Wood Quality… Impact on Product Yields, Grades and Values

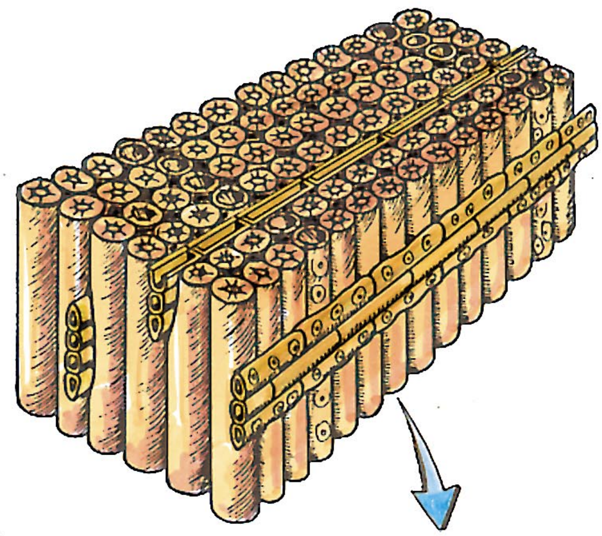
Forest Practices Branch
Ministry of Forests

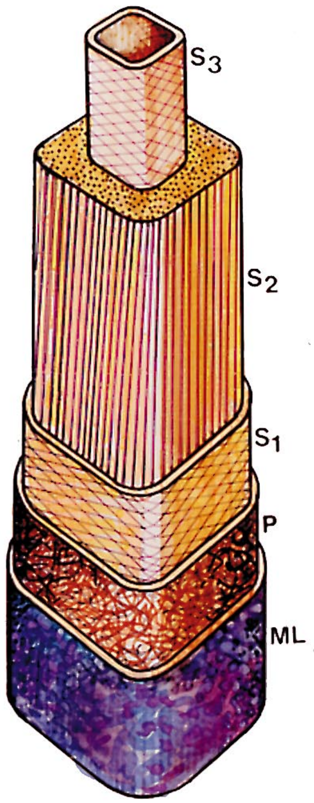
Canada

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

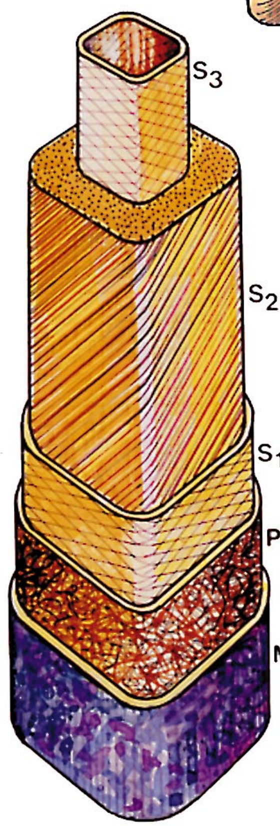
BC

Forintek
Canada
Corp.

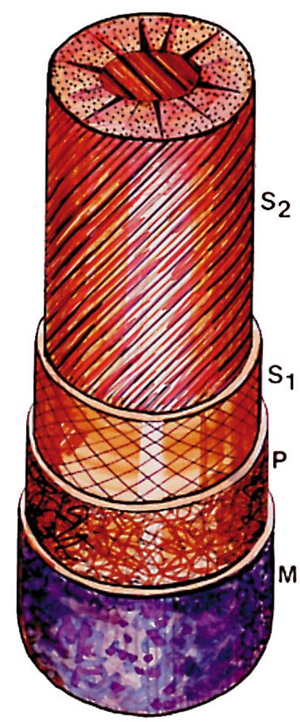




Mature wood



Juvenile wood



Compression wood

Overhead 41

Fibre length is a wood quality attribute that is easily overlooked from the solid-wood products perspective, however, it is very important to the pulp and paper sector.

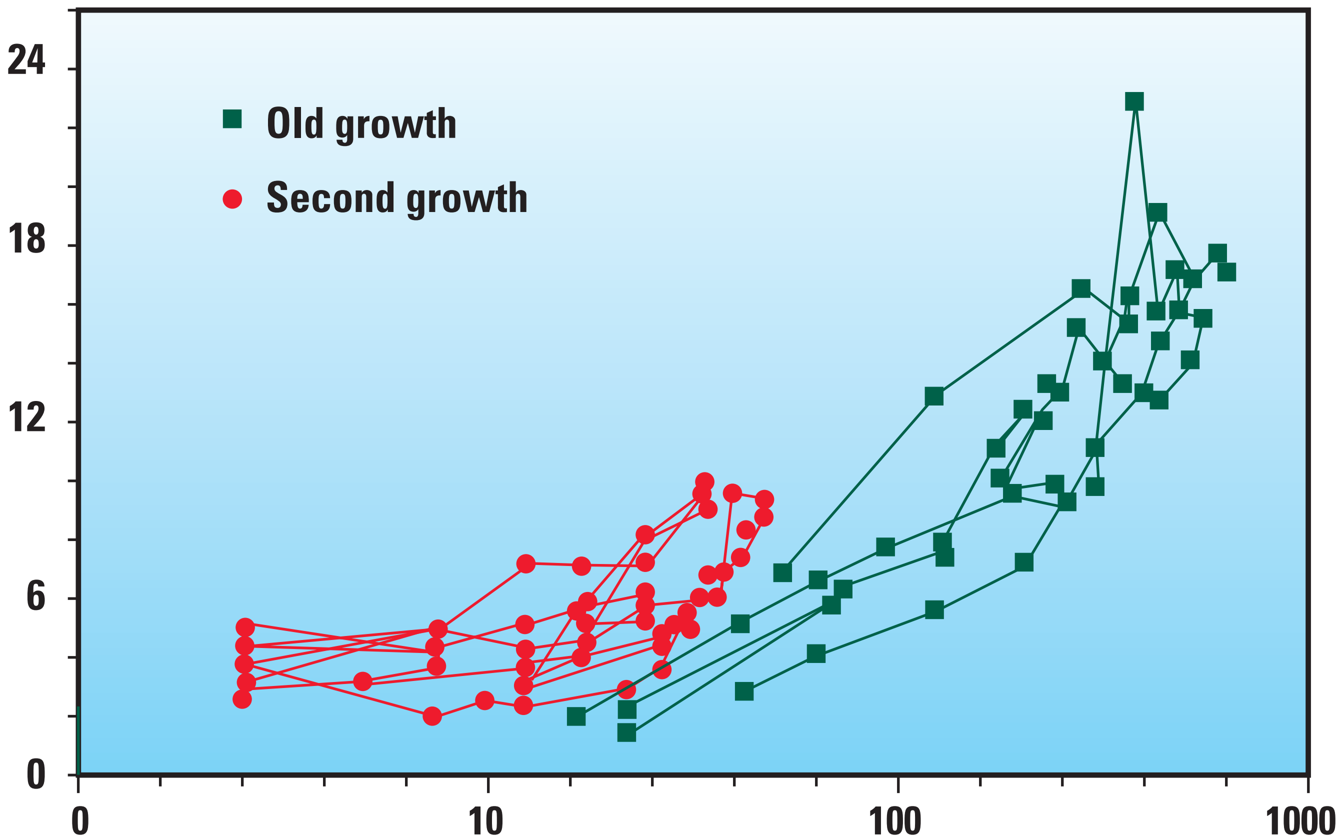
This overhead shows fibre length as a function of age at five height levels in 50 year old Douglas-fir trees (from Forintek's Douglas-fir Task Force). Fibre length was measured for each five-year interval for the first 15 years, and in 10 year increments thereafter. Rapid increase is evident for the first 25 years of growth at all height levels; this levels off gradually, as shown here. With the exception of the BH sample (where fibre length is about 15% shorter), trend-lines are very similar at the other four height levels.

Based on work done to date, it is likely that in all Canadian softwoods fibre length is shortest next to the pith at all height positions in the stem, and it increases gradually outward with age. This means that sawmill chips taken from tree tops, thinnings, and from peeler cores will yield shorter fibres (by at least 1 mm) than chips taken from the outer parts of logs (like sawmill slabs and edgings).

Other researchers have reported a close correlation between fibre length and fibril angle, linking increased fibril angles with shorter fibres; contributing to the lower strength and stiffness of crown-formed (juvenile) wood.

Western Redcedar

Ethanol:Benzene extractives (%)



Overhead 42

This overhead shows why we see hollow western redcedar logs on logging trucks during our travels in the province. Younger wood, like the first 50–100 years of growth in this example, does not have as much extractives as the older wood (>200 years in this example). The results of this work also suggest that a certain loss in extractives occurred in the innermost heartwood of the old-growth trees, particularly for the first 100–200 years.

Consider also the large amount of extractives in the >300 year old wood; 16–18% by weight! Every 6 kg of wood contains about 1 kg of extractives!

Interestingly, **extractives** do not figure in the chemical composition of wood, because by definition they are extraneous substances in wood.

Extractives are formed and deposited in cell cavities and cell walls at the time when sapwood “dies” and turns into heartwood. Extractives often impart significant colour and decay resistance to wood. They can be put into solution, using neutral solvents (not acidic or basic) like water, alcohol, cyclohexene, etc. In fact this is what happens when we make tea or coffee; we drink extractives dissolved by hot water.

When woods are naturally resistant to decay and insects, it is attributable to the toxic and repellant nature of their extractives. This is the case with western redcedar and yellow-cypress.

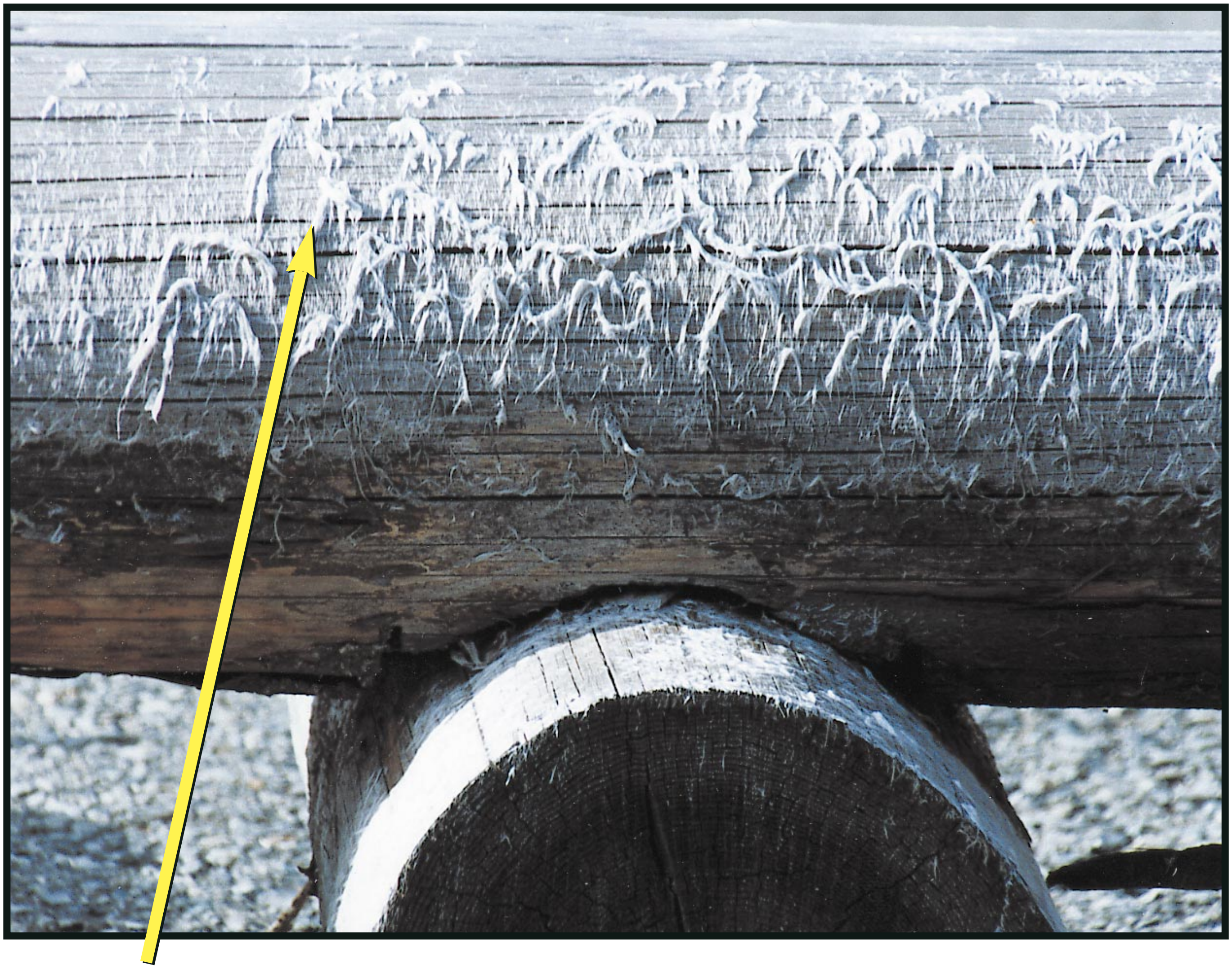
In western redcedar thujaplicins are responsible for the fungitoxic nature of heartwood. Thujic acid has juvenile hormone properties against a variety of insects, while methyl thujate is responsible for the odour of the heartwood. Plicatic acid is responsible for the health effects found in some workers.

Overhead 42a

Unfortunately, there can be one major problem with these extractives in certain situations because they are water soluble. My colleagues at Forintek studied barn shakes on an experimental roof, at UBC's Malcolm Knapp Research Forest at Haney, and found 25%, 90% and 100% reduction in **thujaplicins** in the exposed butt regions after 1, 3 and 5 years exposure, respectively. This leaching explains why in service decay starts in the butts, and progresses upwards through the shake or shingle. It must be emphasized that these problems can develop only in extremely wet and warm climates, when houses are shaded by trees, litter accumulates on the roof, and the shakes remain moist almost year-round.

For these reasons even western redcedar shakes and shingles should be protected in climates with high decay hazard, using pressure treatment with chemical preservatives.

Evaluation of chromated copper arsenate (CCA) pressure treated shakes have shown high retention at the butt ends after 11 years of exposure (at Haney).



Wood fibres from U.V. (ultraviolet) exposure damage from sunlight.

Overhead 43

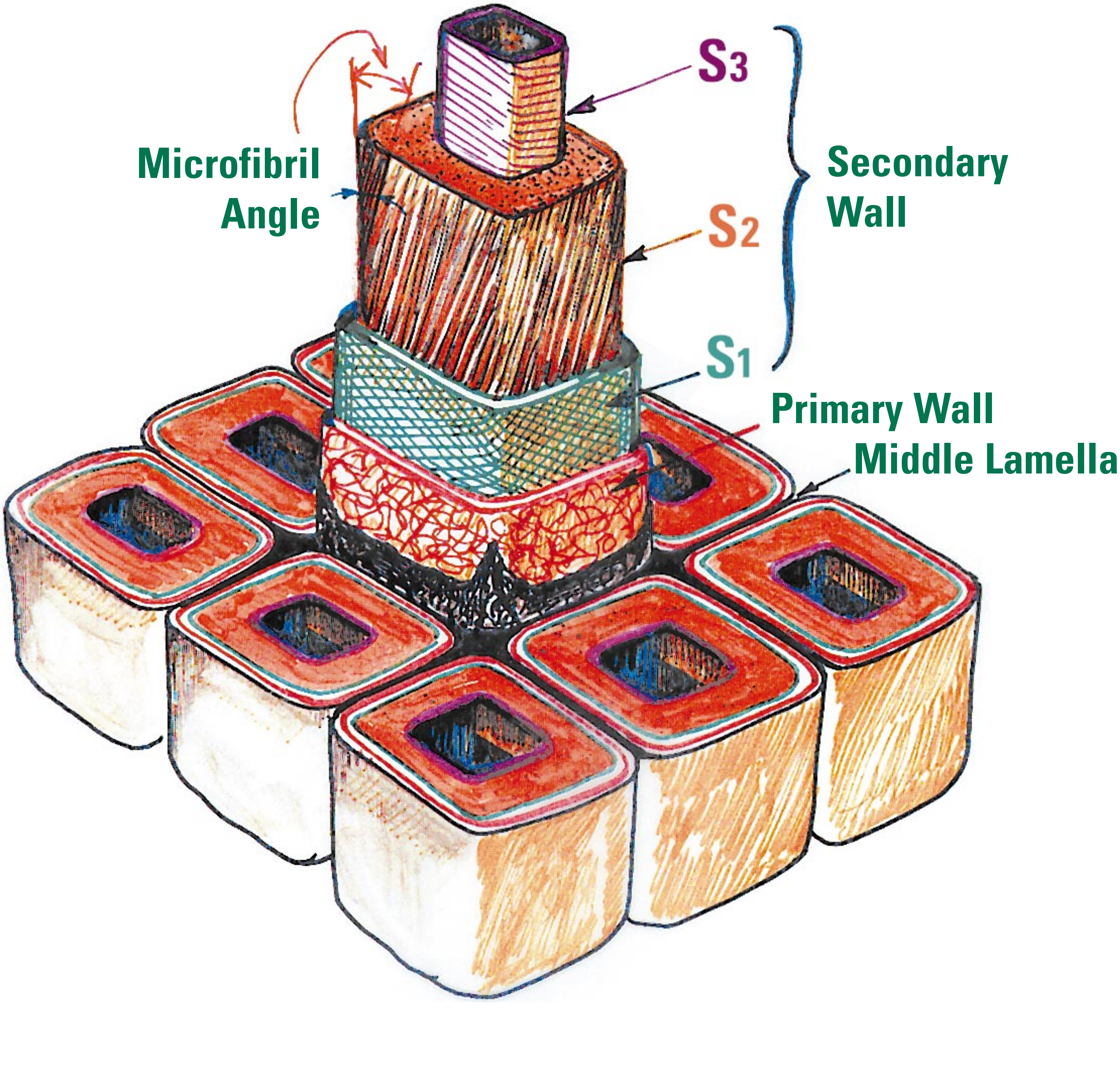
Because of photochemical degradation by ultraviolet light, about 1 millimetre erosion rate was documented in eight years for untreated shakes with a southerly exposure at the UBC test site. This erosion rate was reduced to less than one-fifth with CCA preservative.

This Douglas-fir bumper-log is from the parking lot at the Mesachie Lake Research Station. Note fibre bundles washed by rainwater, and trapped on slivers of wood. Ultraviolet exposure created a slow pulping process, by dissolving the lignin bond between fibres.

71-year-old open-grown
lodgepole pine.

Overhead 44

To close our discussion of crown-formed (juvenile) wood, lets look at a 71 year old open-grown lodgepole pine tree with live crown to the ground, thick branches, and excessive taper.

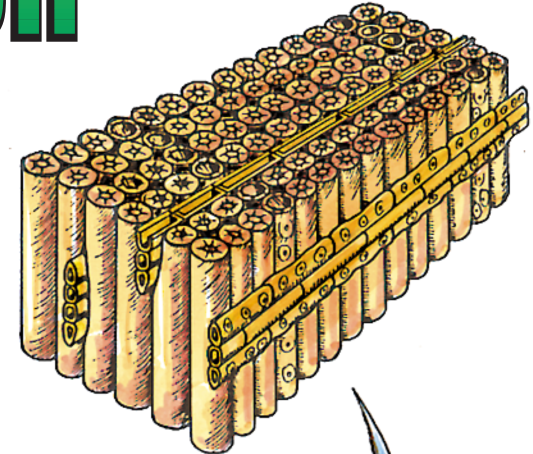

S3
Microfibril
Angle
Secondary
Wall
S2
S1
Primary Wall
Middle Lamella

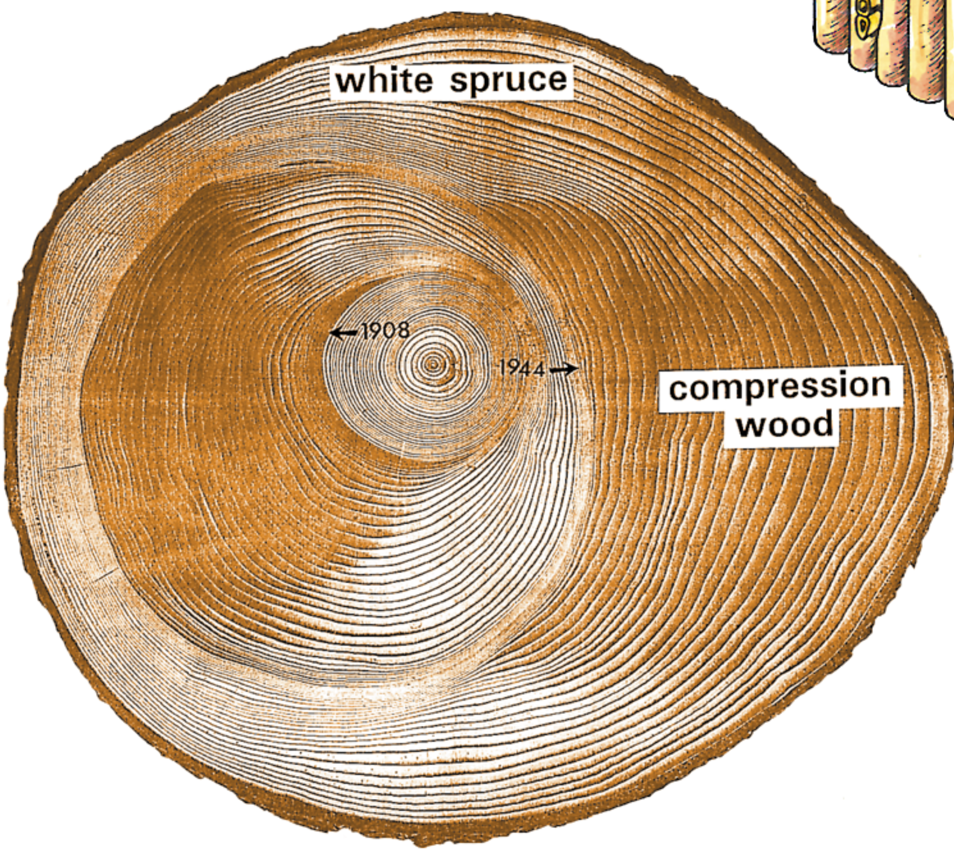
Overhead 45

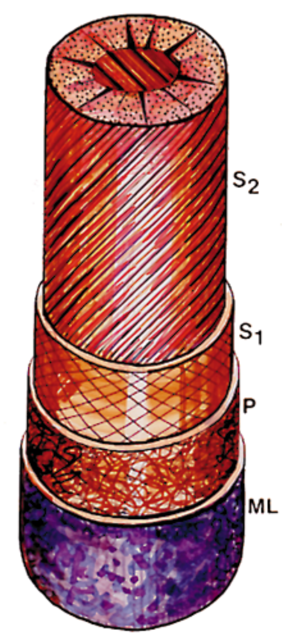
To introduce the concept of **compression wood,** we should review the layered structure of the fibre wall in **normal wood**.

The lignin-rich middle lamella is the “glue” that holds individual wood fibres together. The primary wall is made up of a loose and random weaving of cellulosic microfibrils, intermixed with lignin. In the secondary wall, made up of S1, S2, and S3 layers, the cellulosic microfibrils are closely packed. The S2 layer is the thickest of the three (from 3 to 15 times thicker in EW and LW), as a result has the greatest impact on strength and shrinkage/swelling. As discussed earlier under crown-formed wood, particularly important is the orientation of microfibrils in the S2 layer.

Compression Wood







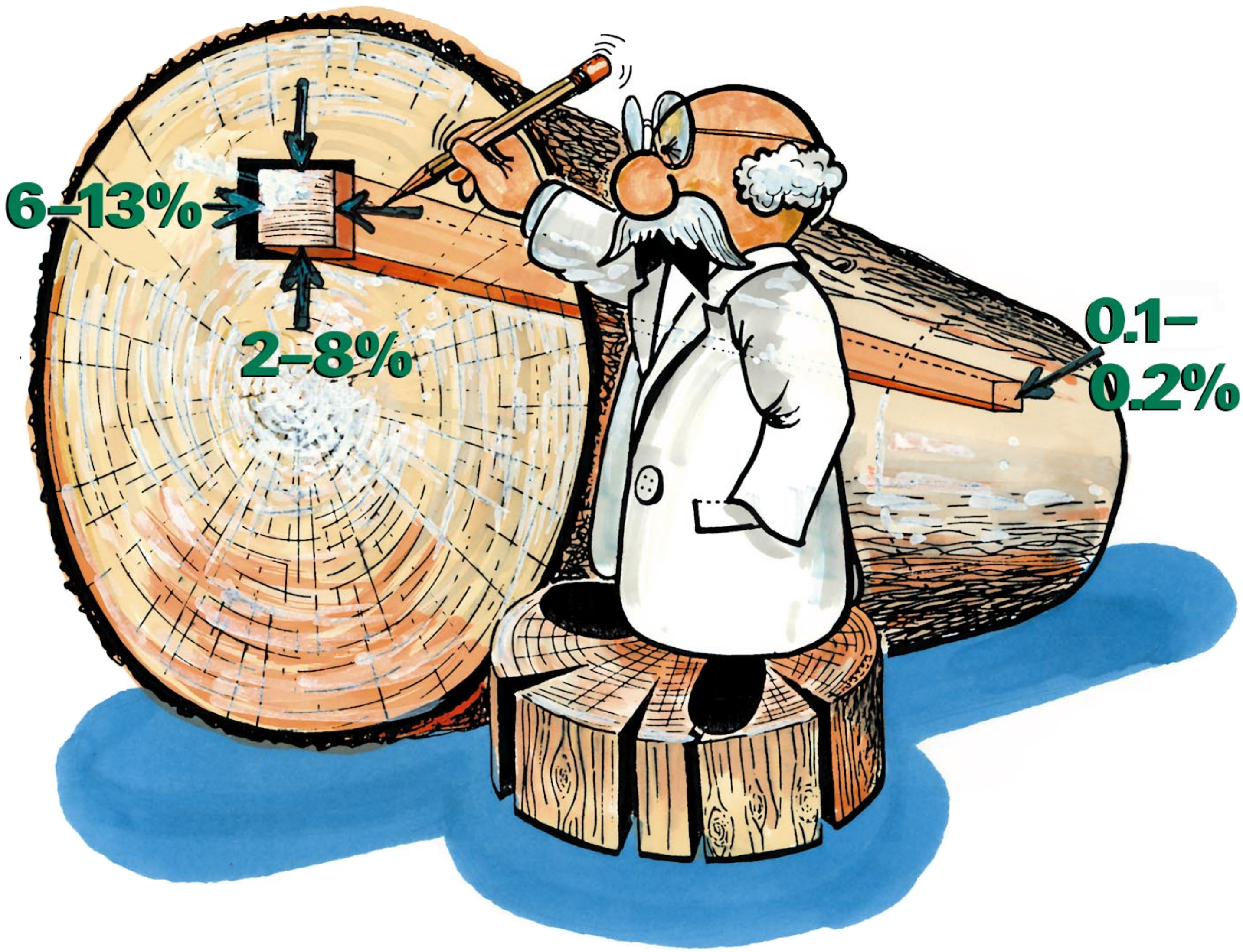
Overhead 46

This white spruce cross section was collected in the early 1970s in Mackenzie River Valley, NWT, for studying landslide activity in the Mackenzie Valley Pipeline corridor. This tree was growing in the upright position from 1876 to 1908, when a landslide pushed it to the left into a leaning position. In 1944 the tree was tilted to the right by another landslide event. Note that there are the same number of rings in the compression wood zone as in the opposite wood zone.

In cross section, compression wood fibres are always rounded, leaving voids (intercellular spaces) where the fibres come together. Compression wood annual rings seem to be composed entirely of latewood, and therefore the wood is very dense. Unfortunately, compression wood is very weak because of the 45 degree microfibril orientation in the S2 layer. Microscopic examination of the fibre wall reveals that the S3 layer is missing. Furthermore, there are deep helical checks or separations in the fibre wall, which extend from the fibre cavity right through the S2 layer. It must be emphasized that these are not drying checks, they exist in the wet and living tree. These helical checks contribute to the opaque appearance of compression wood in transmitted light; the helical checks refract light, while normal wood fibres transmit light not unlike “optical fibres”.

Discuss silvicultural implications in late-thinning tall, slender trees, that get pushed into permanently leaning position, hence growing “useless” compression wood. Don’t do it! Consider ht/diam.!

Typical Shrinkage Values for "Normal" Wood

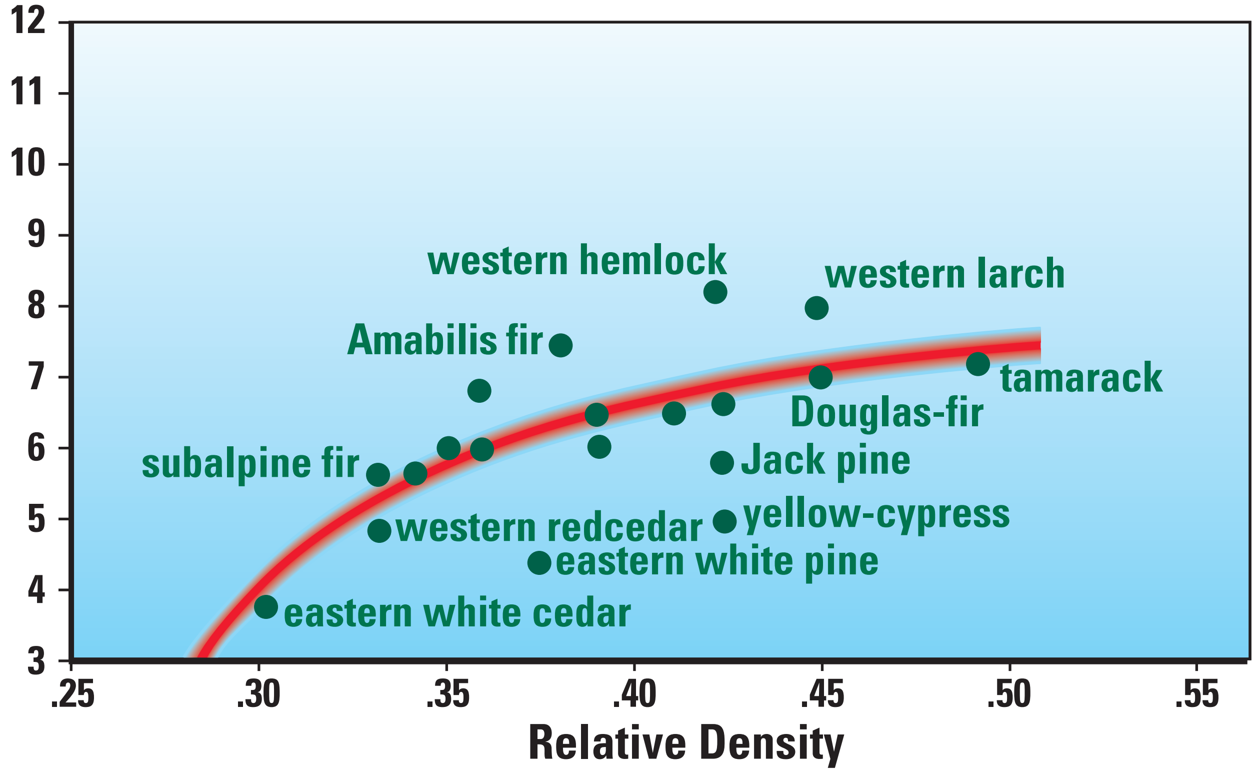


Overhead 47

Typical shrinkage values for “normal wood”. Review the anisotropic nature of wood, contrasting edge grain with flat grain. Ask the students for their explanation of nearly 2× shrinkage in flat grain (tangential section).

Ask for examples of end-uses where flat/edge grained wood is preferred. “Hot buttons” include appearance, even wearing, and dimensional stability.

% Volumetric Shrinkage at 12% MC



Overhead 48

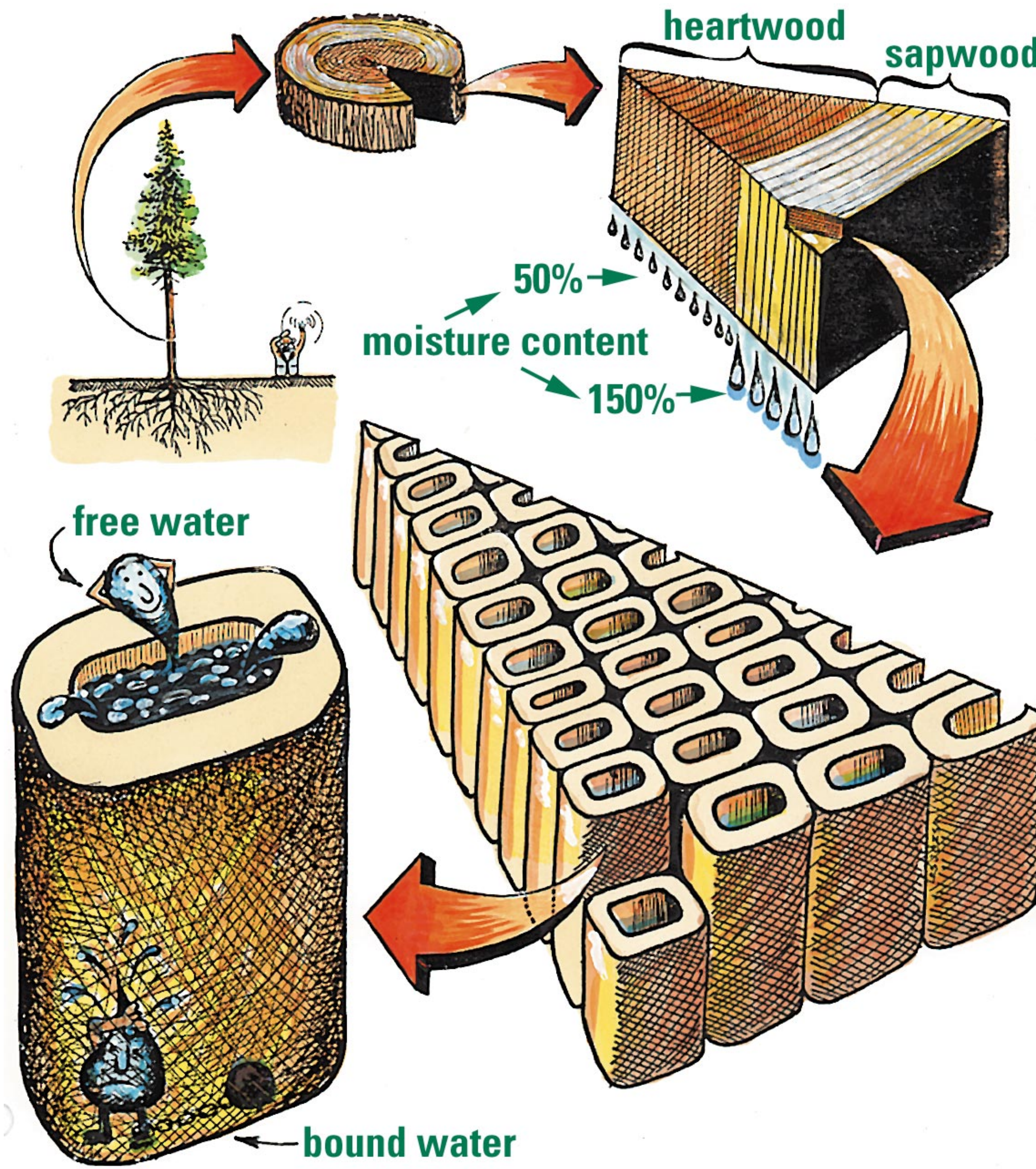
Higher density woods shrink more than light woods, although there are notable exceptions when we zoom in on western hemlock and yellow-cypress. Invite suggestions for rationalizing these differences (extractives, fibril angle, etc.).


WHY DRY WOOD ?
VOL. 1

Overhead 49

Explain the main reasons for drying wood, and why foresters/silviculturist should concern themselves with lumber drying. The main reason they started drying lumber in the Interior was shipping charges were based on weight. Apparently, it was cheaper to remove the water through lumber drying than paying for transporting the water. More importantly, proper drying provides dimensional stability, and prevents moulding and decay.

Swedish and German scientists surveyed 100 professional carpenters, asking them to list (in order of importance) the most important characteristics of structural lumber products. Dimensional stability was the number one requirement! The study conclusions and recommendations included the suggestion that no carpenter should be allowed to enter the trade without six months prior forestry experience. Also, all potential foresters should have at least six months experience on a framing crew, or in carpentry.

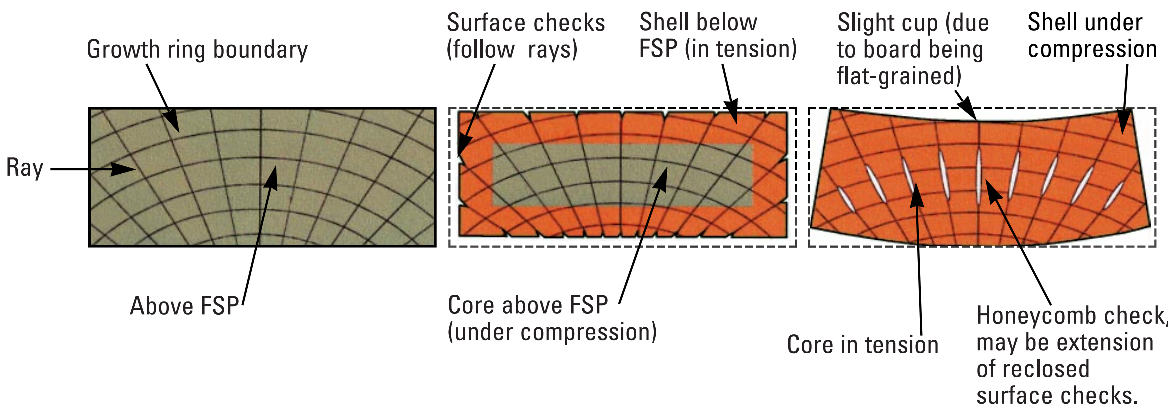

heartwood
sapwood
50%
moisture content
150%
free water
bound water

Overhead 50

To demonstrate the concept of free and bound water, start with two identical dry cellulose sponges. Draw everyone's attention to the identical thickness, width, and length. Put one of the dry sponges into a bucket of water, until it is fully saturated (squeeze it a couple of times). Pull out the wet sponge, dripping water, and make a size comparison with the dry one; it is thicker, wider, and longer, because of its swollen state. If we squeeze the wet sponge, free water pours out. Similarly, we can squeeze out free water from wet wood, as in hitting green lumber with a hammer in nailing; we can see water spurt out (and sometimes feel it on our face). Now squeeze out all the water from the wet sponge, by wringing as hard as you can. One can even use dry paper towels to wick water away. A point will be reached when no more water can be squeezed or blotted from the sponge, yet it remains flexible and damp to the touch. It is still the same size as was when dripping wet. Therefore, removing free water from wood (sponge) will not result in shrinkage. This state, as in wood, is the fibre saturation point: the fibre cavities are emptied of free water, but the fibre walls are saturated with bound water. Shrinkage starts to happen when we start removing some of the bound water.

The Process of Wood Drying

Drying Stage:	I	II	III
Moisture Condition:	Above fibre saturation point (FSP) throughout: Drying begins with loss of free water from surfaces.	Shell now below FSP, core still above FSP. Core moisture migrates outward to shell.	Below FSP throughout, eventually reaches uniformly low EMC.



Stress Condition:	Stress-free	Shell tries to shrink, creates tension across surfaces, squeezes the core into compression. Drying sets shell in oversized condition.	Core now trying to shrink away from oversized shell. Core develops tension, pulls shell into compression.
Defects:	Defect-free	Surface may check; core may collapse.	Surface is casehardened; core may honeycomb.

Overhead 51

Lumber drying is explained in this overhead in three stages: moisture condition, stress condition, and drying defects in the wood.

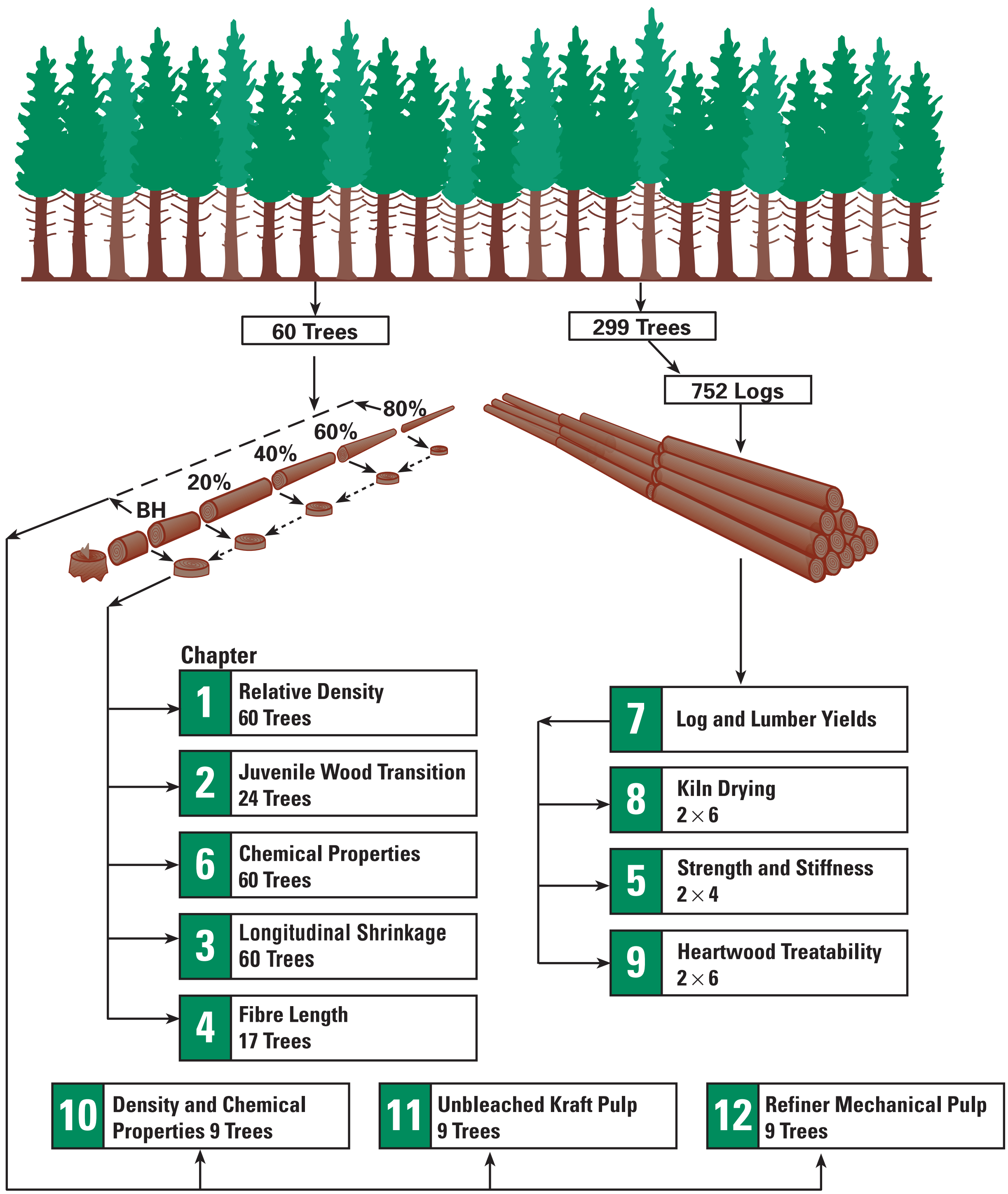
Don't show this overhead all at once! To start, expose only the title and the boxes on the left-hand side. Explain what is coming and why we aim at defect-free lumber. Next, reveal and discuss the three stages one-by-one.

In this overhead perhaps the most difficult concept to demonstrate is the set condition. One attempt is to place a medium size (length about 19 cm) rubber band over the extended fingers of one hand. Show that there is hardly any tension in the rubber bend, it sits loosely over the fingers between the first and second knuckles. This represents a stress-free piece of lumber at stage I in this overhead. Next, double over the rubber band. This causes considerable squeezing over the fingers. This is what happens in stage II in terms of stress condition; the shell is trying to shrink because it is below the fibre saturation point, but the core will not let it happen, because it is fully bulked up (its moisture content is still above the fibre saturation point). This "tug-of-war" between the shell/core, tension/compression results in the shell "giving up, and saying the heck with it, I am going to stay at this size, no matter what happens next". The shell is set.

Overhead 52

With remanufacturing lumber into secondary high-value products, stress-free lumber is very important. Excessive drying degrade can be very expensive. For example, if a large sawmill were to reduce its drying degrade by 1%, it could result in a $1,000,000 saving/profit in one year.

Second Growth Douglas-fir Resource



Overhead 53

The Douglas-fir Task Force study trees were evaluated for basic wood properties (Chapters 1–4), lumber conversion (Chapters 7–9), and for pulp and paper manufacturing. This flowchart shows the number of trees and logs studied.

Overheads 54 and 55

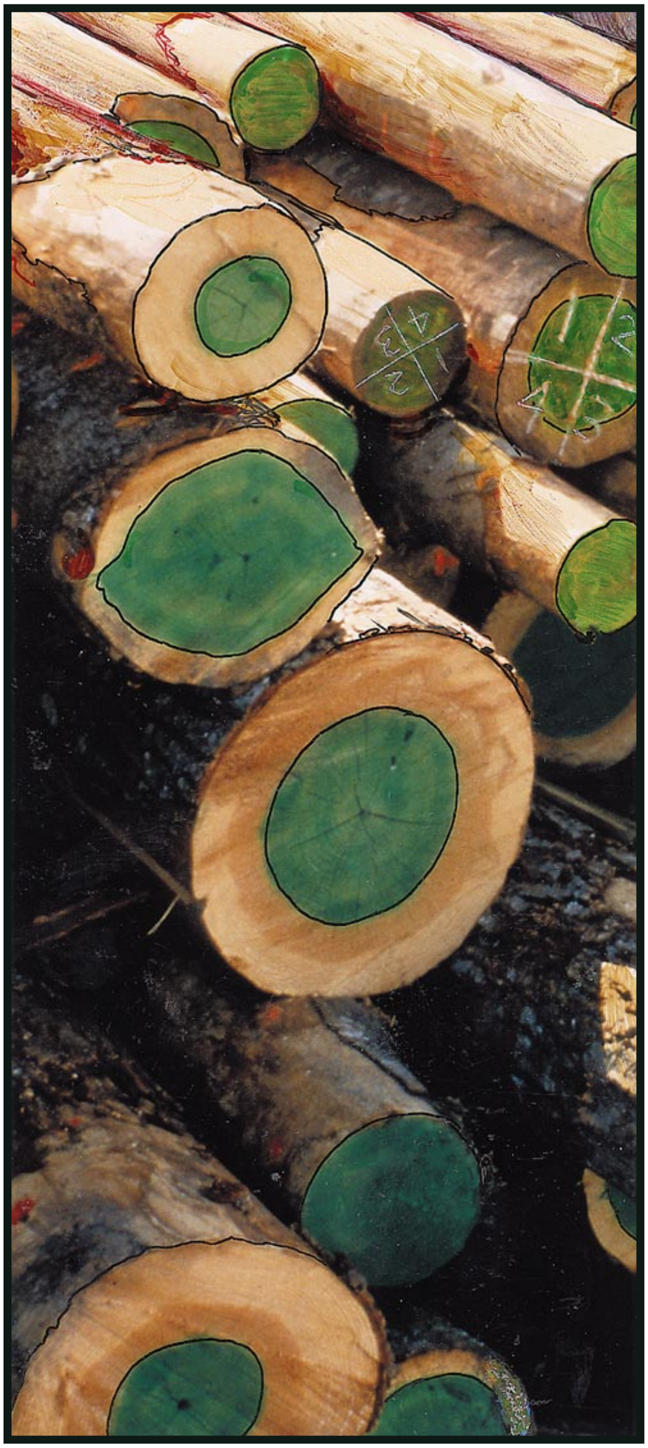
Douglas-fir log ends from 50 year old trees are marked with the first 20 years of growth and with the four quadrants for log diagramming.

Log diagramming is used to document surface indicators of log quality, which include diameter, length, taper, spiral grain, branch stubs and knot indicators, splits, breakage, rot, etc.

To keep track of our logs in a production run, food colouring was used to code log numbers (in groups of five) as they entered the sawmill. At strategic locations in the mill, additional matching colour was sprayed on each piece of lumber. This strategy, along with no end-trimming, allowed the proper identification of each board from each of 752 logs and 299 trees.

The dark centre-disks on log ends show the first 20 years of growth (juvenile- or crown-formed wood), which made up one half of the stem volumes.

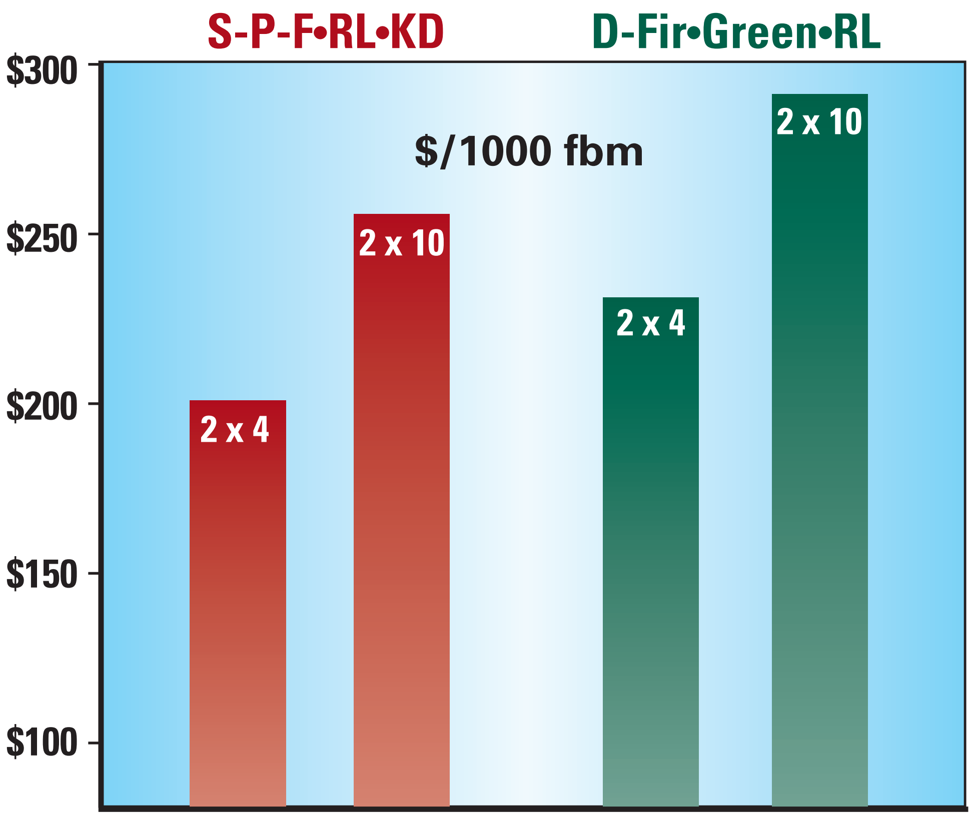
“Rainbow lumber” shows part of the end products from 50 year old second-growth Douglas-fir.



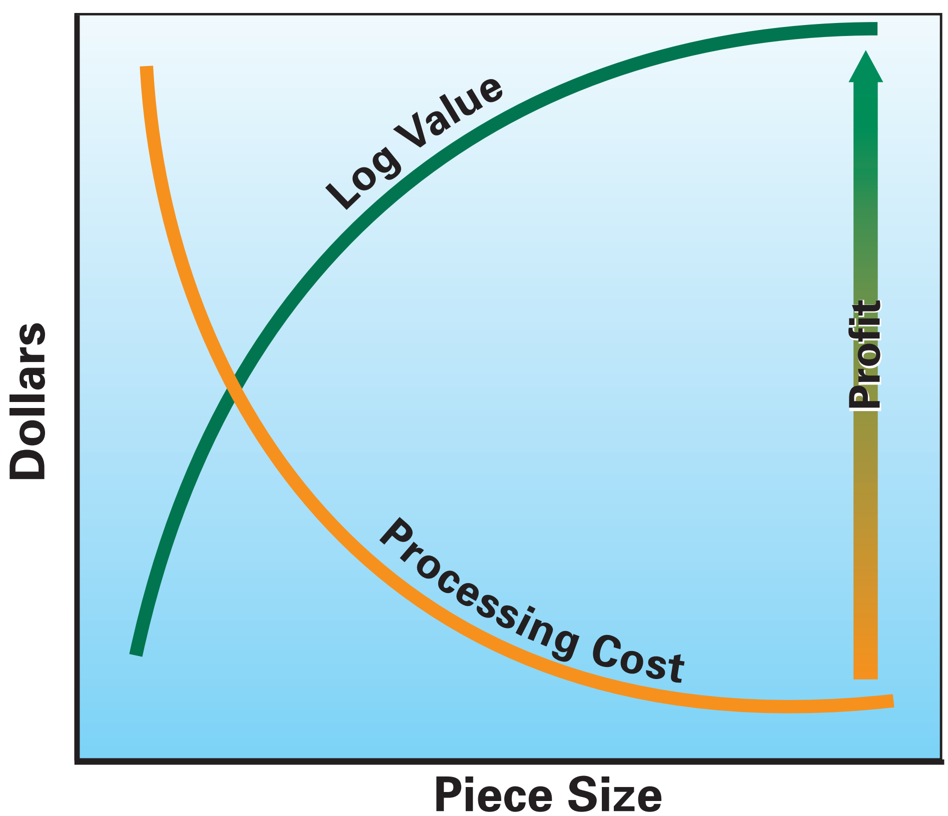
Overheads 54 and 55

See notes on previous page.

Size Premium



Random Lengths/
Key Price Indicator
January, 1992 Prices

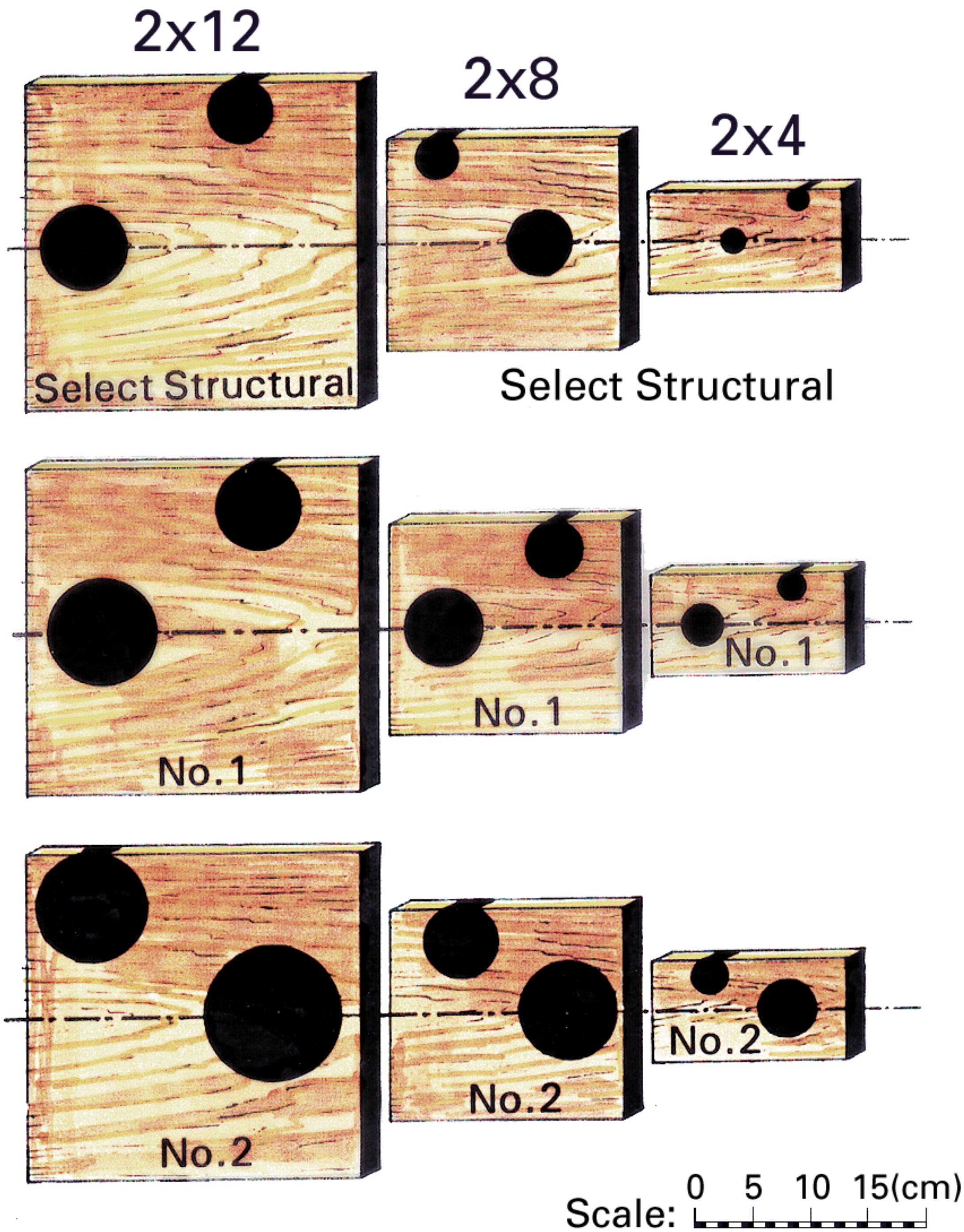


Overhead 56

Lumber prices reflect product quality differences. Price premiums have been a reality for wider widths for many decades. Some argue that in the future this not will be the case. What do you think? and Why? Why is Douglas-fir lumber more expensive than S-P-F?

Log values increase with increasing piece size. Conversely, processing costs decrease with increasing piece size.

Refer to sawmill study example where they cut on average 19 cm and 24 cm diameter logs. With the 24 cm logs lumber recovery factor (fbm/m^3) was up 7%, while productivity was 28% higher (than with the smaller logs).


2x12
2x8
2x4
Select Structural
Select Structural
No.1
No.1
No.1
No.2
No.2
No.2
Scale: 0 5 10 15(cm)

Overhead 57

In visual lumber grading **knot size** is just one of the many variables that determines lumber grade. This illustration shows that as piece size increases, so does the maximum knot size allowed in each grade. For example, if the No. 2 2×4 could have been cut into a 2×8, it would have made the top grade, Select Structural. Incidentally, some of our 50–100 year old dog-hair stand lodgepole pine are smaller in diameter than the maximum knot size allowed in the No. 2 2×12!

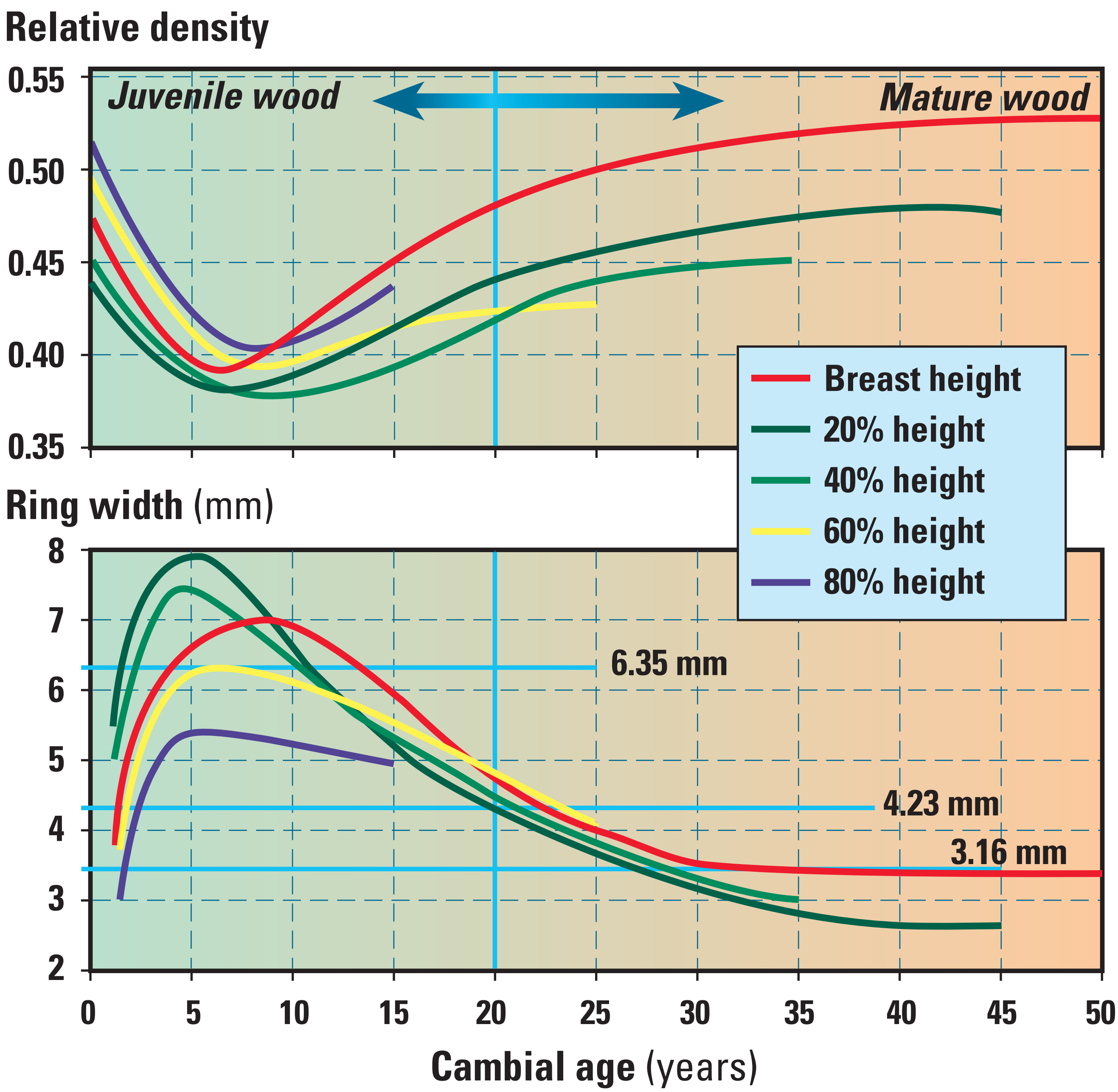
Of course, the critical factor in these grades and sizes is the amount of clear fibre that has to carry the load.

Other lumber grade determinants include: number of rings per inch, pitch and bark pockets, slope of grain, decay, insect holes, wane, etc.

In **joinery grades** (wood destined for door, window, furniture, etc. manufacturing) maximum knot size allowances are much more stringent, and a distinction is made between live and dead knots. Demonstrate these points with props.

For the 299 Douglas-fir trees, in the task force study, over 100 000 knots were measured. The overhead shows the frequency distribution of knot size, and averages.

50-year-old Douglas-fir



Overhead 58

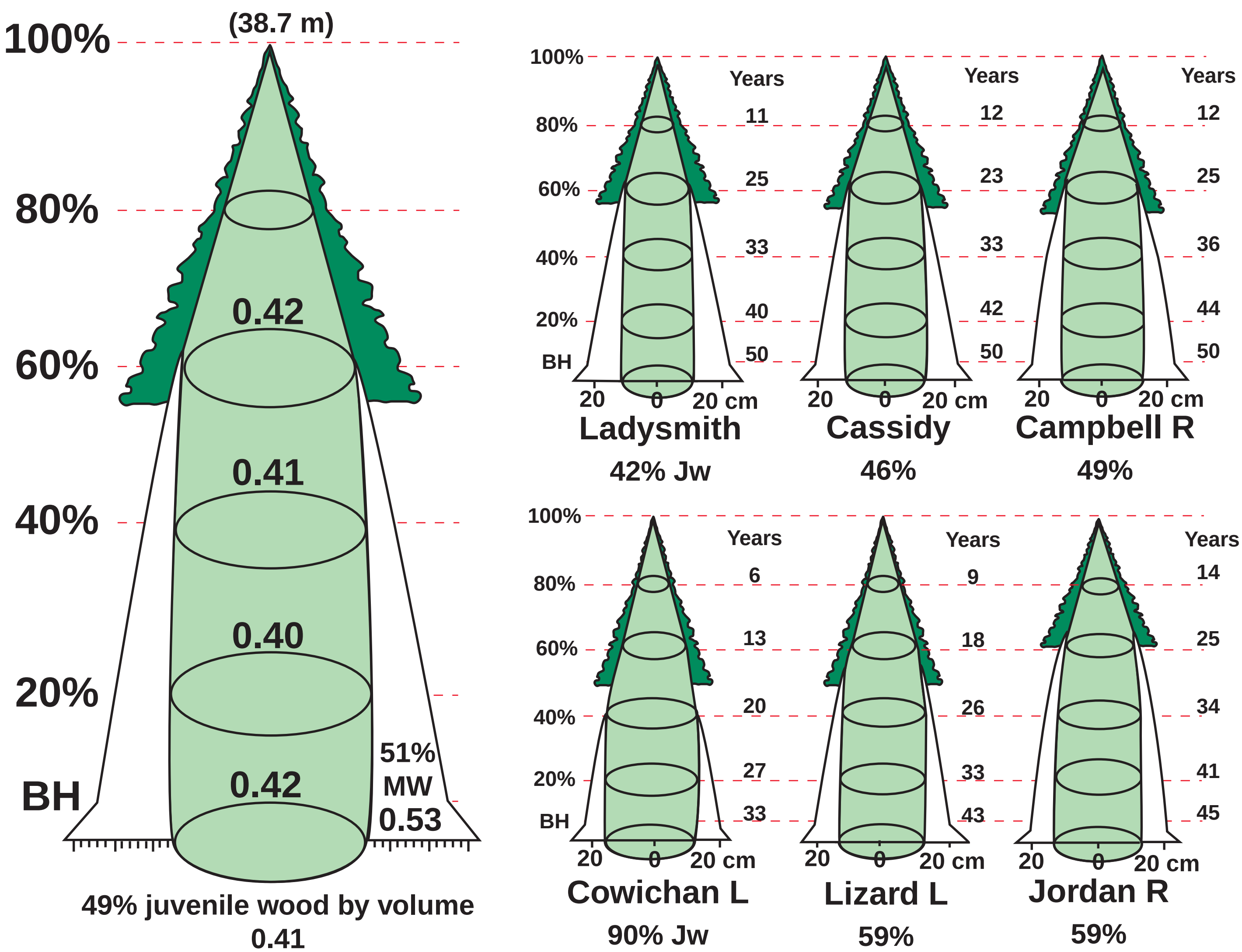
Yearly ring density and ring width trend-lines are shown here for five sampling heights, from BH to 80% tree height.

Note the following:

- With the exception of the 80% sample (because of mortality, by age 50 the top of the tree is growing in a more open environment?), wood relative density at any given age is highest at stem base.
- The higher density at 80% height could be the result of mechanical stimulation from the wind, as are the pith-associated rings at all height levels. Invite opinions from the class.
- Old-growth standard of 0.45 relative density is reached at BH at age 15, at 20% at age 22, and at 40% at age 30. At 60% height the trend-line flattened out at about 0.425.
- Minimum ring density at all sample heights was reached between age 5–10, about the same time as maximum ring width.
- From age 11–13 onward these rapidly growing trees produced more than four rings per inch (the minimum requirement for visual structural visual grades).
- From age 22 and 30 onward, these trees produced “medium” and “fine” grained wood, respectively.

Juvenile Wood Cylinder

First 20 Years of Growth in 50-year-old Douglas-fir



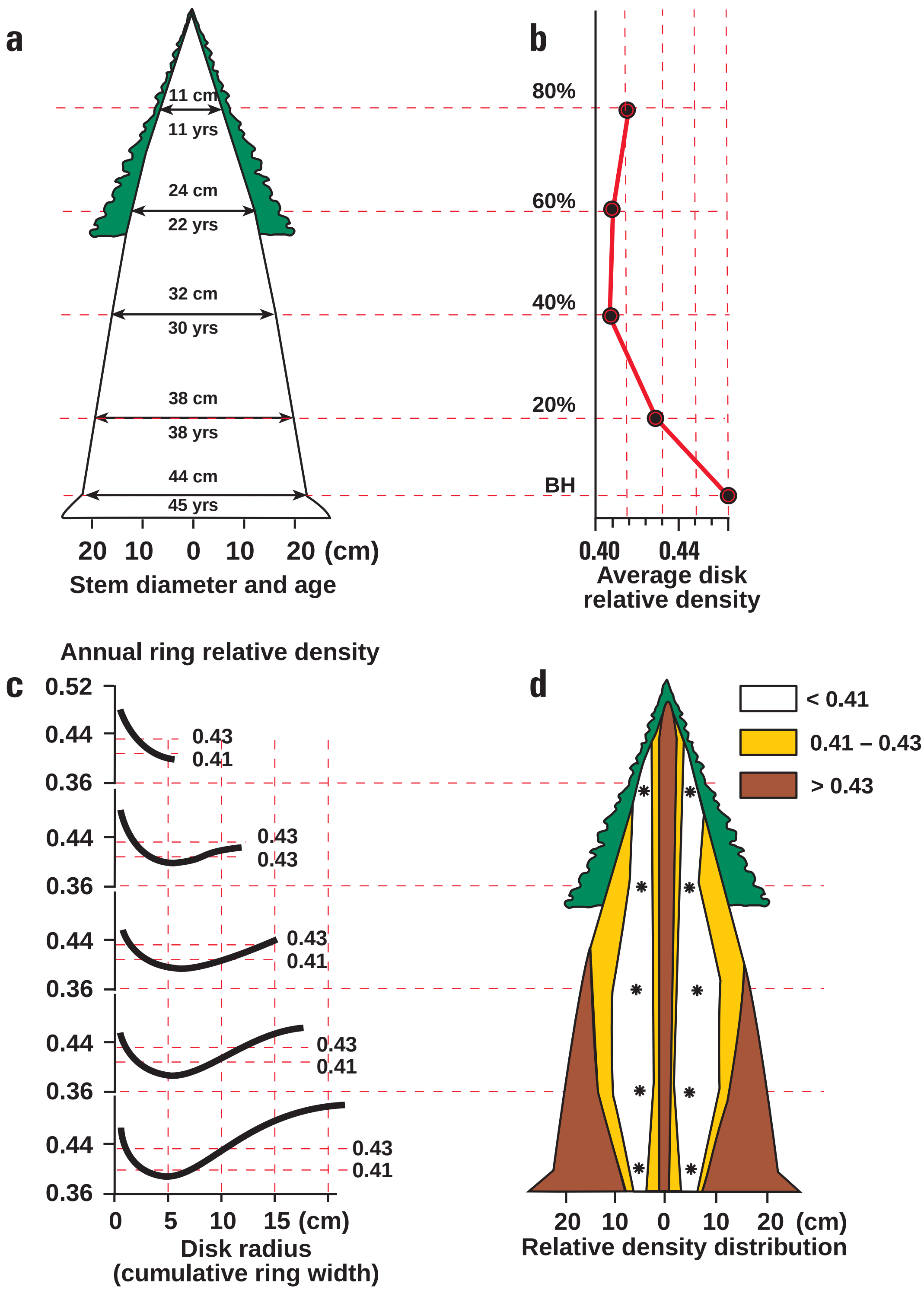
Overhead 59

Tree profiles and the size of live-crown were drawn to scale.

Note:

- About 45 % live crown for 50 year old trees at 530 trees/ha.
- Even at age 33 at Cowichan Lake, the average live crown was 50%.
- Juvenile wood (crown-formed wood) was defined as the first 20 years of growth. Note cylindrical shape.
- On average, juvenile wood had 0.41, and mature wood had 0.47 relative density.
- Mature wood resides below the live crown.
- The youngest stand was 33 years old at Lake Cowichan, and it had 90% juvenile wood. The other five stands, from 43 to 50 years of age had 42% to 49% juvenile wood.

Diameter, Taper and Density Distribution in Douglas-fir



Overhead 60

On average, these trees grew 1 cm in diameter each year, at all height levels (panel **a). Highest** density wood is in the bottom half of the tree (panel **b**). Top half in not unlike lodgepole pine (0.41), or western hemlock (0.42).

Yearly average ring density trend-lines are shown from pith-to-bark at the five sample heights (panel **c**). This is the same data that was shown in Overhead 58, except here the trend-lines are offset.

Note arbitrary density-zone demarcations at 0.41 (low), 0.41–0.43 (transitional), and 0.43 (high).

Relative density zones were mapped to show density distribution in the stemwood (panel **d**).