Forest Products Research Institute

Edinburgh Napier UNIVERSITY

Wood structure & biomechanics

an overview

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SIRT

Strategic Integrated Research in Timber

The advantages of wood

- Environmental
- A vast range of species and properties
- Versatile
- Good strength to weight ratio
- Easily worked and easily repaired
- A good insulator
- Good shock absorption
- Attractive
- Can last a very long time

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Types of wood product

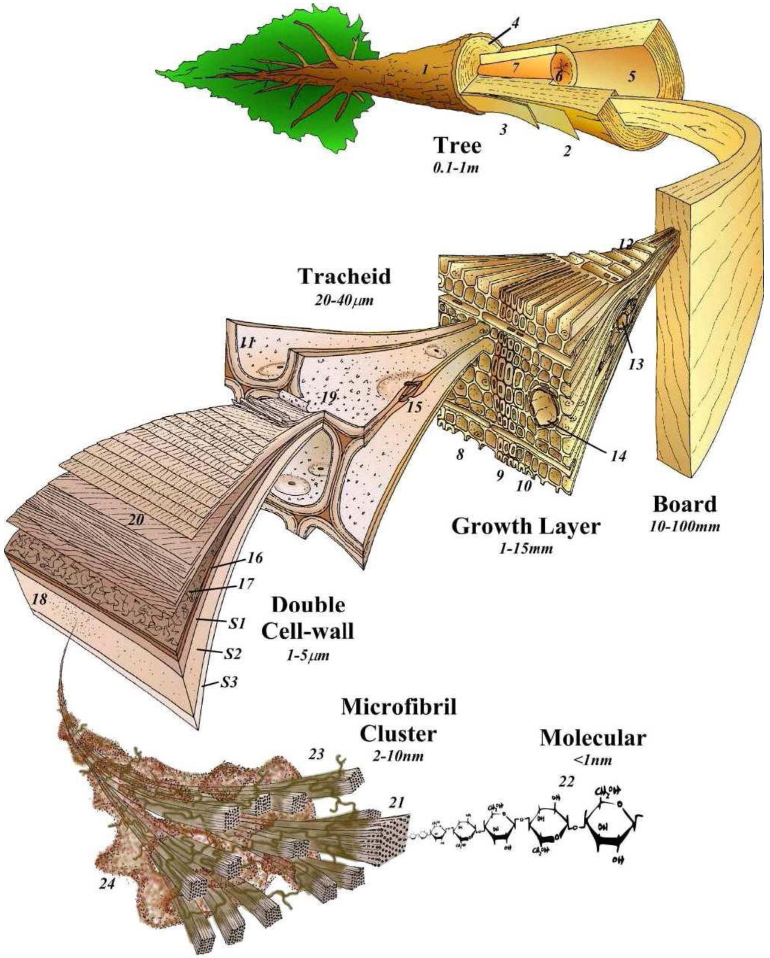
- Sawn timber (lumber)
- Engineered wood products based on…
  - Planks / lamella
  - Veneers
  - Flakes
  - Fibres
  - Cellulose
- Modified wood
  - Chemical
  - Thermal

Why is micromechanics important?

- Varied and complicated natural composite
- Still not well understood
- Need to understand and model wood mechanics and micromechanics in order to:
  - Produce wood products with improved performance
  - Enhance quality control
  - Design more adventurous, more efficient and more reliable structures
  - Improve silviculture for timber

Why is micromechanics important?

	Tree	Building
m	Log	Assembly
	Sawn timber	
cm	Clear wood	
mm	Growth layer	
	Wood anatomy	
	Cell	
µm	Cell wall	
	Cell wall layers	
	Microfibril clusters	
nm	Molecular	



Harrington, J. J. (2002). Hierarchical Modelling of Softwood Hygro-Elastic Properties. PhD thesis, University of Canterbury.

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nm		Molecular	

Performance in wood and wood-based products strongly influenced by behaviour at these levels

Ultimate limit state
- Fracture
- Crushing

Serviceability
- Drying distortion
- Creep

Manufacturing
- Wood treatments
- Modified wood
- Wood forming

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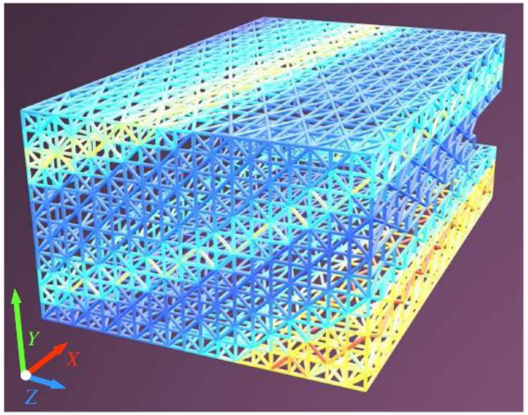
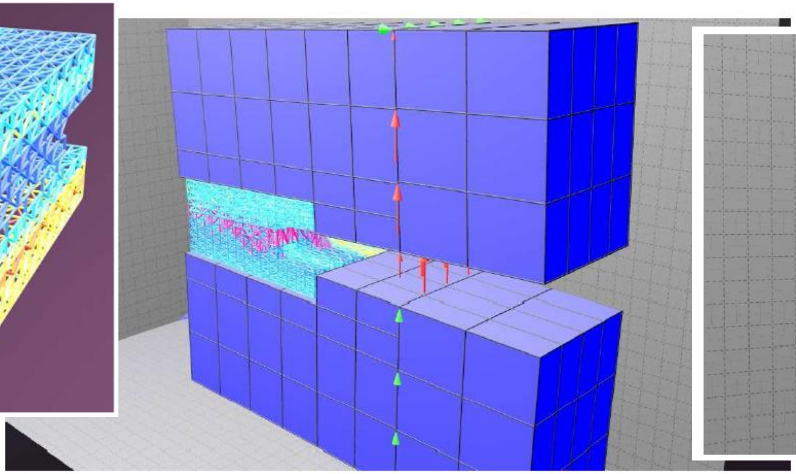
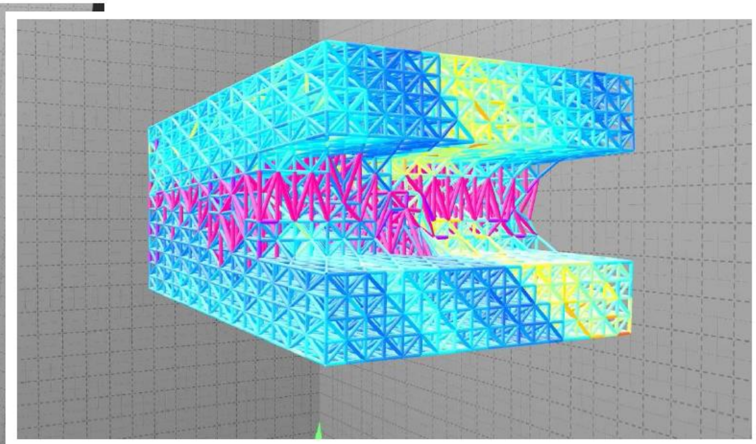
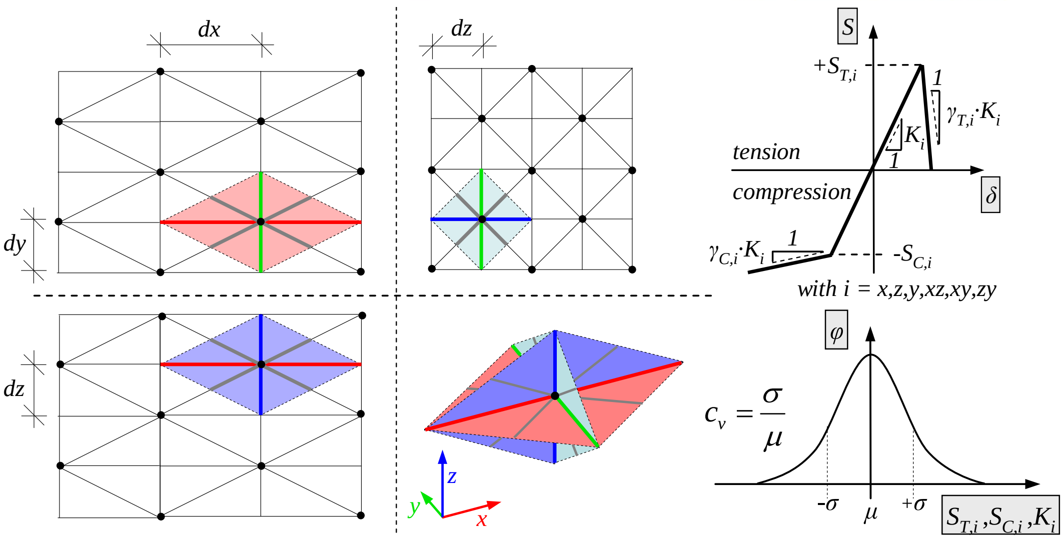
Modelling across different scales









Reichert, T. (2009) “Development of 3D lattice models for predicting non-linear timber joint behaviour. PhD thesis, Edinburgh Napier University.

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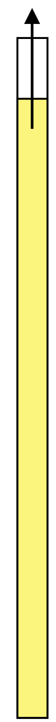
Wood

- Gymnosperms (seeds outside the ovum)
  - "Softwood"
    - Conifers (and gingko)
    - e.g. pine, spruce, fir, larch, yew, cedar
- Angiosperms – (flowering plants)
  - "Hardwoods" (dicots)
    - All the other "trees"
    - e.g. oak, beech, birch, teak, mahogany, balsa
  - "Woody monocots"
    - Bamboo and palms

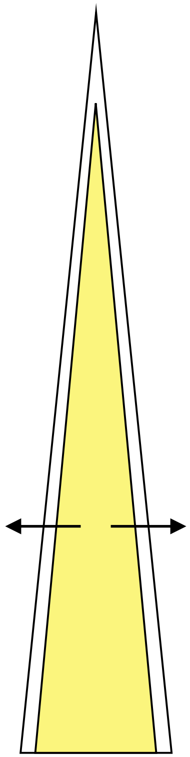
Primary and secondary growth

- Primary growth
  - Increase in length



woody
monocots

- Secondary growth
  - Increase in width



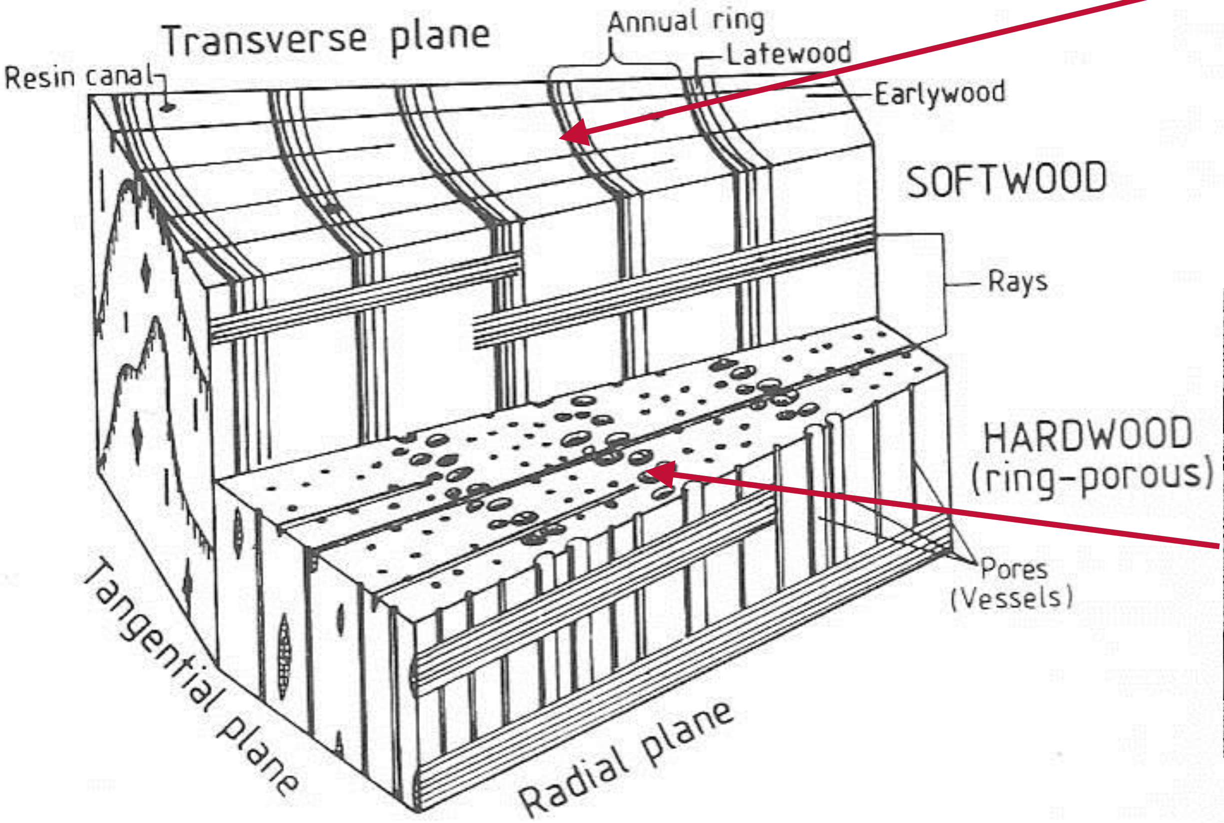
hardwoods
and
softwoods

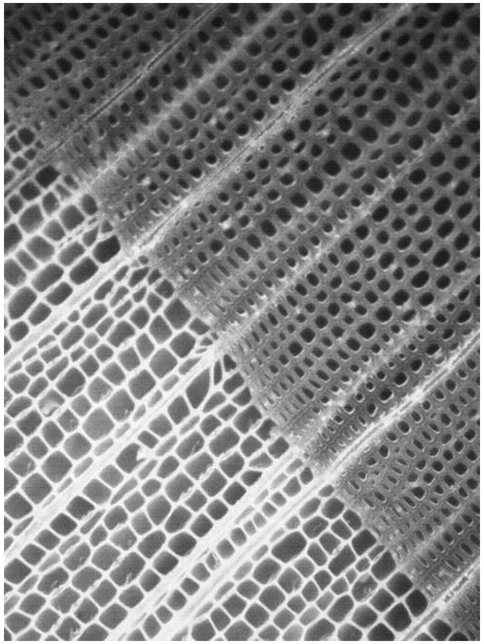
Softwoods and hardwoods

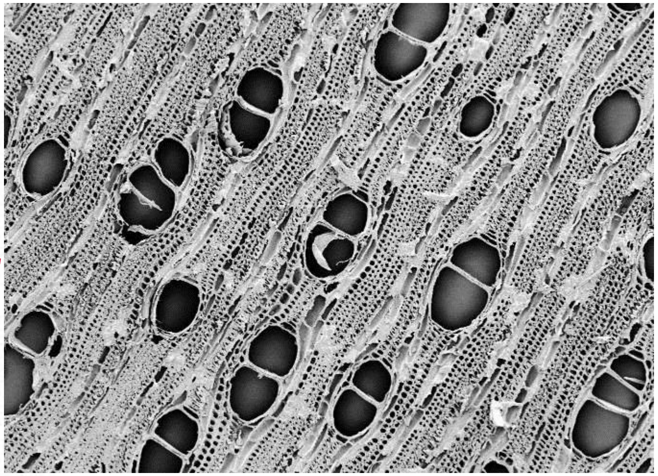
- Softwood
  - 300 million years old
  - Simpler structure
  - Needle-like leaves and cones

- Hardwood
  - 100 million years old
  - Complicated and varied

Structure







Fengel and Wegener 1984 “Wood” Walter de Gruyter

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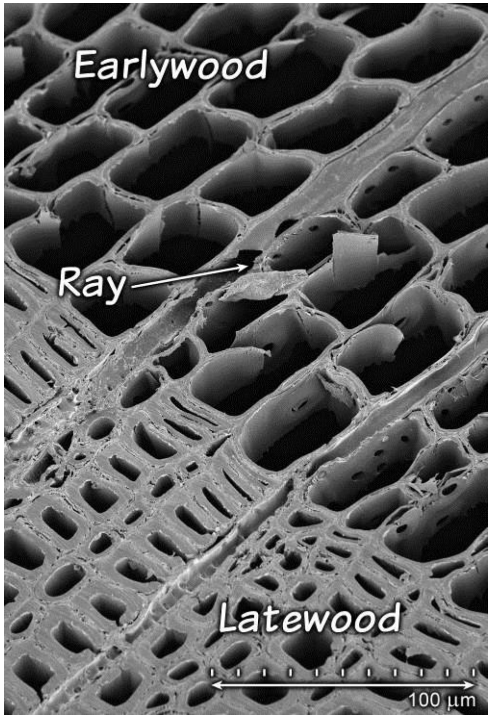
Earlywood and latewood

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



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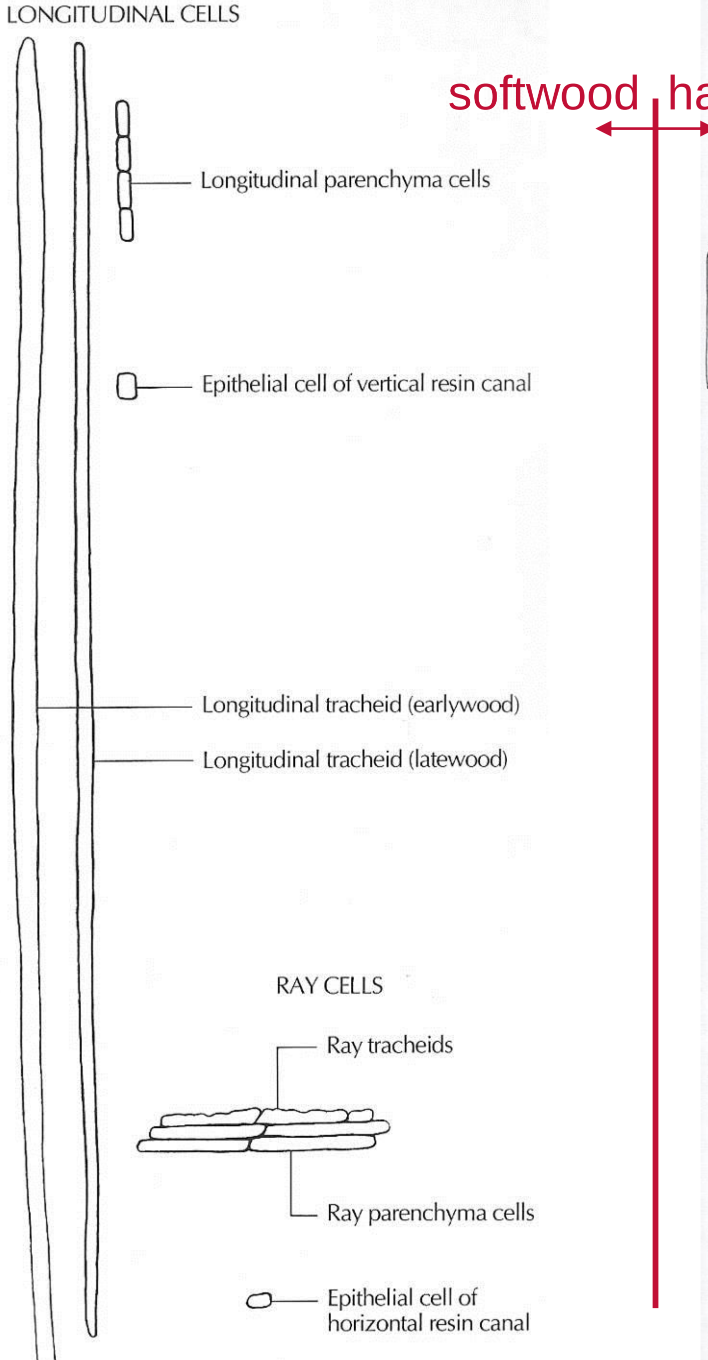
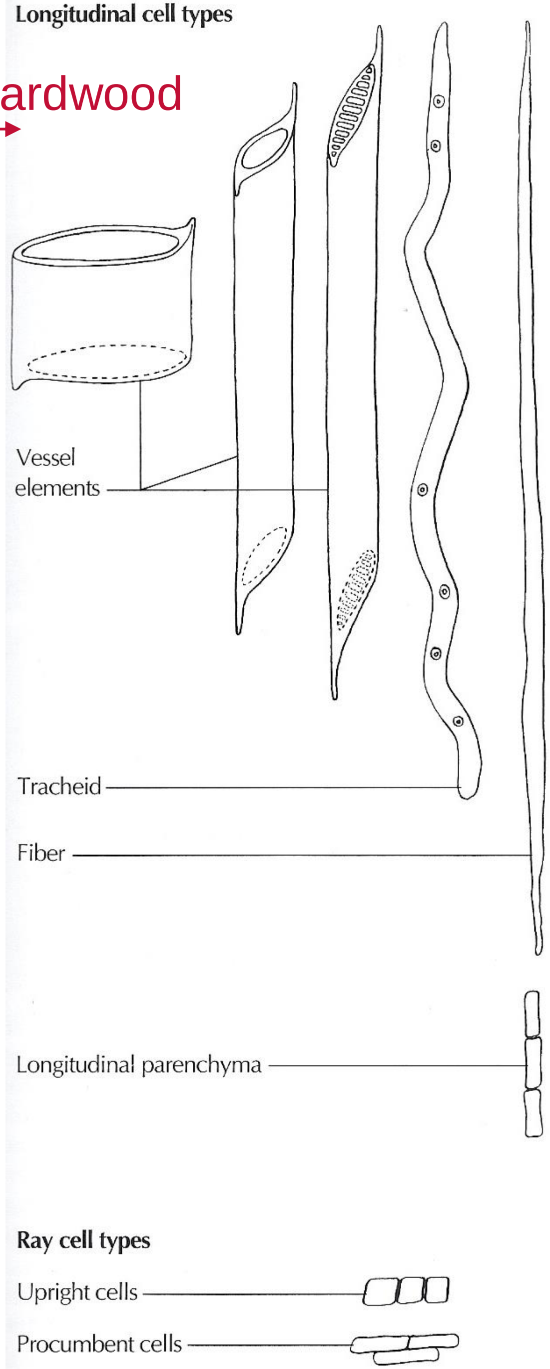
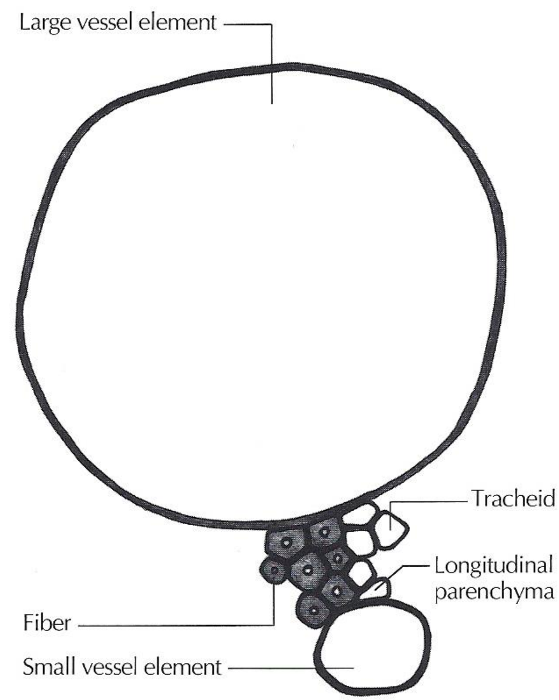
Cell types

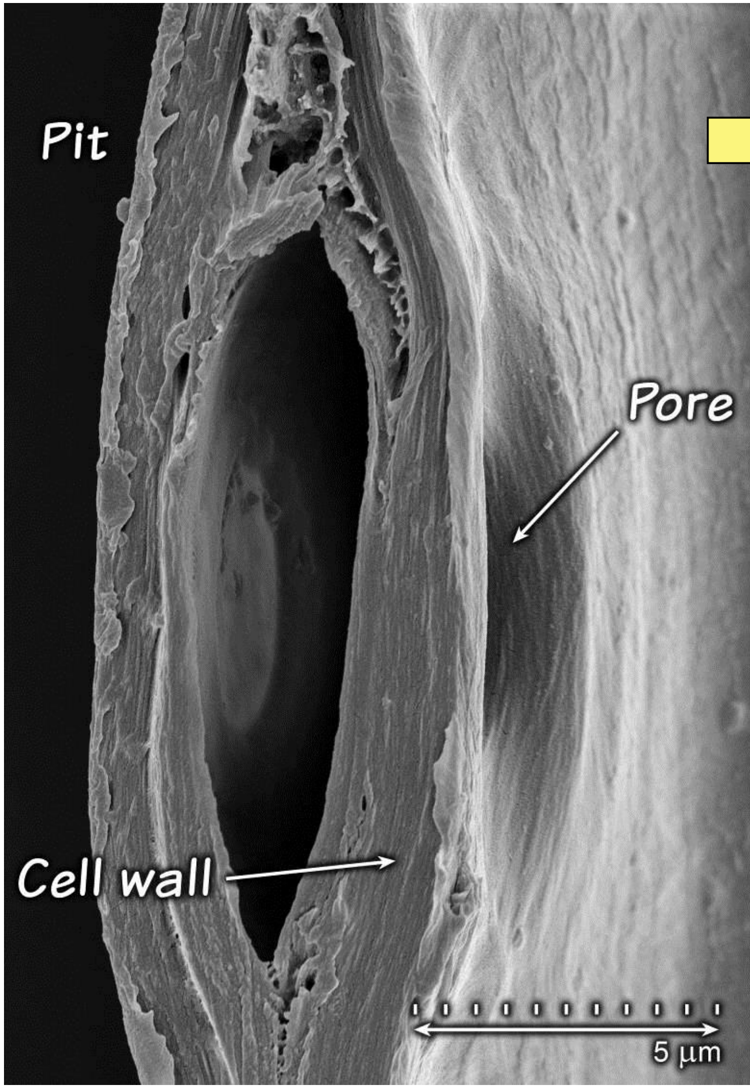




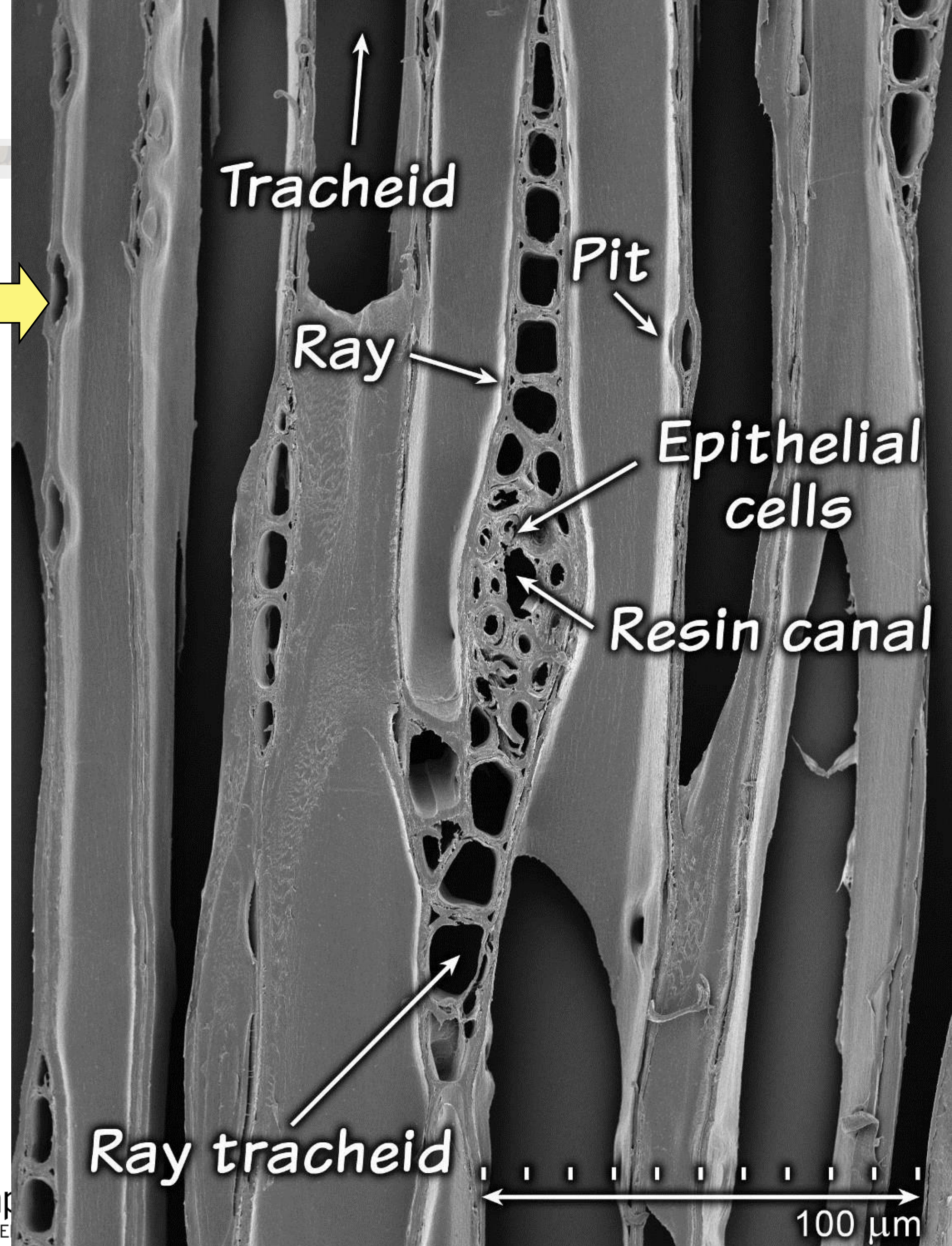


Hoadley, B. (1990) “Identifying wood” Taunton Press

Pits

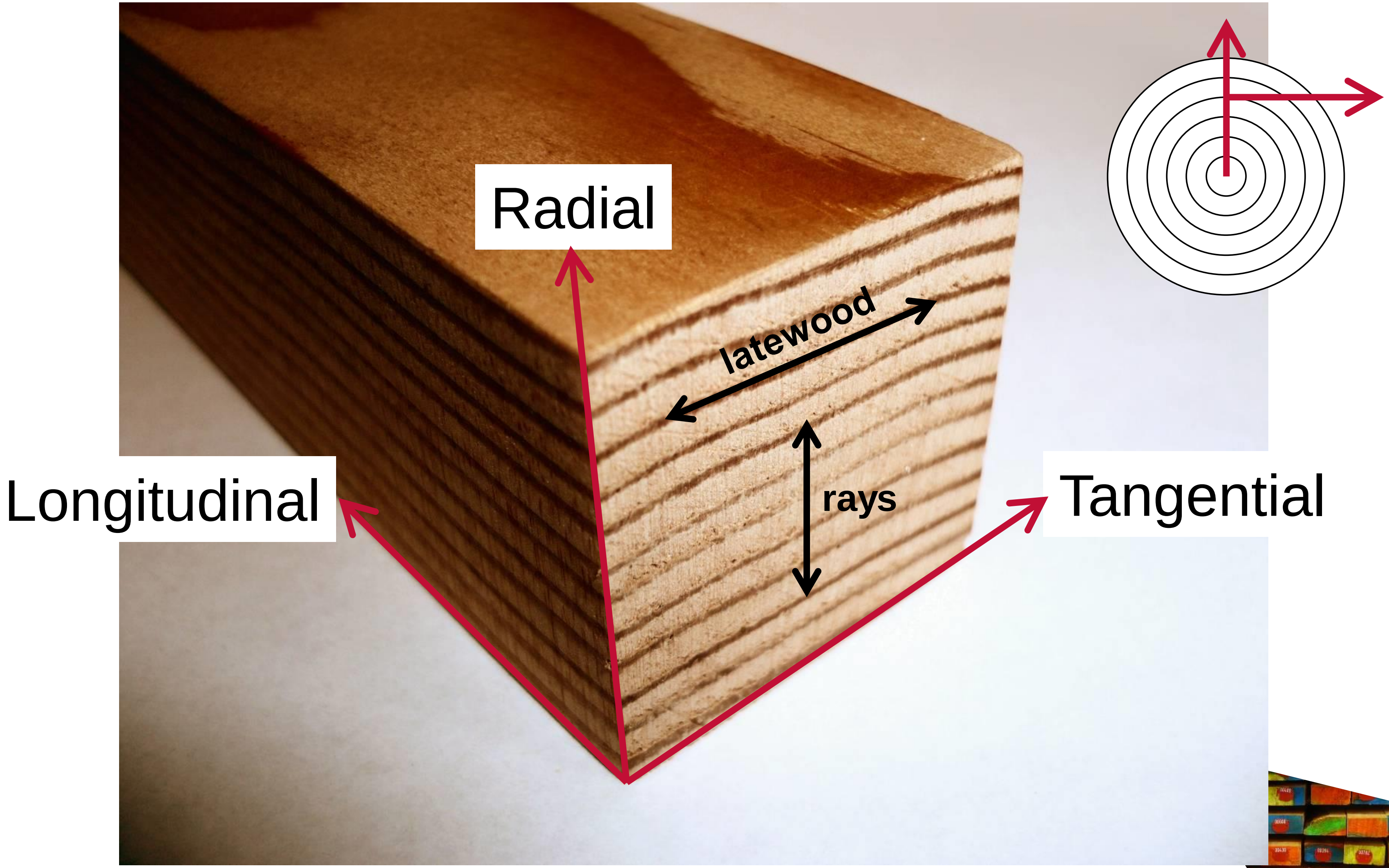


Pit
Pore
Cell wall
5 µm



Tracheid
Pit
Ray
Epithelial cells
Resin canal
Ray tracheid
100 µm

Principal directions



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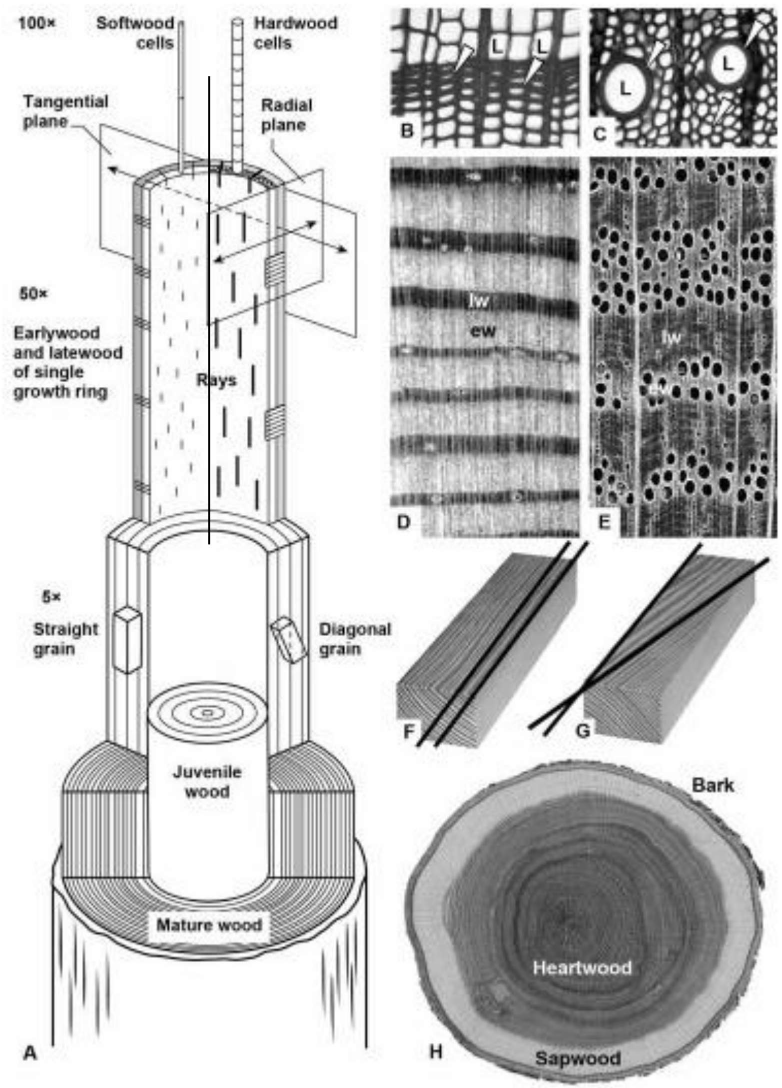
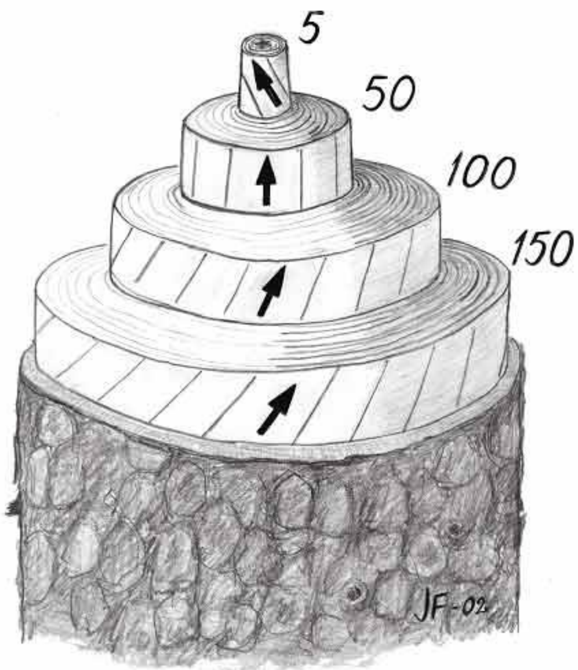
Perpendicular to grain

Structure of wood





Säll H. (2002) *Spiral grain in Norway spruce*. Doctoral thesis. Acta Wexionesia No. 22/2002 Wood Design and Technology. Växjö University Press. ISBN 91 7636 356 2.

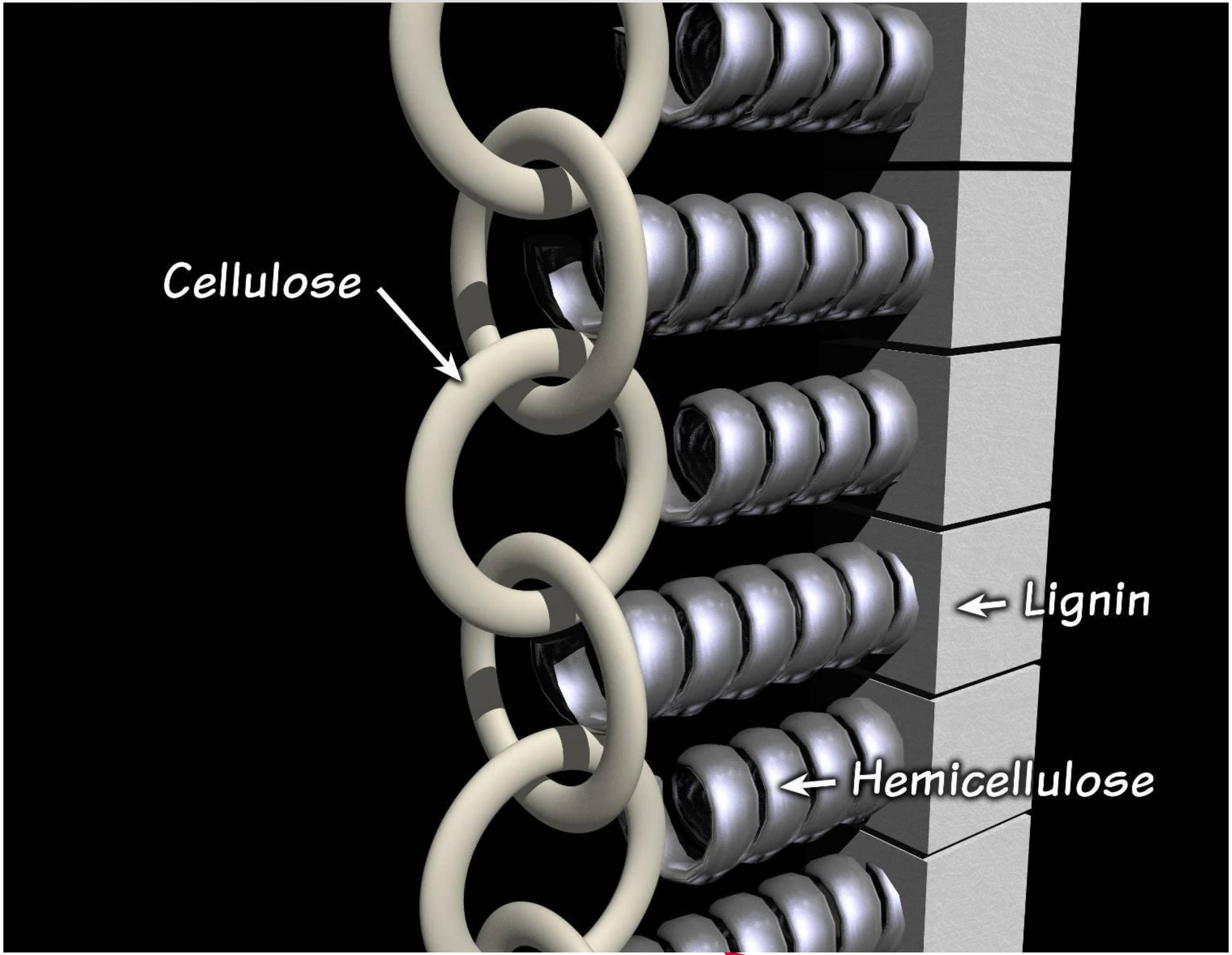
Forest Products Laboratory (2010) Wood handbook - Wood as an Engineering Material. U.S. Department of Agriculture, Forest Service. FPL-GTR-190

Grain and knots

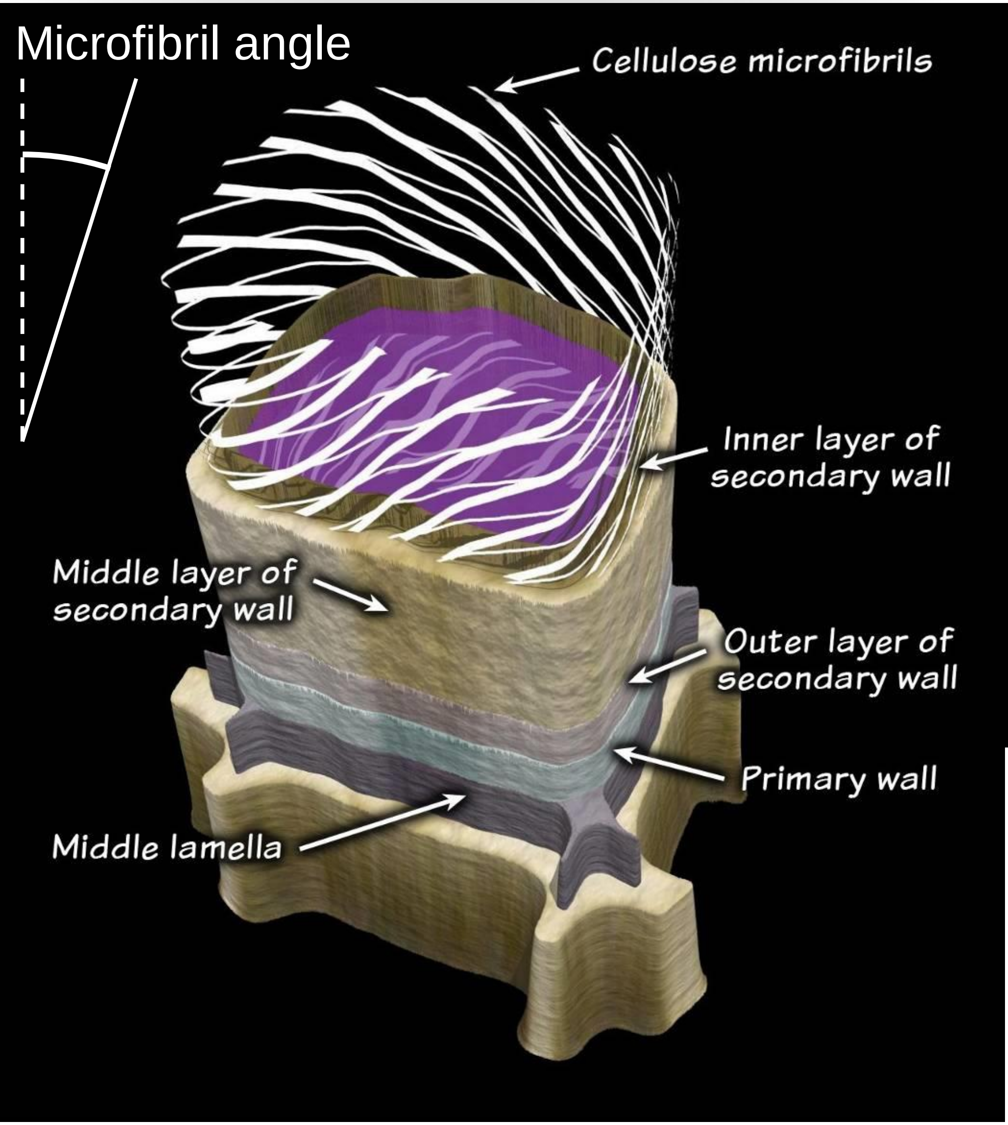
Constituents of wood

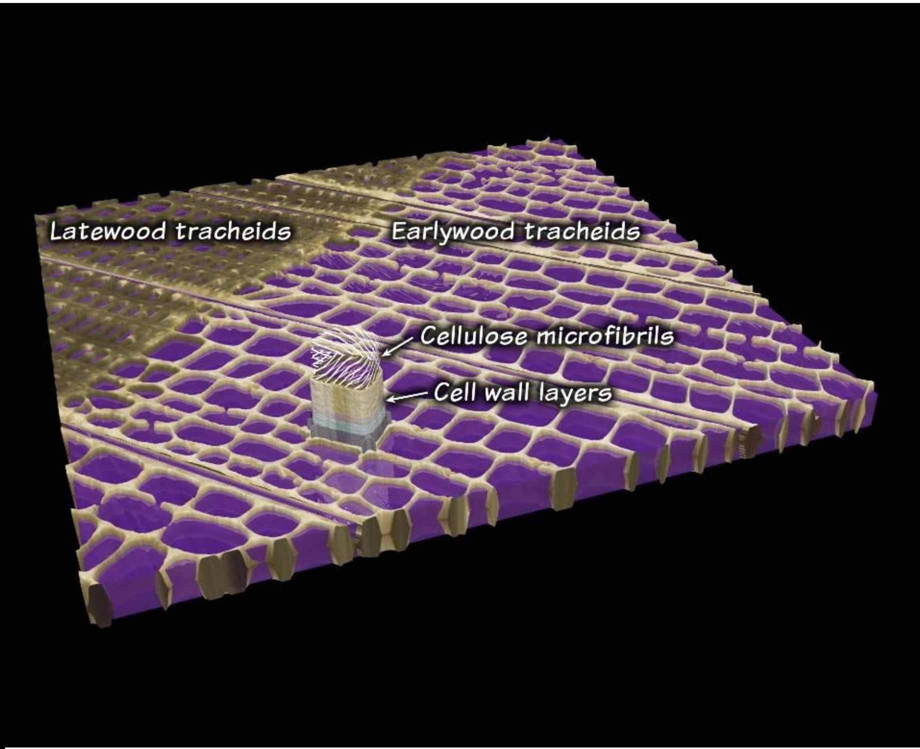
- Cellulose
  - A long polysaccharide molecule $(C_6H_{10}O_5)_n$
  - Analogous to reinforcing strand (main role tension)
- Lignin
  - A number of complex 3D biopolymers
  - Analogous to cement (main role compression)
- Hemicelluloses
  - Mixture of different sugar monomers
  - Links the cellulose and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

Molecular scale



Cell wall structure





The more vertical the microfibrils the stiffer and stronger the wood

Reaction wood

- Grown in response to ‘pressure’
- To correct stem form, support branches, resist wind
- Higher longitudinal shrinkage when dried

- Compression wood (softwoods)
  - Lignin rich (dark, reddish colour)
  - Works by ‘pushing’
  - Dense and brittle
- Tension wood (hardwoods)
  - Cellulose rich (silvery white colour)
  - Works by ‘pulling’

Heartwood and sapwood

- Sapwood
  - The younger outermost part of the log
  - Transporting water and storing food
  - High moisture content in living tree

- Heartwood
  - Older innermost part of the log
  - Pits closed
  - Strength and storage of waste products

Juvenile wood / crown formed wood

- The older part of the tree
- Often characterised by wide growth rings
- Often lower density
- Abnormal properties
- Common in plantation softwoods
  - 15 or more years
  - High microfibril angle
  - Lower strength and stiffness

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Further complications

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

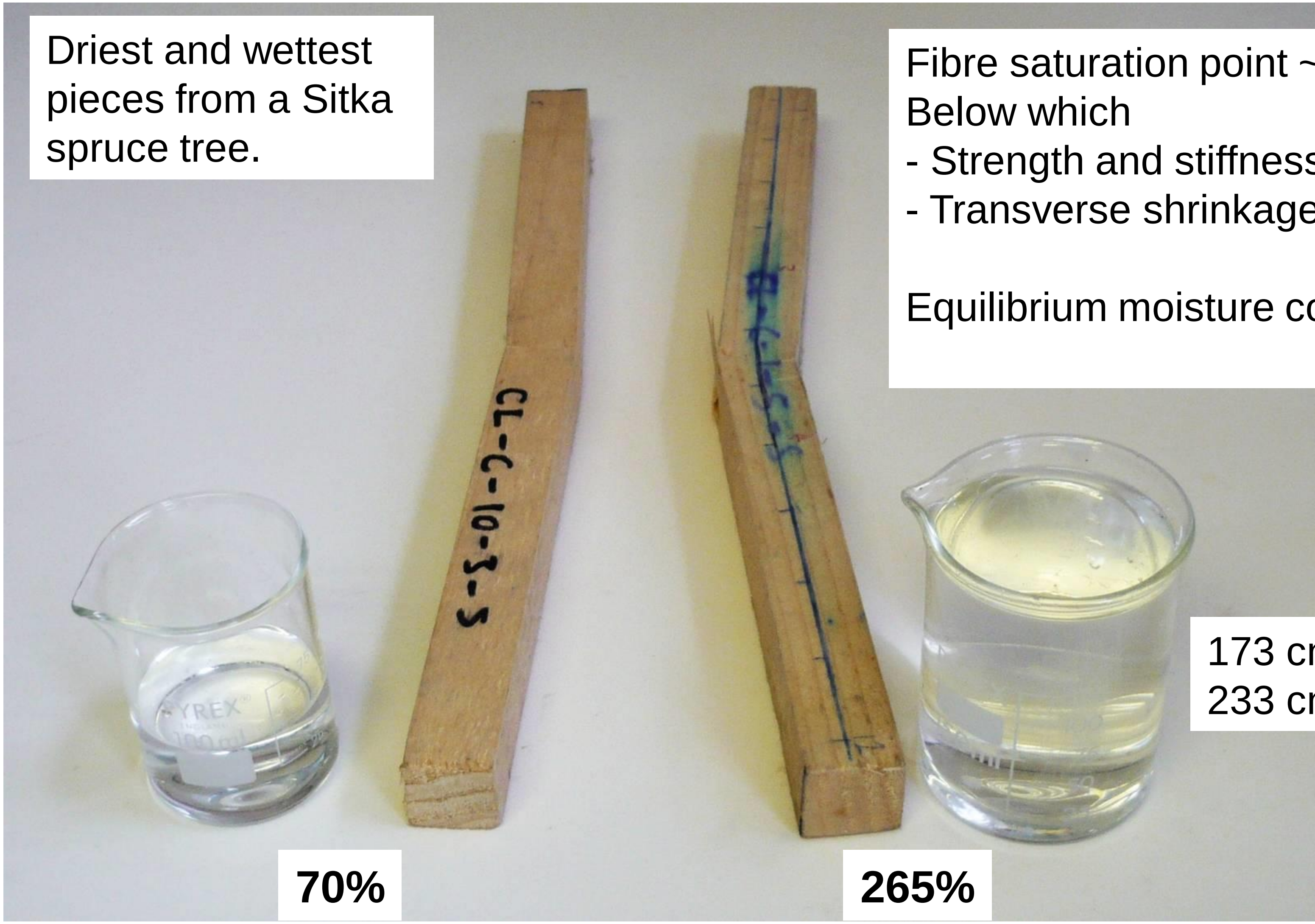
$$\text{Moisture content} = \frac{\text{Weight of water}}{\text{Weight of oven dry wood}}$$

Moisture content

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%

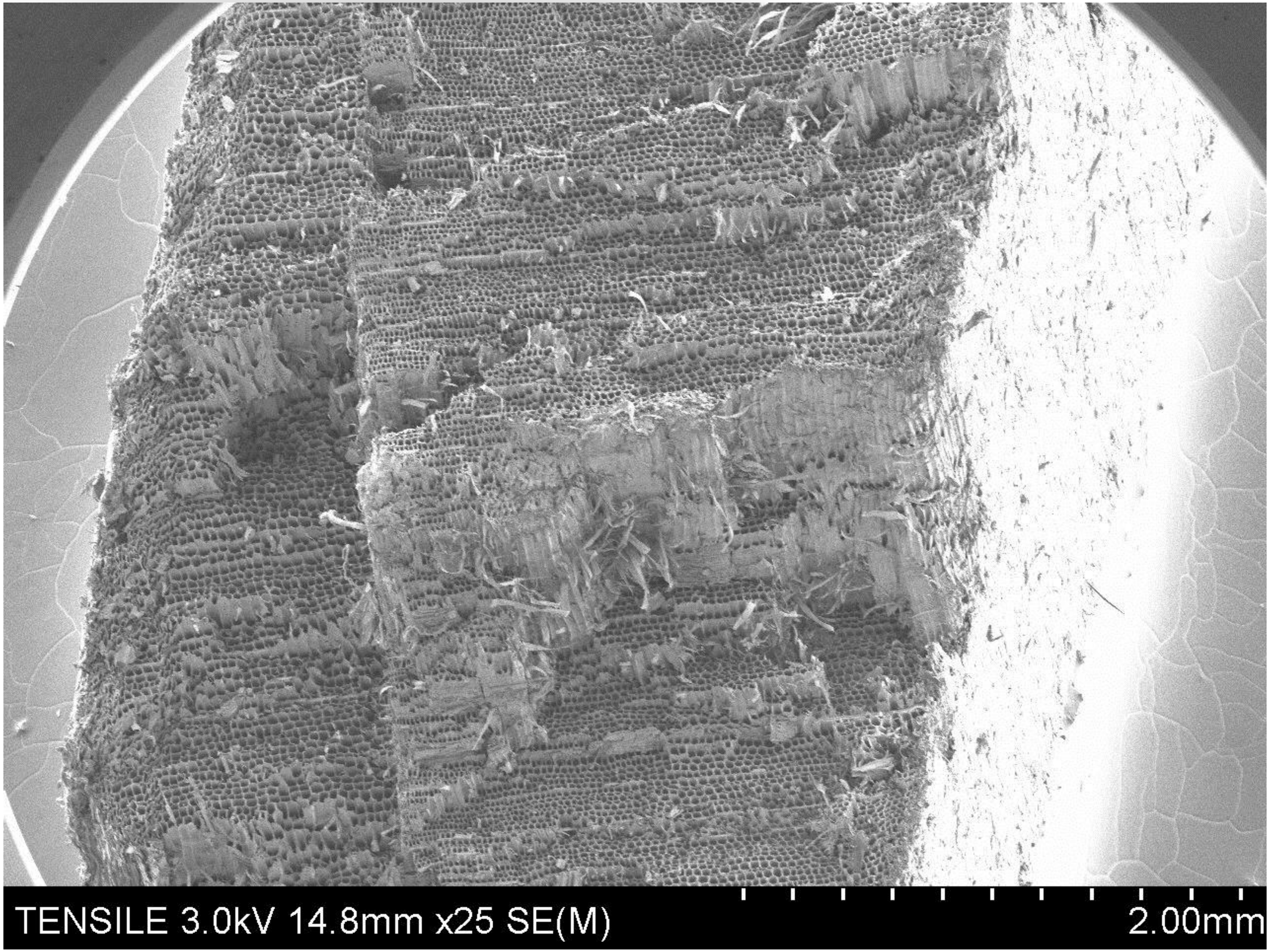


70%

265%

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

Fracture



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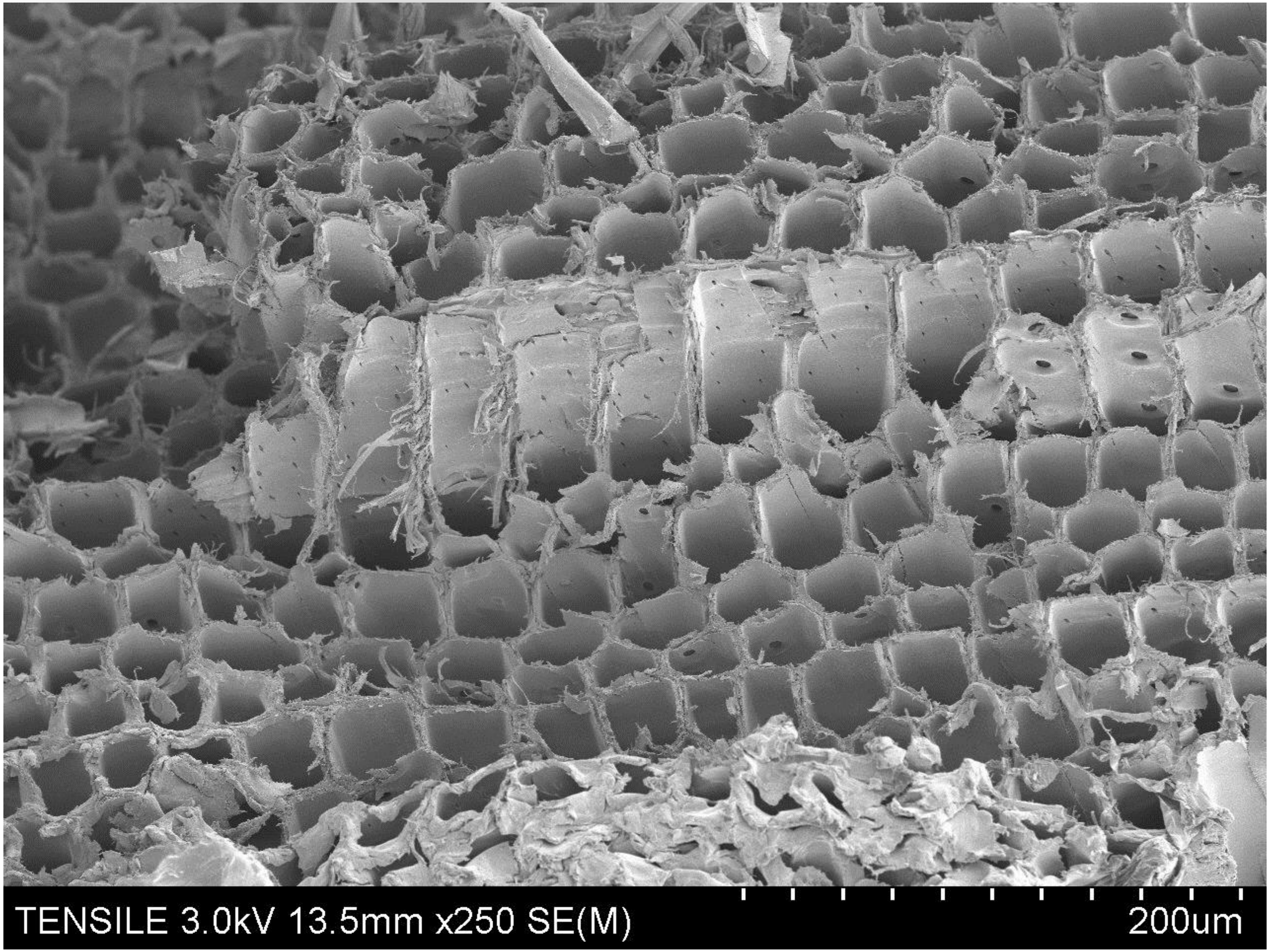

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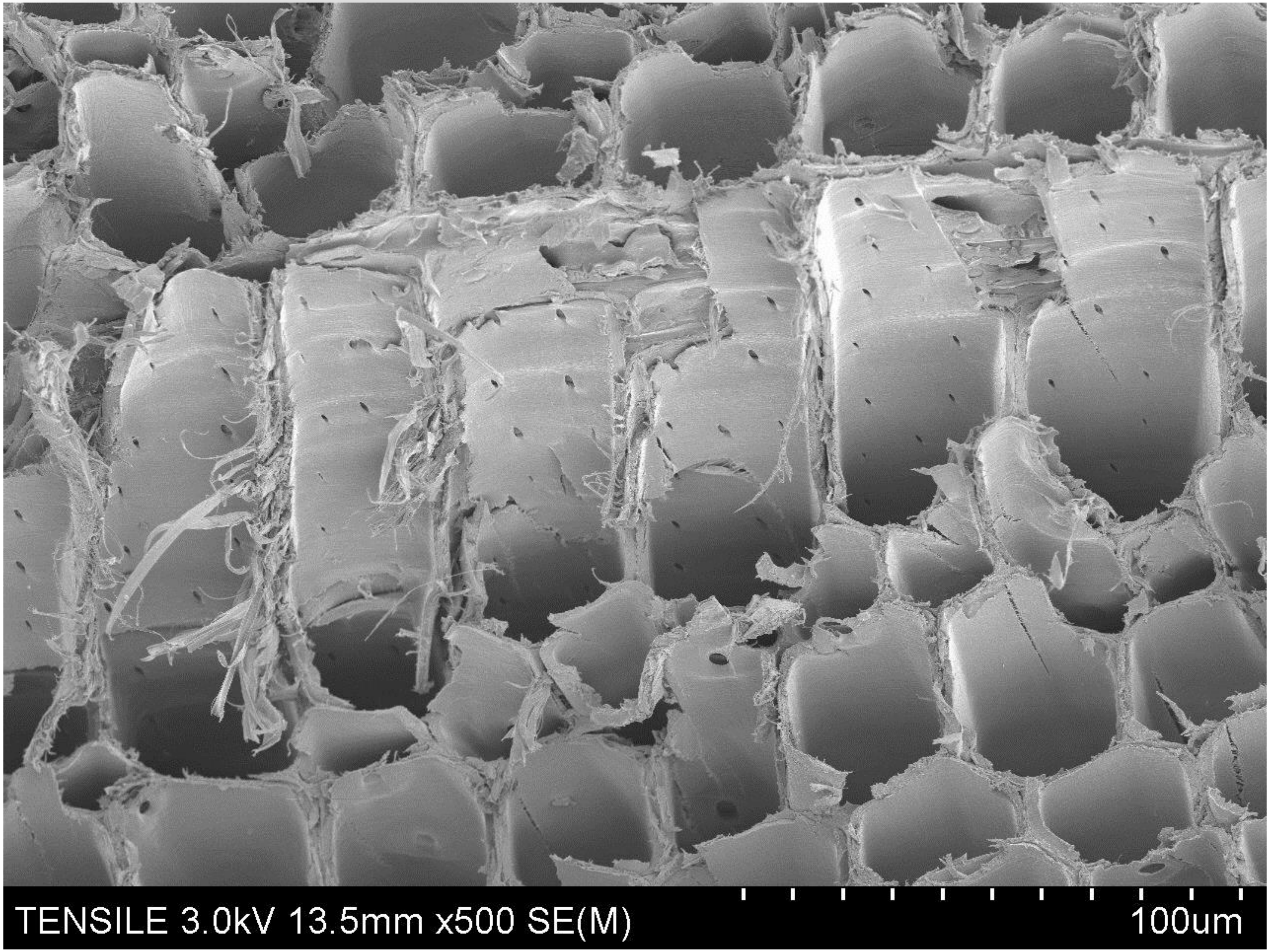

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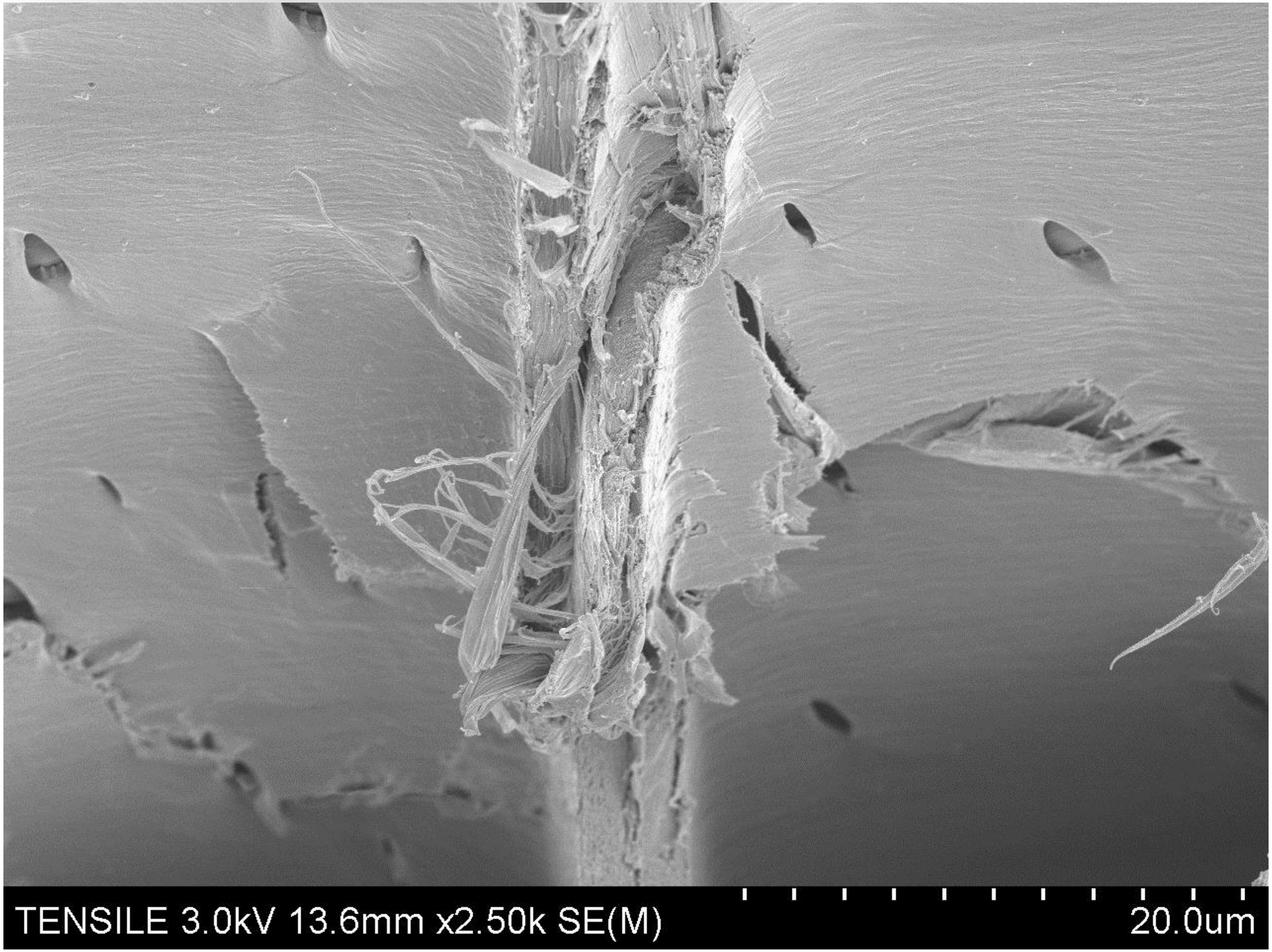

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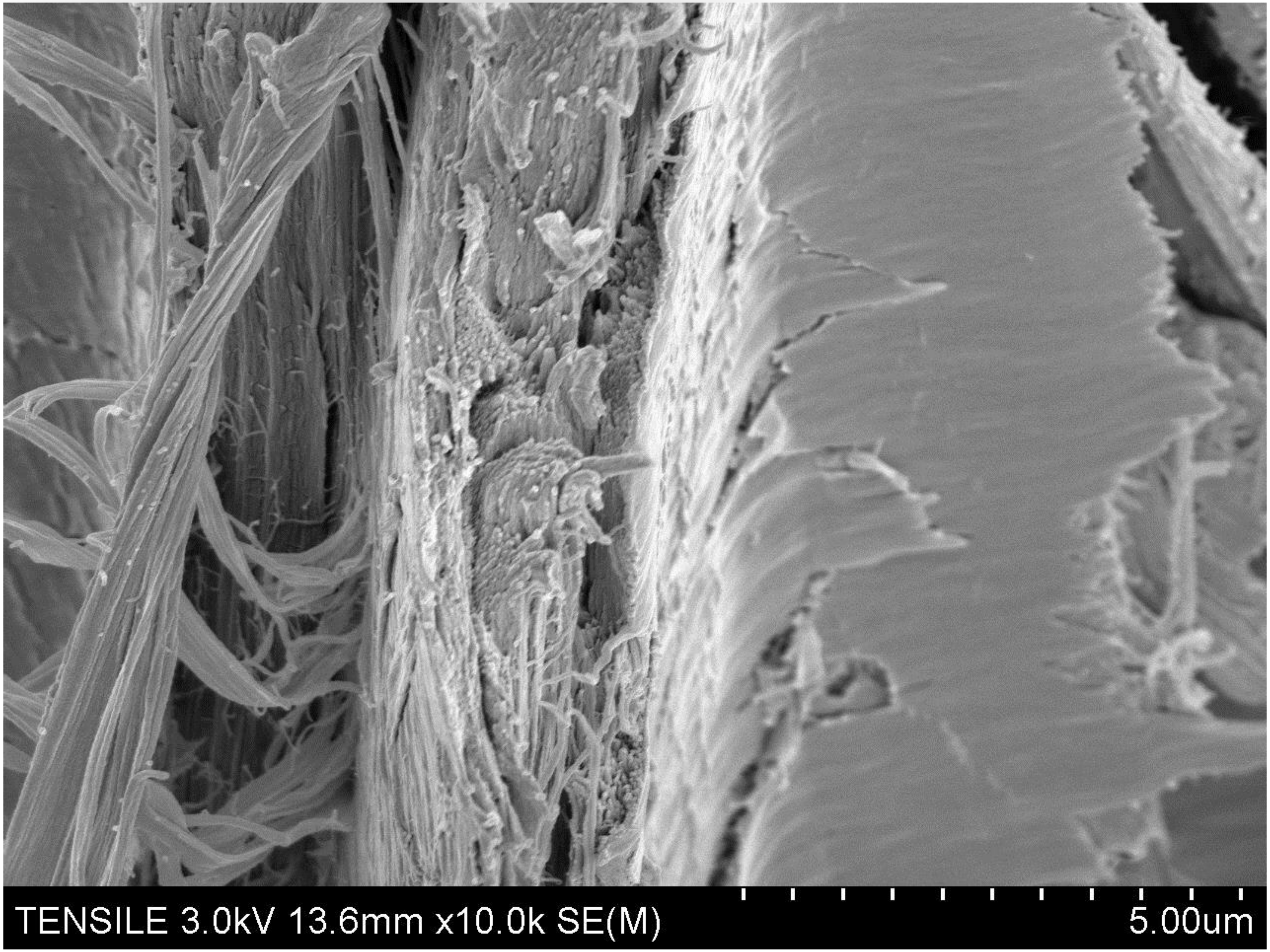

Any Questions?

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The main construction softwoods

European redwood	European whitewood	
Pinus sylvestris (a species of pine tree)	***Picea abies*** (a species of spruce tree)	***Abies alba*** (a species of fir tree)
Scots pine	Norway spruce	European silver fir
Scotch pine	Common spruce	Silver fir
Baltic redwood	European spruce	European fir
Redwood	Whitewood	Whitewood
Red deal	White deal	White deal
Yellow deal	Russian spruce	
Red pine	German spruce	
Finnish pine	Italian spruce	
Swedish pine	Swiss spruce	
Riga pine	French spruce	
Norway pine	Carpathian spruce	
Mongolian pine	Baltic white pine (!)	
Norway fir (!)	Swiss pine (!)	
Scots fir (!)		

UK mainly grows
Picea sitchensis
"Sitka spruce"

Sustainable forestry

- One of the few truly renewable materials