SIRT
Strategic Integrated Research in Timber

Edinburgh Napier UNIVERSITY

Timber material properties

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The Queen's Anniversary Prizes
For Higher and Further Education
2015

Issues

- Water
- “Figure” and “Defects”
- Anisotropy
- Inhomogeneity
- Variation and uncertainty

Definition of a tree

- A tall land plant (except when not tall)
- Living more than a couple of years
  - Perennials
    - Trunk remains from year to year

    e.g. Oak
    Pine
    Coconut
    Bamboo
    Tree fern

    ← "Proper trees" (for the purposes of today)
  - Tall herbaceous perennials
    - Trunk bit dies back each year

    e.g. Banana

Trees (for the purposes of today)

- "Softwoods"
  - Gymnosperms ("naked seeds")
    - Conifers (and gingko biloba)
    - e.g. pine, spruce, fir, larch, yew, cedar
    - Typically evergreen (but not always)

cones

flowers

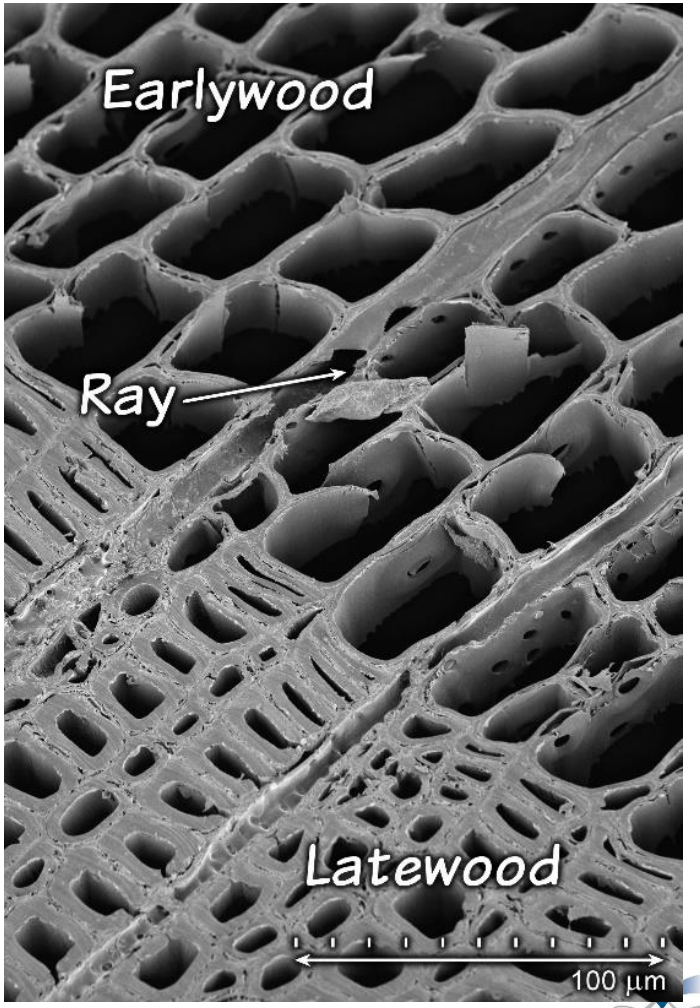
- "Hardwoods" (broadleaves)
  - Angiosperms – ("enclosed seeds")

    e.g. oak, beech, birch, teak, mahogany, balsa
    - Can be deciduous or evergreen

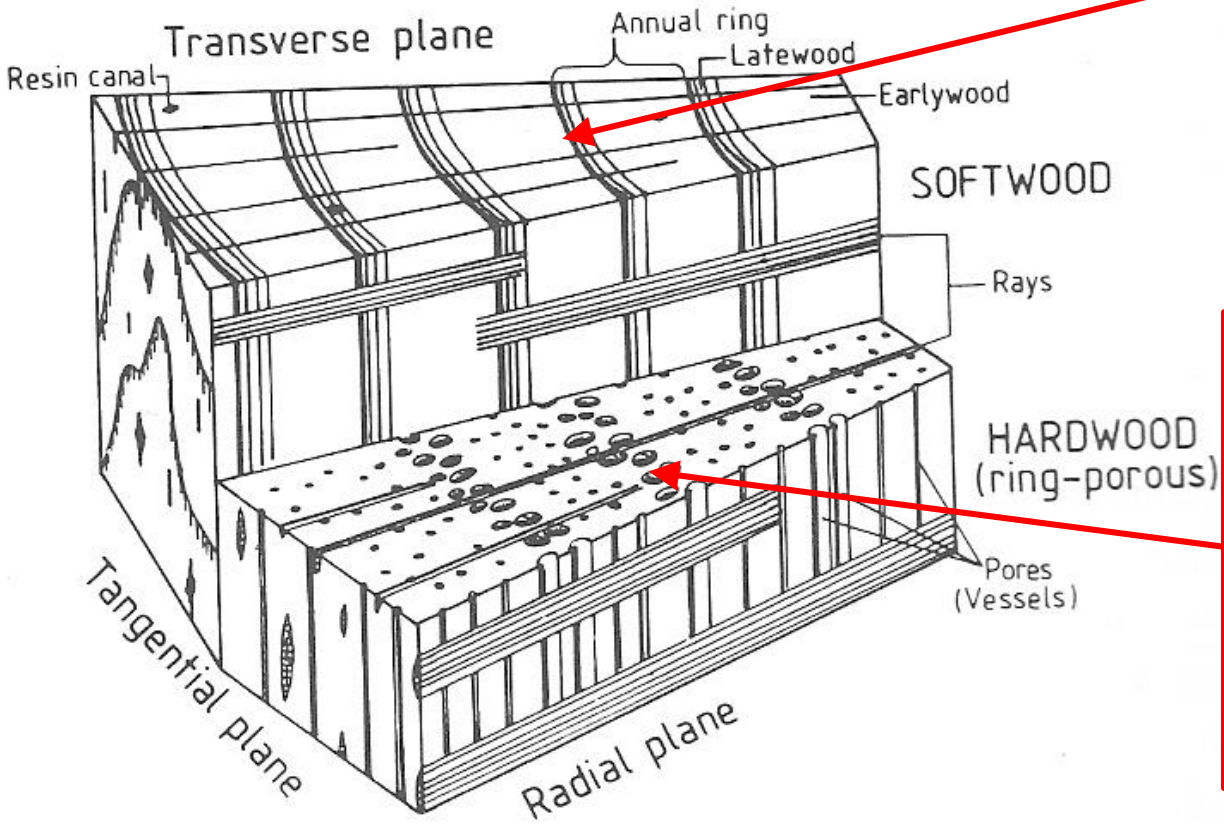

sapwood
heartwood
(might be more durable)
bark
growth is outwards
cambium
pith
AB16-S
AB16-N

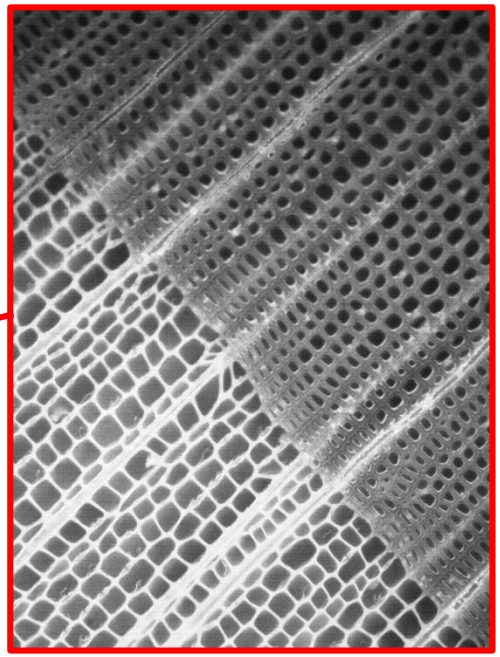
The tree rings

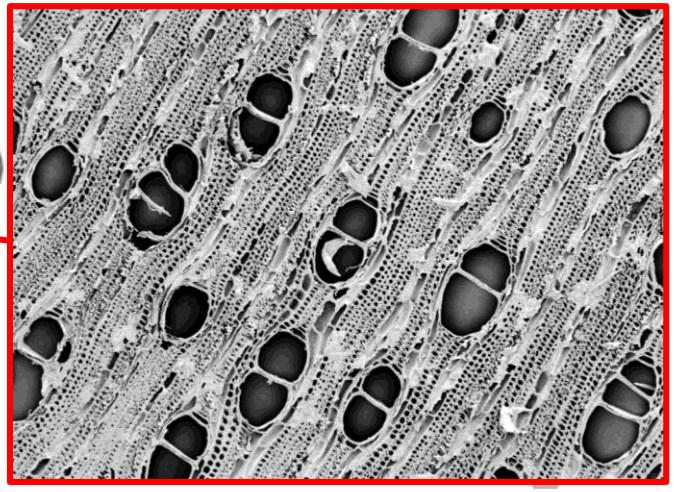
- Earlywood
  - Grown earlier in the season
  - Cells are wide with thin walls
- Latewood
  - Grown later in the season
  - Cells are narrow with thick walls



Softwoods vs hardwoods



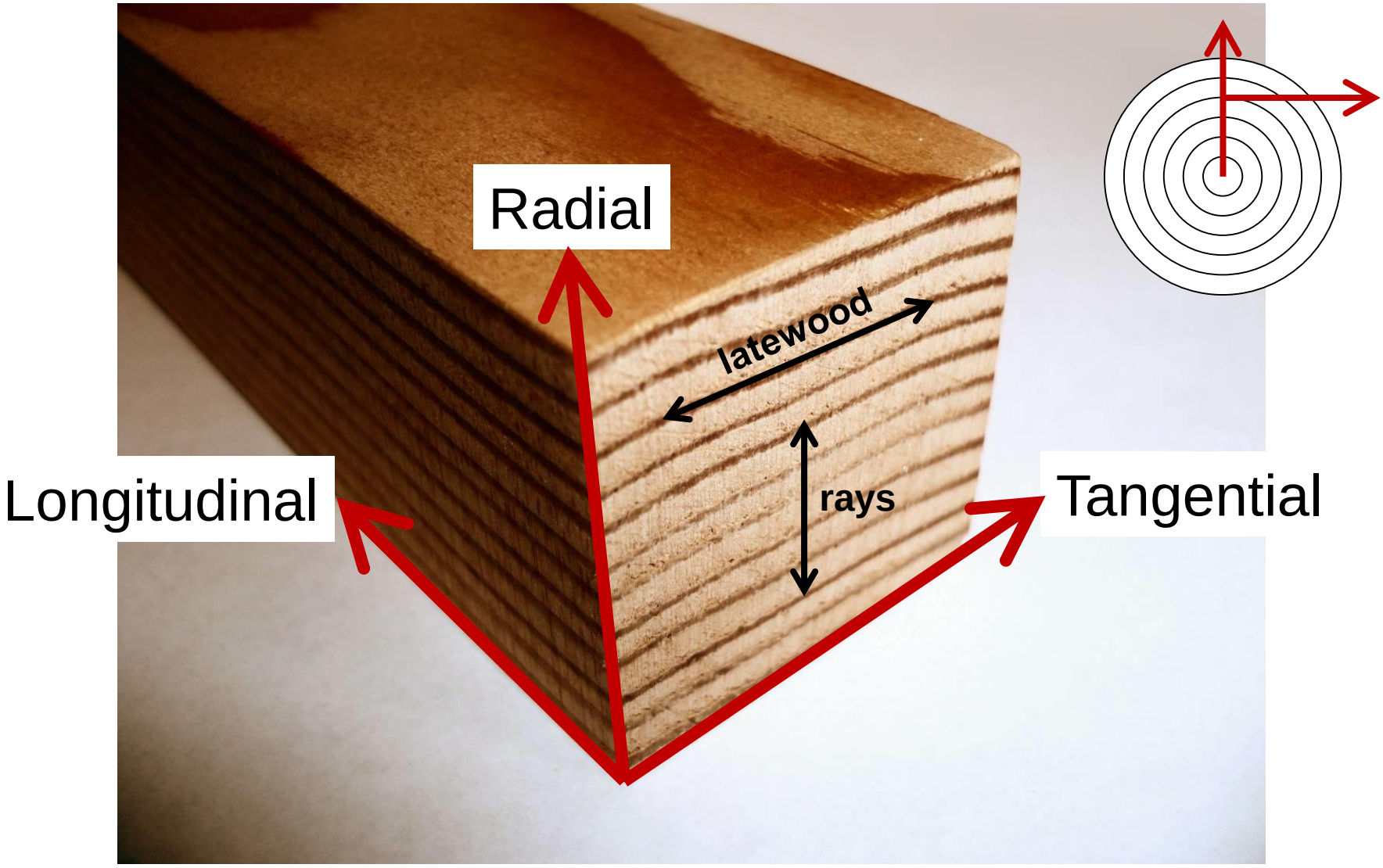




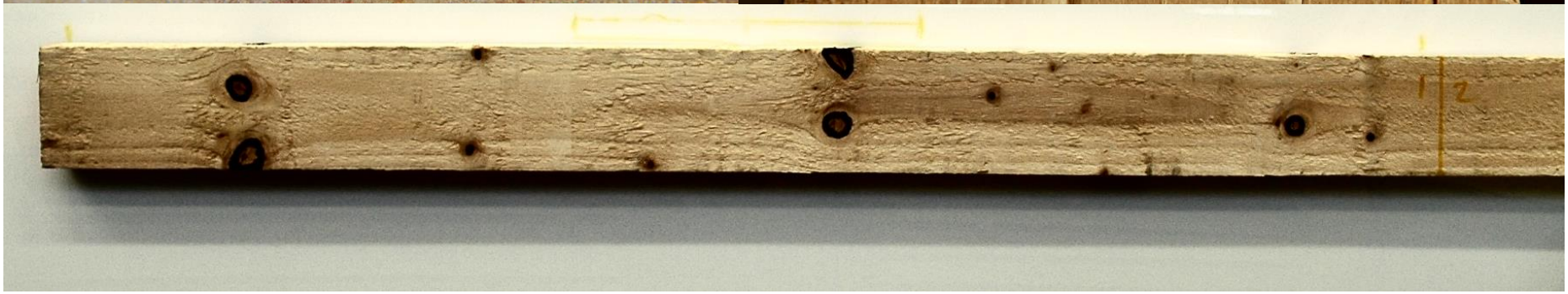
Vessels

Fengel and Wegener 1984 “Wood” Walter de Gruyter

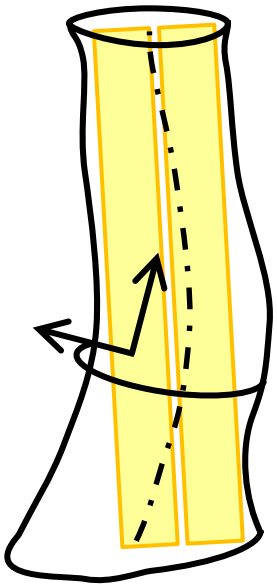
Isotropy

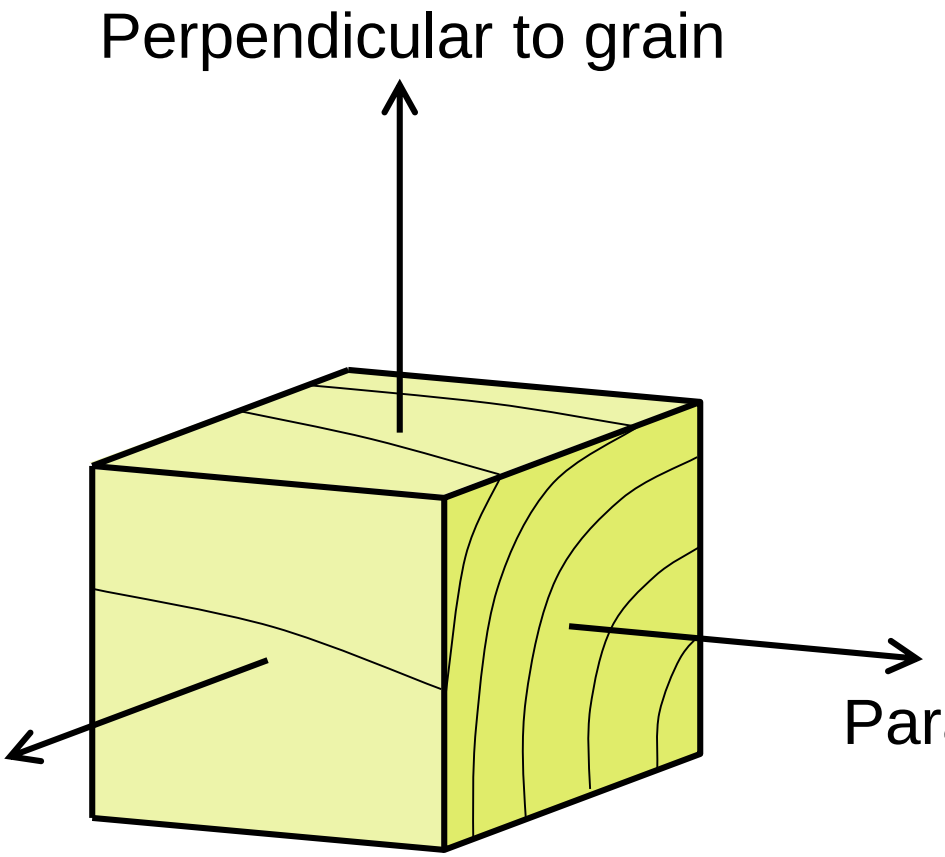


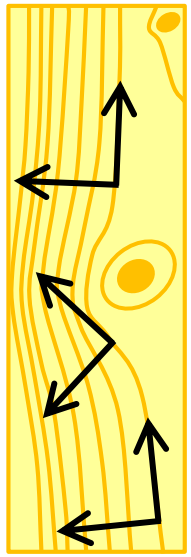
Knots and grain



Directions







Perpendicular to grain

Softwoods vs hardwoods

- Diversity
- Tree form
  - Sawn sizes
  - Knots

Constituents of wood

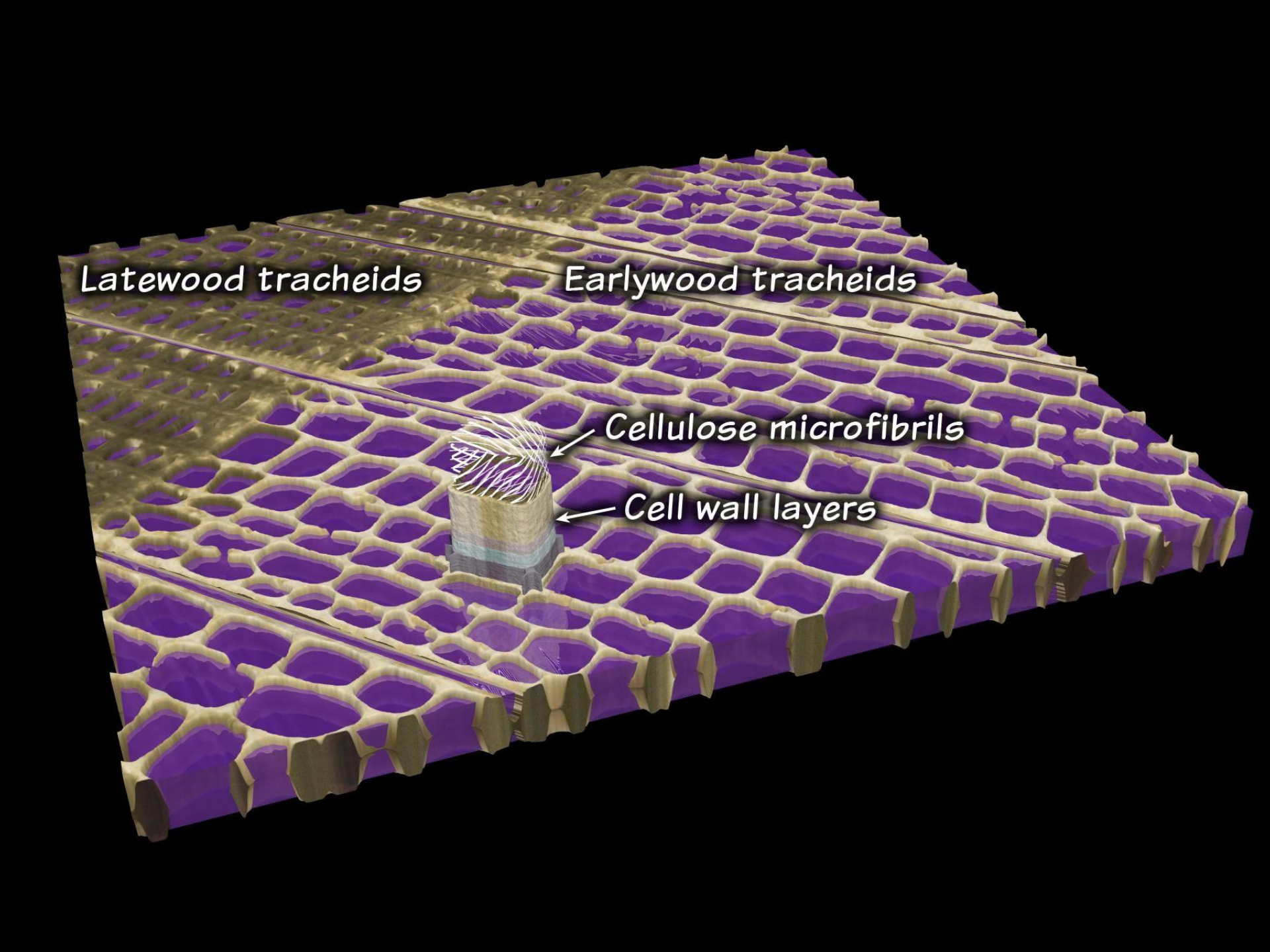
- Cellulose
  - A long polysaccharide molecule $(C_6H_{10}O_5)_n$
  - Analogous to reinforcing strand (main role tension)
- Lignin
  - A number of complex 3D biopolymers
  - Analogous to cement (main role compression)
- Hemicelluloses
  - Mixture of different sugar monomers
  - Links the cellulose and the lignin (giving flexibility)
- Extractives
- Water

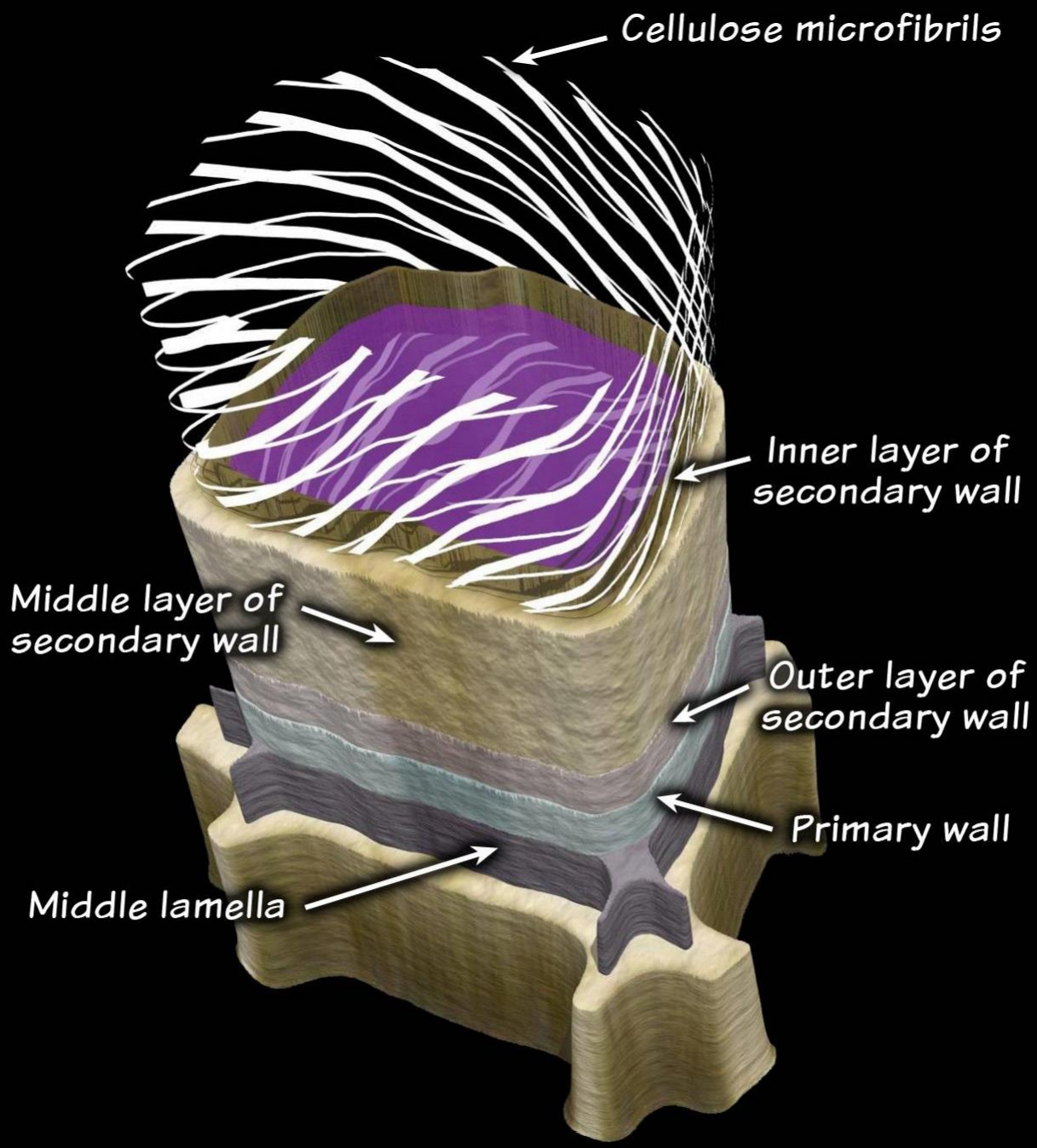
How wood is made

- Elements are
  - Carbon (C), Hydrogen (H) and Oxygen (O)
- Photosynthesis

$$n CO_2 + 2n H_2O + \text{photons} \rightarrow (CH_2O)_n + n O_2 + n H_2O$$

carbon dioxide + water + light energy → carbohydrate + oxygen + water


Latewood tracheids
Earlywood tracheids
Cellulose microfibrils
Cell wall layers


Cellulose microfibrils
Inner layer of secondary wall
Middle layer of secondary wall
Outer layer of secondary wall
Primary wall
Middle lamella

Water

- Mechanical properties depend on
  - **Moisture content**
  - Duration of loading
  - Temperature

$$\text{Moisture content} = \frac{\text{Weight of water}}{\text{Weight of oven dry wood}}$$

Moisture content

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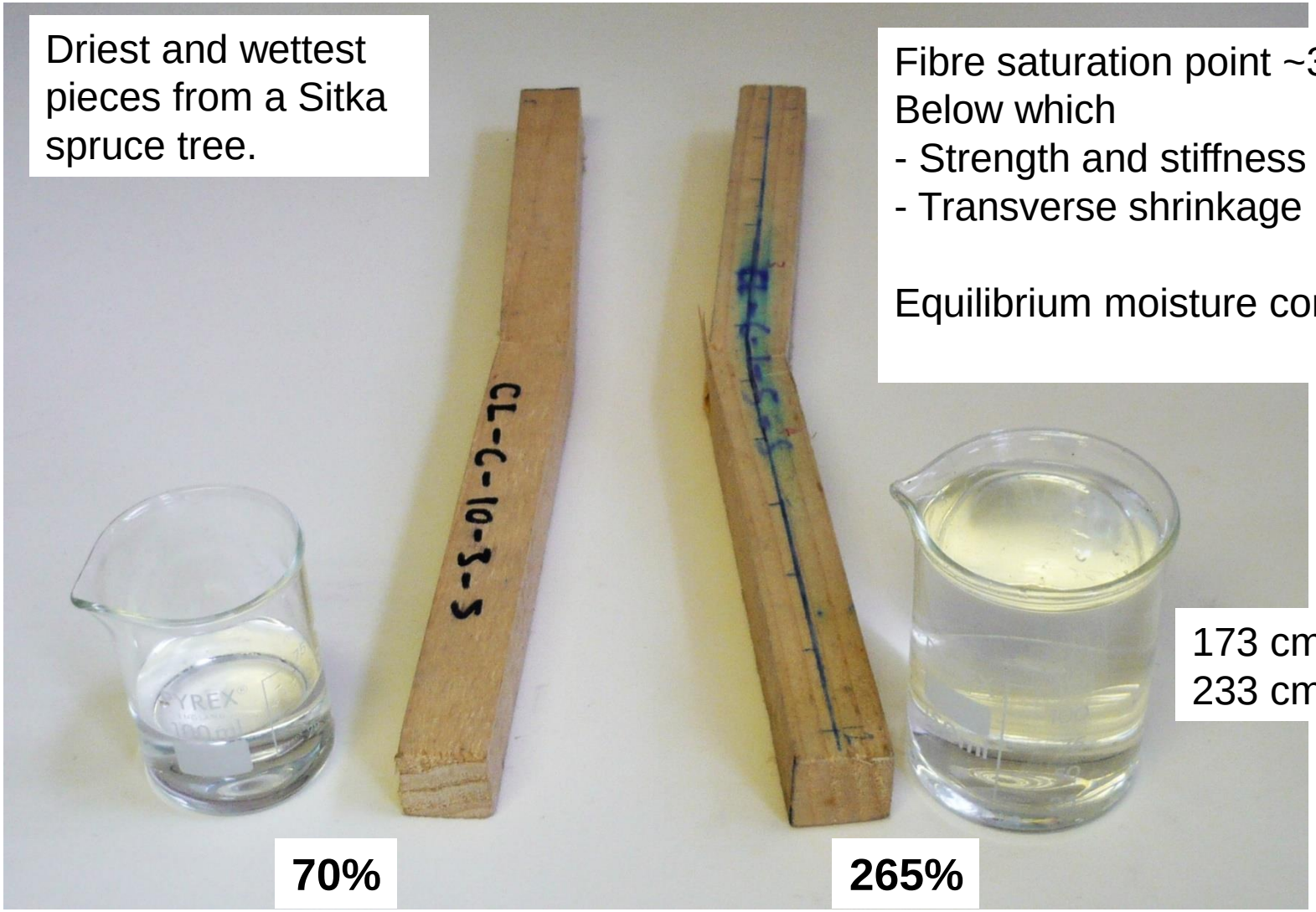
Driest and wettest pieces from a Sitka spruce tree.



Fibre saturation point ~30%
Below which
- Strength and stiffness increase
- Transverse shrinkage

Equilibrium moisture content ~12%

173 cm^3 of water in
233 cm^3 of wood

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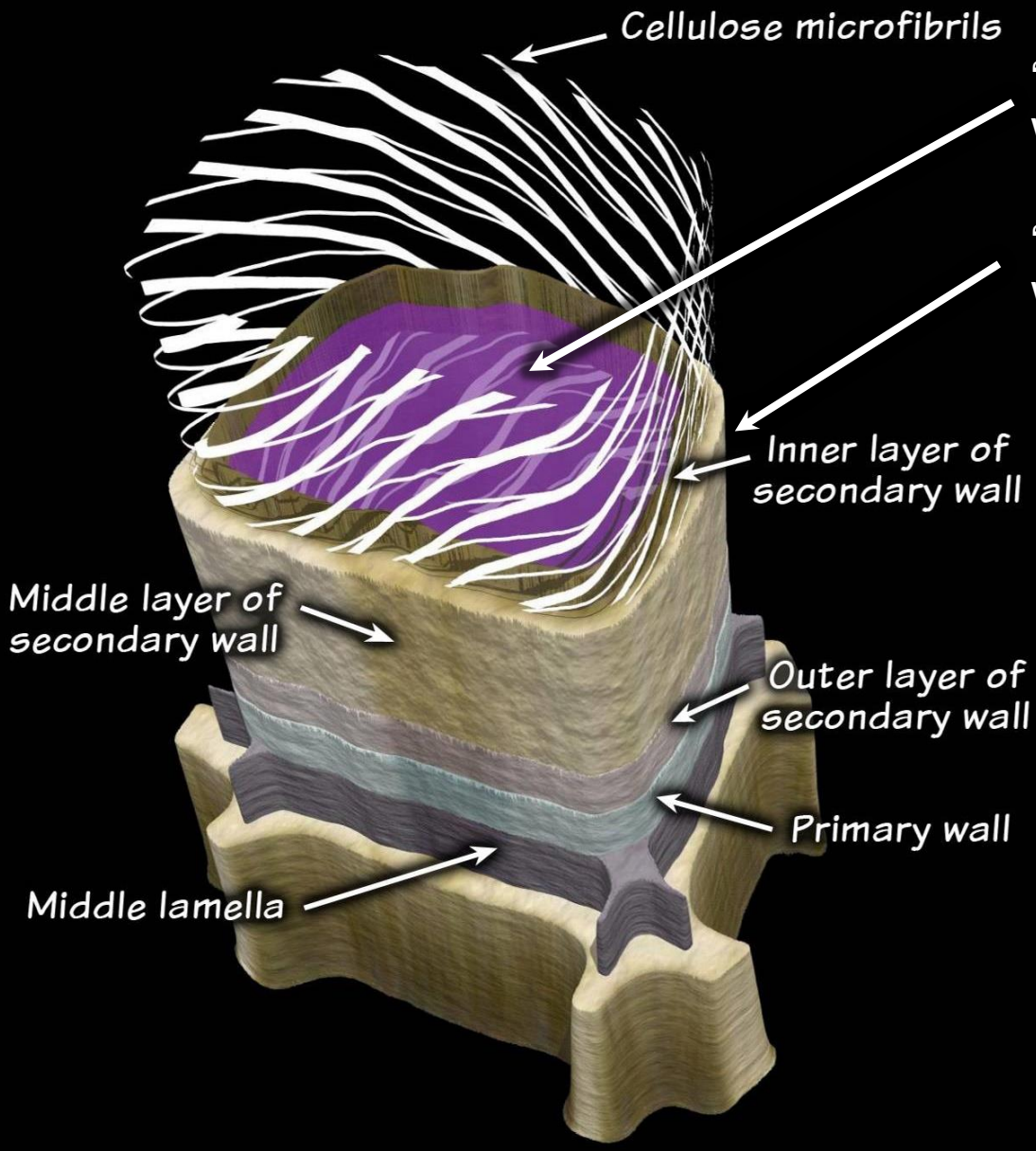
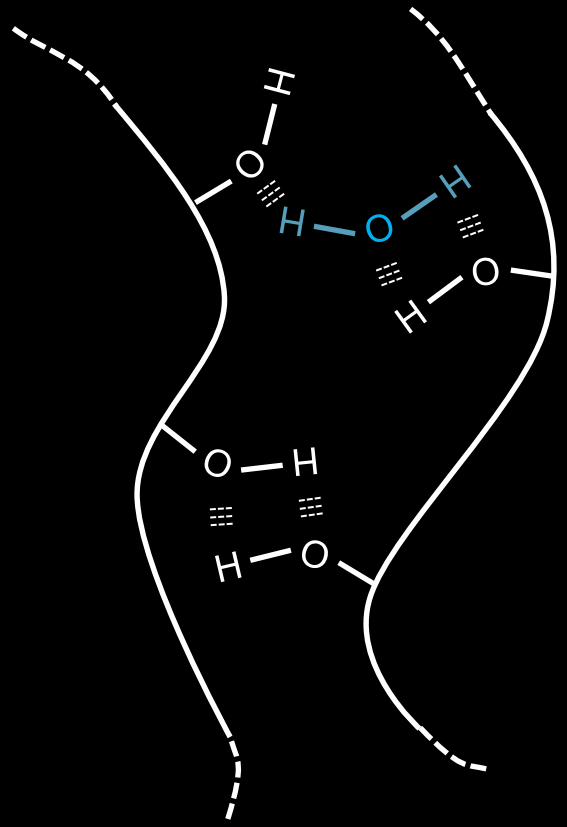


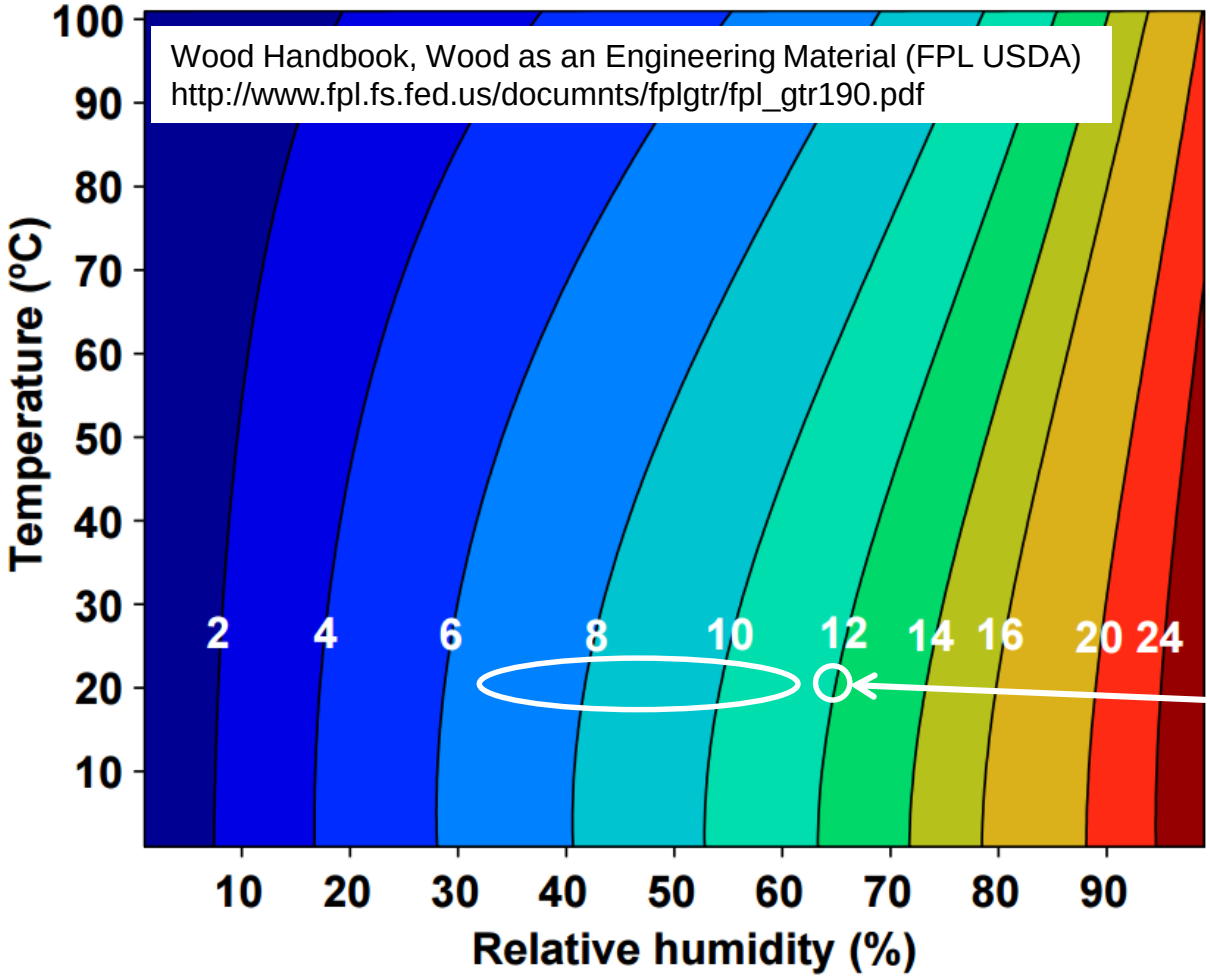
"Free water"
When mc > ~30%

"Bound water"
Water molecules in the cell wall



Equilibrium moisture content

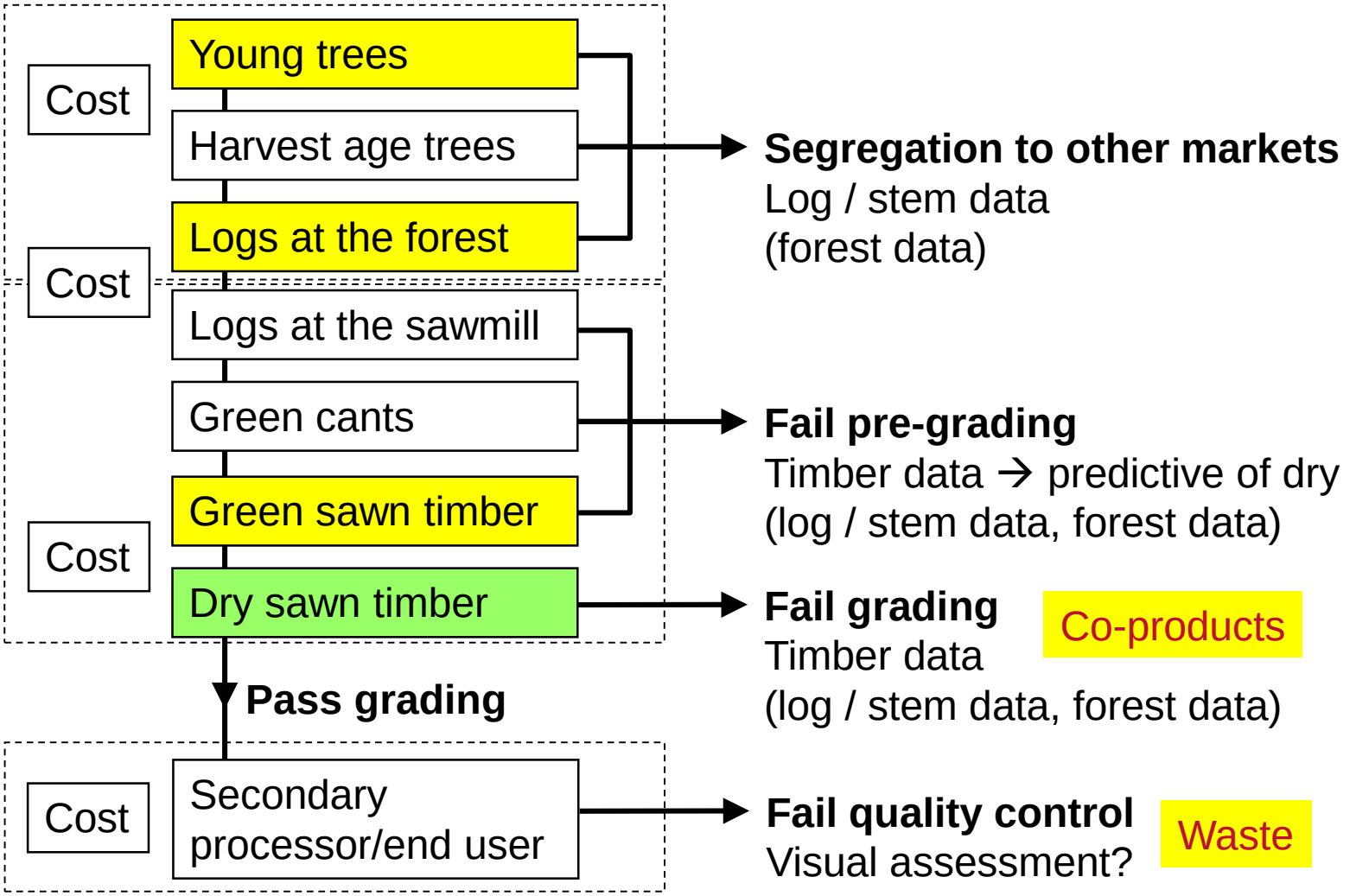
(wood not in contact with liquid water)



For practical purposes, applies to all species

Standard reference: 12%

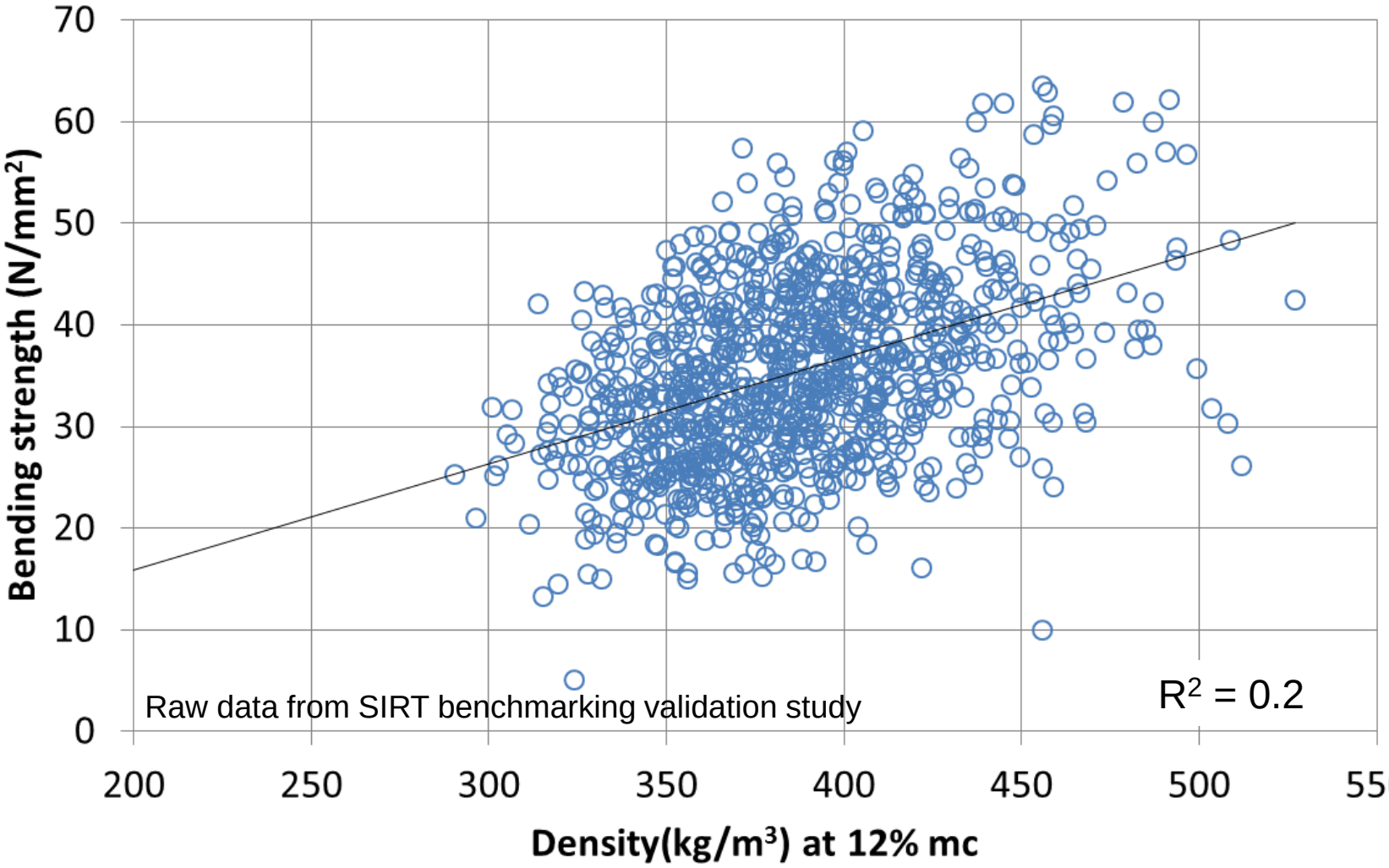
Our work - quality & wastage



British timber - misconception

- “No good for construction”
- “Because it grows too quickly”

Density and bending strength



Mechanical properties

- Amount of cell wall material
  - Wood density
- How that cell wall material is arranged
  - Grain, earlywood, latewood
  - Knots
- How that cell wall material is made up
  - Cellulose : lignin
  - Microfibril angle

Juvenile core (softwoods)

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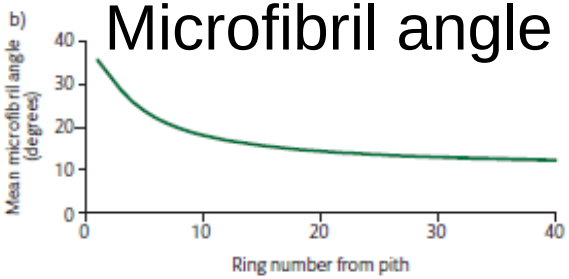
Microfibril angle



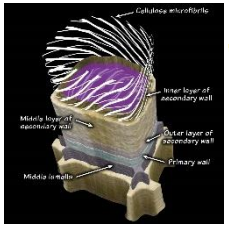
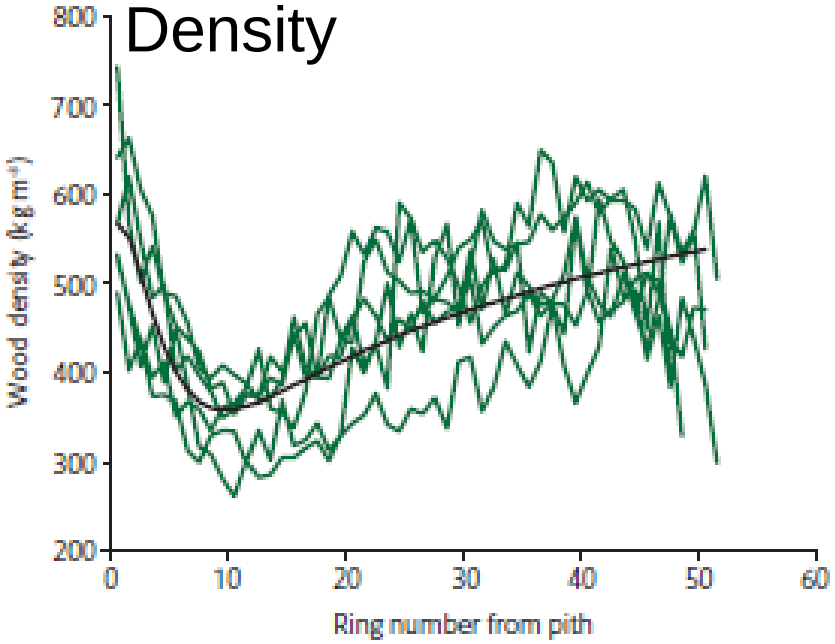


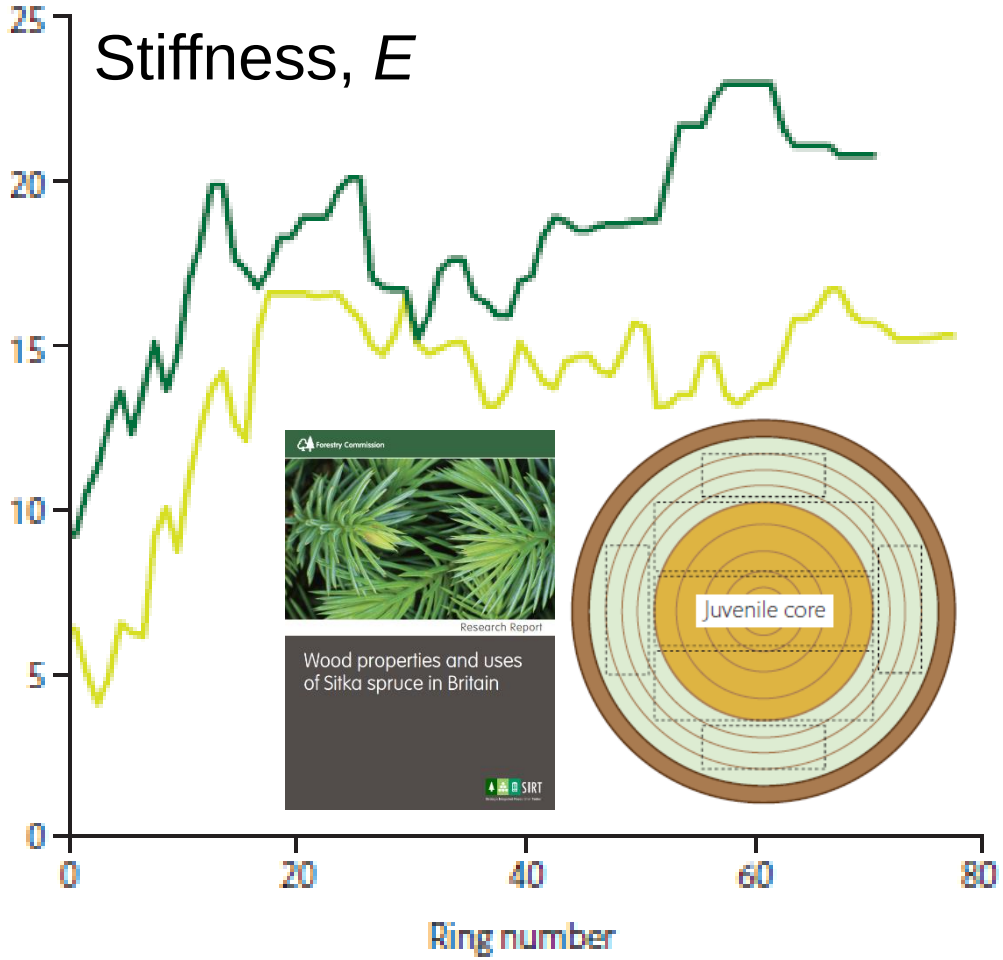
Figure 2.20 Example of the radial variation in modulus of elasticity for two specimens of Sitka spruce wood. Modulus of elasticity was estimated from data on density and microfibril angle obtained from SilviScan-3.

Figure 2.15 Radial profile of Sitka spruce wood density. The green lines show profiles for five individual trees sampled at Baronscourt in Northern Ireland, while the black line represents a model fitted to these data.

Density

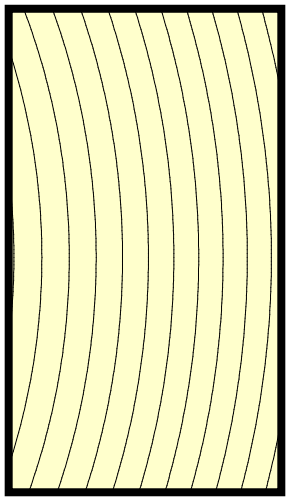


Stiffness, *E*

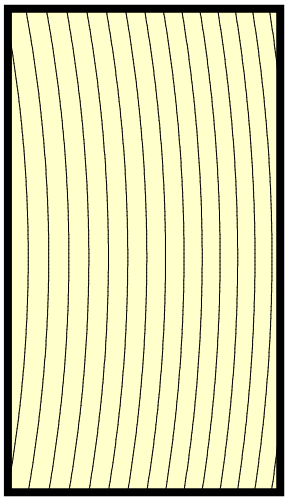


“Rate of growth”

Grew in ~11 years



Grew in ~15 years



“Rate of growth”

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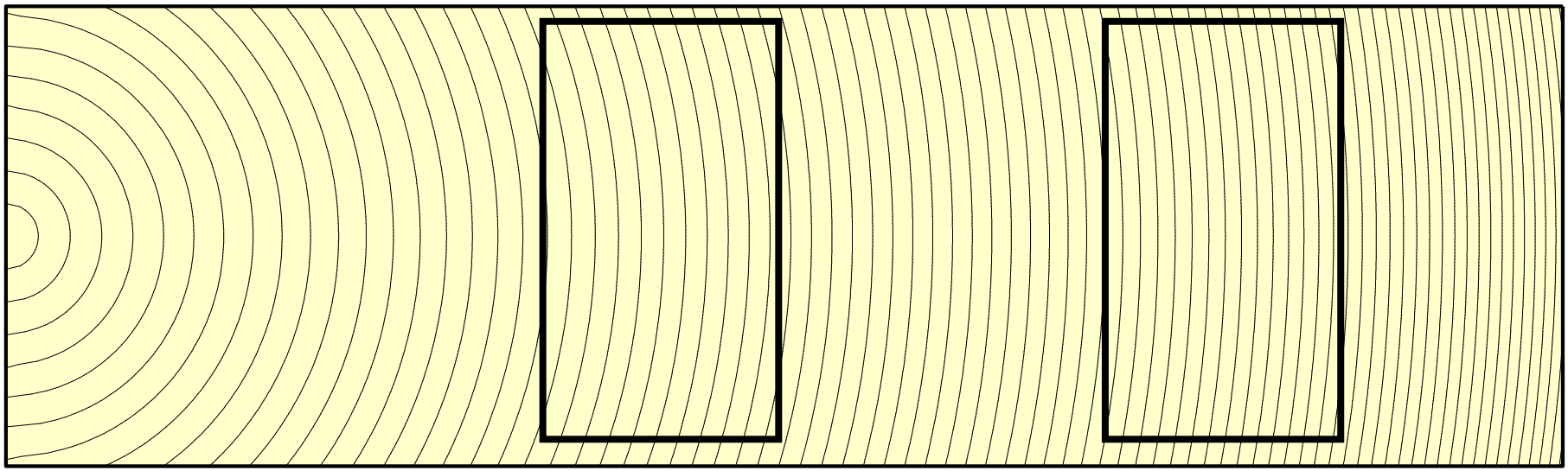
Bigger tree – actually growing faster (more wood) at this point



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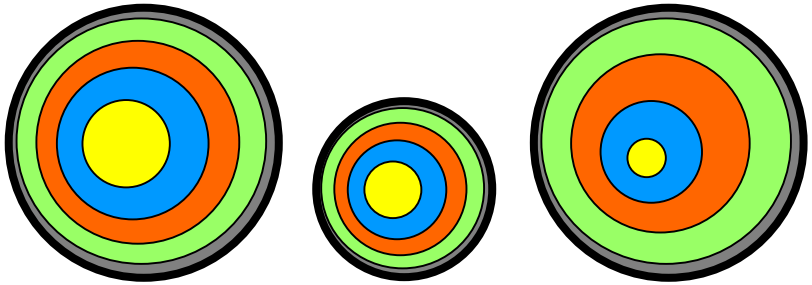
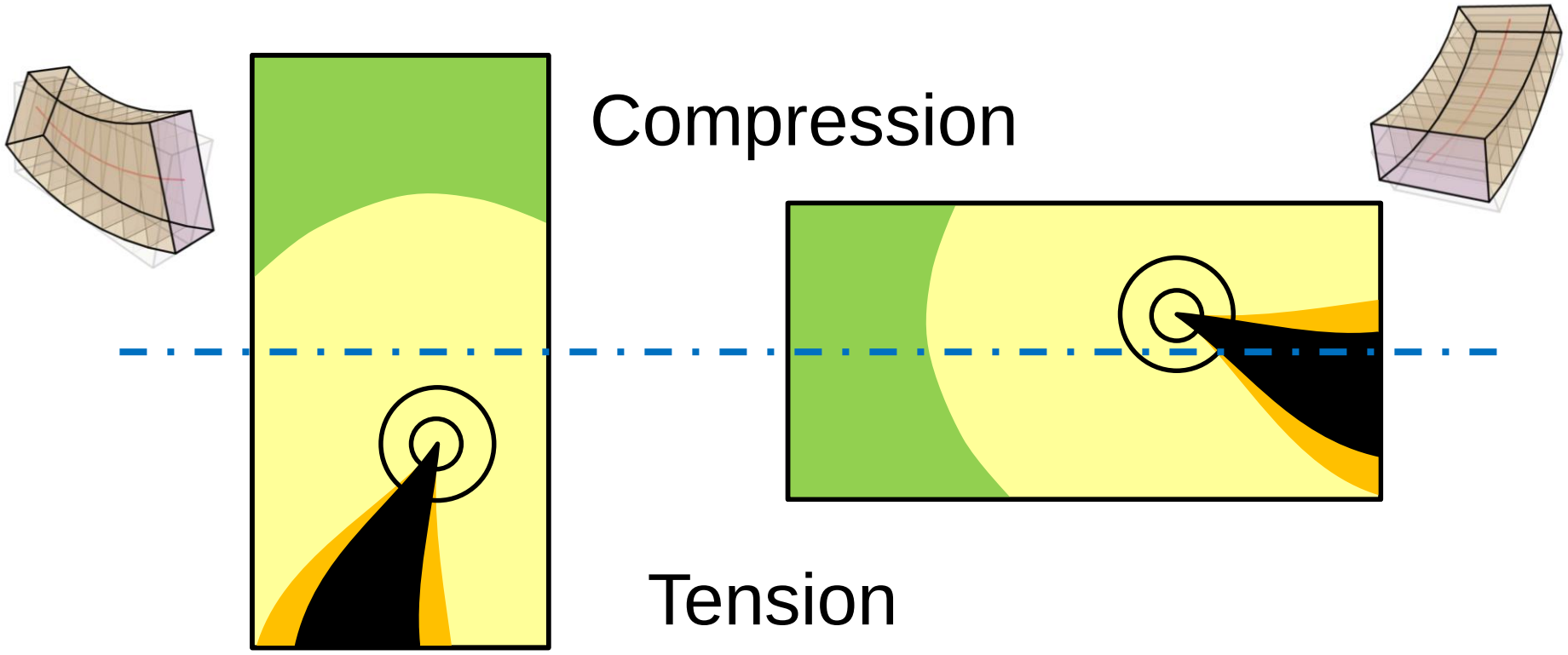
Factors → softwood quality

- Position within the tree
  - Radially & vertically
- Silviculture
  - Spacing, thinning, **rotation length** etc
- Site
  - Exposure, temperature, rainfall, soil type etc
- Genetics
  - Species, variety and individual



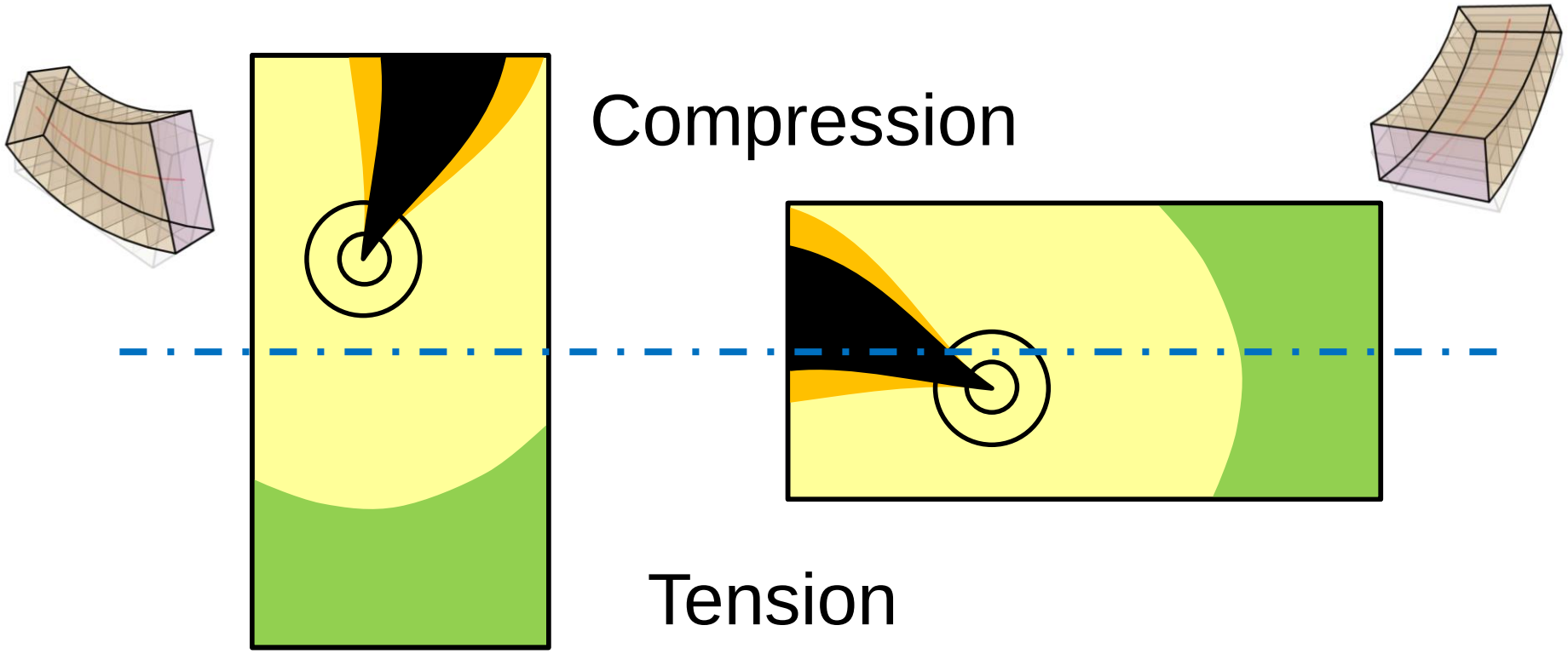
Bending



Major axis
(as a joist)

Minor axis
(as a board)

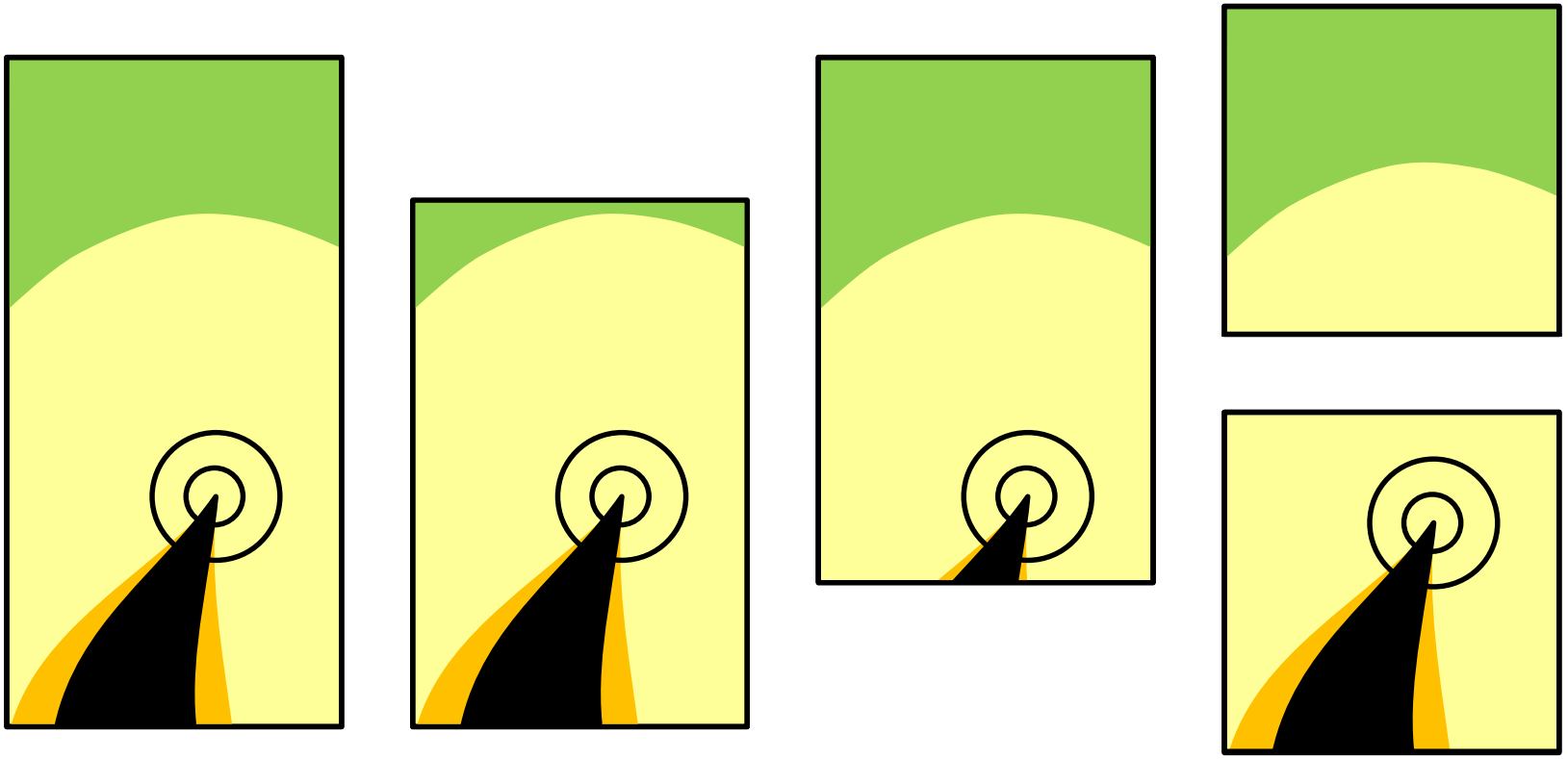
Bending



Major axis
(as a joist)

Minor axis
(as a board)

Changing the cross-section



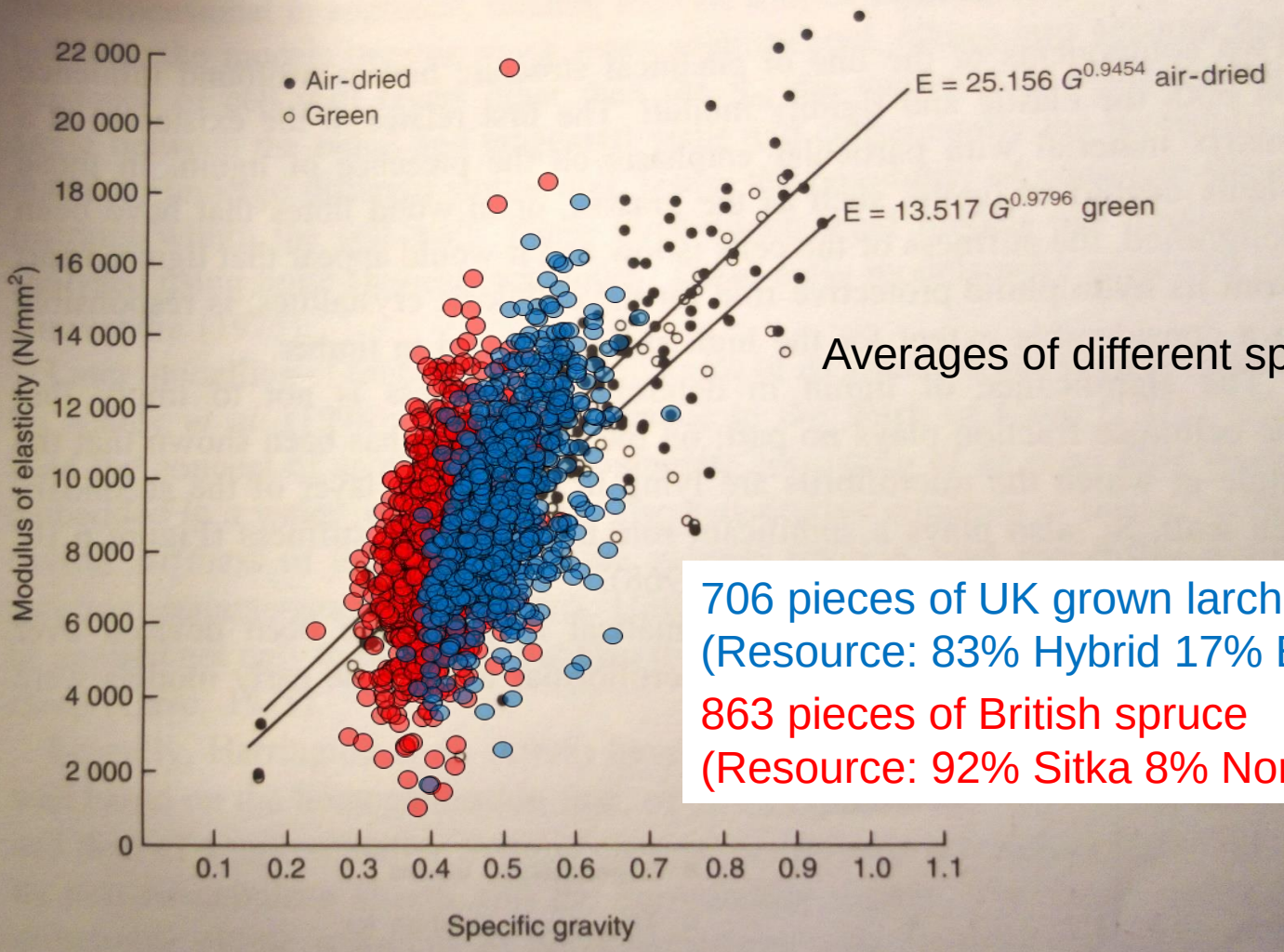
EN 14081-1 gives acceptable limits for cross-section change after grading

Variation

- From species to species
- Within species / species group
  - Between countries
  - Within countries
  - Within a forest
  - Within a stand
  - Between trees in a stand
  - Within a tree
  - Within a board
  - Depending on how the board is loaded

Variation of properties

& correlation between properties



Averages of different species

706 pieces of UK grown larch
(Resource: 83% Hybrid 17% European

863 pieces of British spruce
(Resource: 92% Sitka 8% Norway)

Figure 6.9 Effect of specific gravity on the longitudinal modulus of elasticity for over