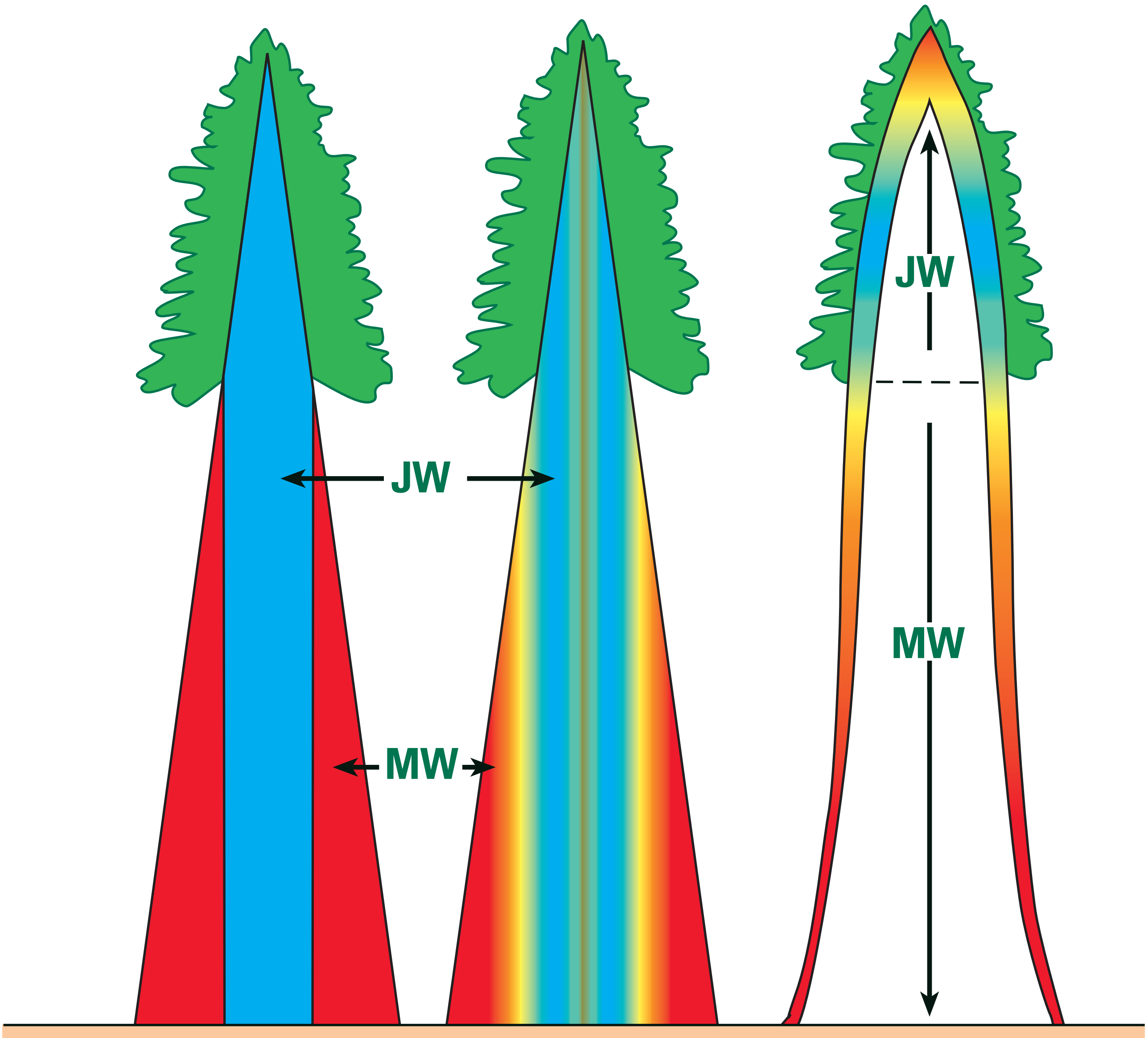
At the outset state that **crown-formed wood** is a much better label than juvenile wood.

Describe crown recession as a function of age and stocking/stand density. Use the lodgepole pine example, where at >2000 stems/ha the branches at breast height died at age 13, and the branches were small in diameter. Conversely, in a 700 stems/ha some branches have >60 annual rings, and they have a large diameter.

The biggest contrast is between an open-grown and a dog-hair-stand- grown tree. Spend some time in drawing out some comments from the class, and refer back to the basics associated with overhead 20. Stem taper and volume are important, but other wood quality attributes should be described next, starting with relative density (from pith-to-bark and from stump-to-top).

Emphasize that there are other measures of wood juvenility, which include the chemistry of wood (lignin,cellulose, and extractives content), fibre length, fibril orientation, which will be described later on.

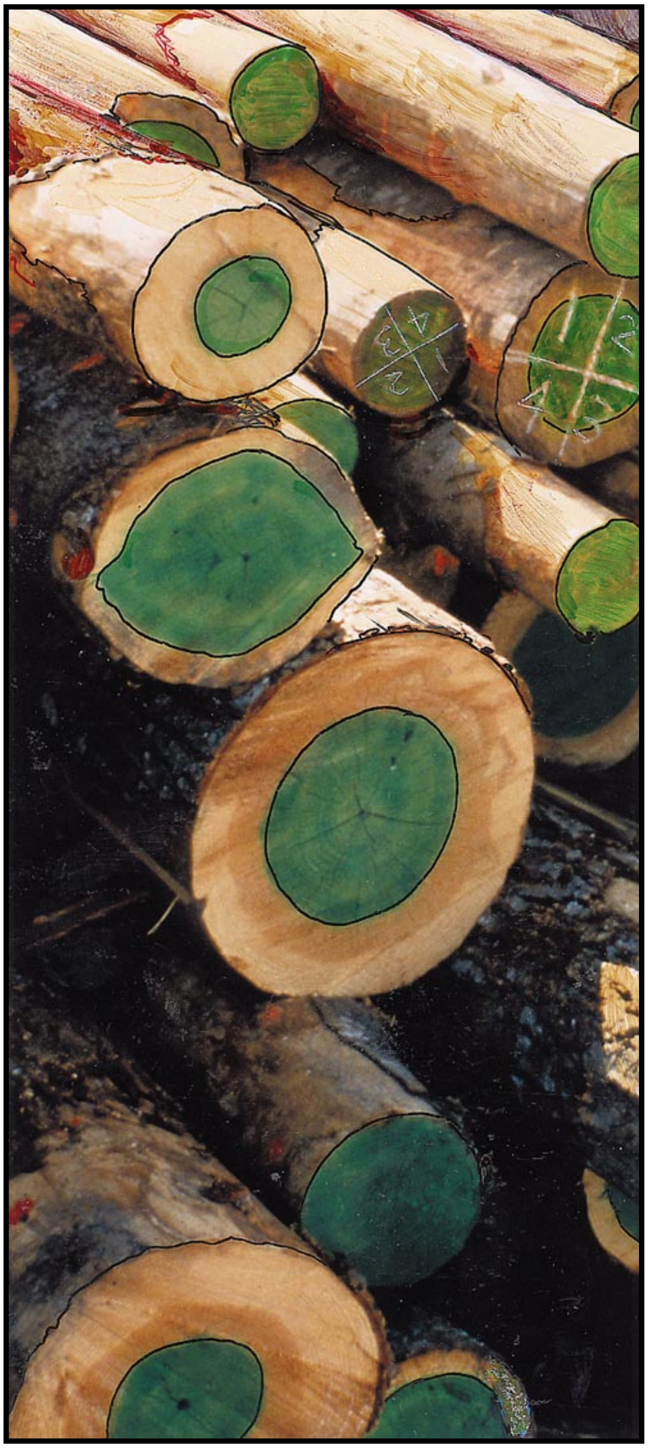
# Juvenile Wood (JW) and Mature Wood (MW)



# Overhead 37

The transition from crown-formed wood to mature wood is not sudden, as might be interpreted from the graphical representations. The transition is gradual, as the middle stem profile shows through subtle shading.

A surprising fact emerges when we examine the last complete growth-layer in an 85 year old lodgepole pine (or any other softwood), from the tip of the tree, right down to the stump. The colour coding, from blue to red, represents the transition from the juvenile to the mature phase. That is, wood that was formed in the live crown, and away from it.

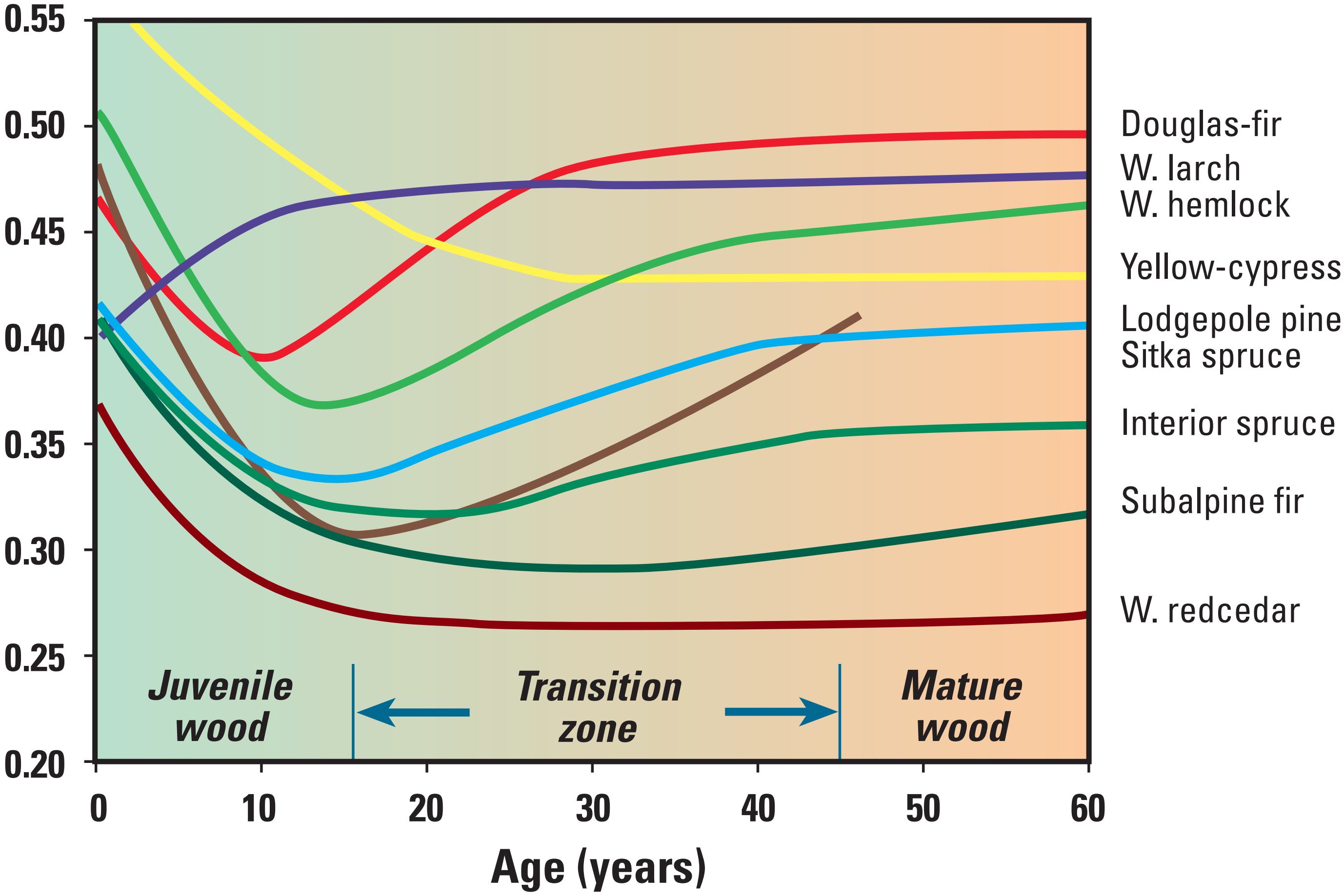


# Overhead 38

This overhead provides a visual representation of the extent of juvenile/mature wood in 50 year old Douglas-fir. Juvenile wood in this example is the first 20 years of growth, painted green on the log and lumber ends. On average, these 50 year old trees contained 50% juvenile wood by volume, running from the stump to the top of the tree like a stove pipe.

Log ends (and the resultant lumber without end-trim) were colour coded to enable researchers to identify the degree and extent of juvenile wood in each piece of lumber. This was needed in relating strength and stiffness results to visual lumber grades, and ultimately to the impact of the presence of juvenile wood in the piece.

# Relative Density at BH of Rapidly Grown B.C. Woods

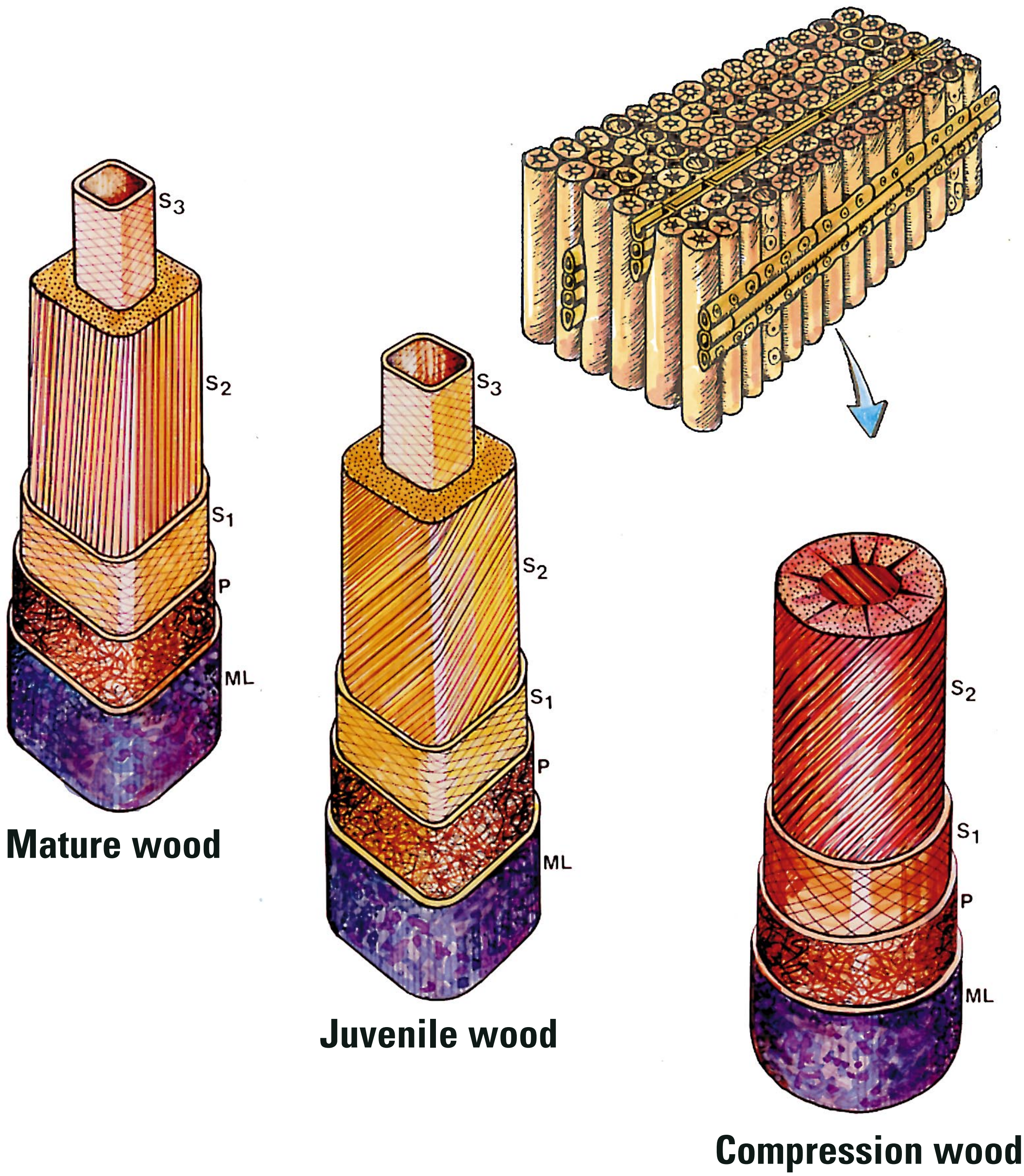


# Overhead 39

**Before showing this overhead** introduce the pith-to-bark density trend by dipping portions of a Douglas-fir and a western redcedar longitudinal shrinkage sample (pre-prepared, painted, and marked for this purpose). Without this introduction (with overhead 37 still on the screen) overhead 38 would be overwhelming and confusing.

The principal points here include:

- **these examples are from the most rapidly grown trees we could find in BC in forest environments! THESE ARE NOT RESOURCE AVERAGE TREND-LINES!** Simply, these trees were selected to study potential wood quality problems in rapidly grown second-growth trees.
- not all species have low-density juvenile wood!
- the transition from juvenile- to mature-wood is very gradual!
- these trend lines are for breast height samples!
- the pith-associated high density wood (from 1–5 years) is thought to be the product of mechanical stimulation from the wind!


S3
S2
S1
P
ML
Mature wood
S3
S2
S1
P
ML
Juvenile wood
S2
S1
P
ML
Compression wood

# OVERHEAD 40

**Fibril orientation** is another measure of wood juvenility, and in case of Douglas-fir it seems to be in good agreement with the density trends just described, in terms of time interval. This example shows the gradual "straightening out" of fibril orientation from age 1 to 20, from >30 degrees to about 10 degrees.

For background information read pages 18–20 of SP No. 34.

The main point to put across here is that we are looking at submicroscopic structure of individual fibre walls. In addition, although we are describing micro features, they have macro consequences in terms of strength and dimensional stability.

This is a good opportunity to show some examples of Simon Ellis' 1 × 1 clear western hemlock strength results (stable density trends with increasing strength values).

Show 2 × 4 with crook (pith-associated wood on one narrow edge, had greater longitudinal shrinkage than the other edge).