Wood as a Bio-Inspiring Material

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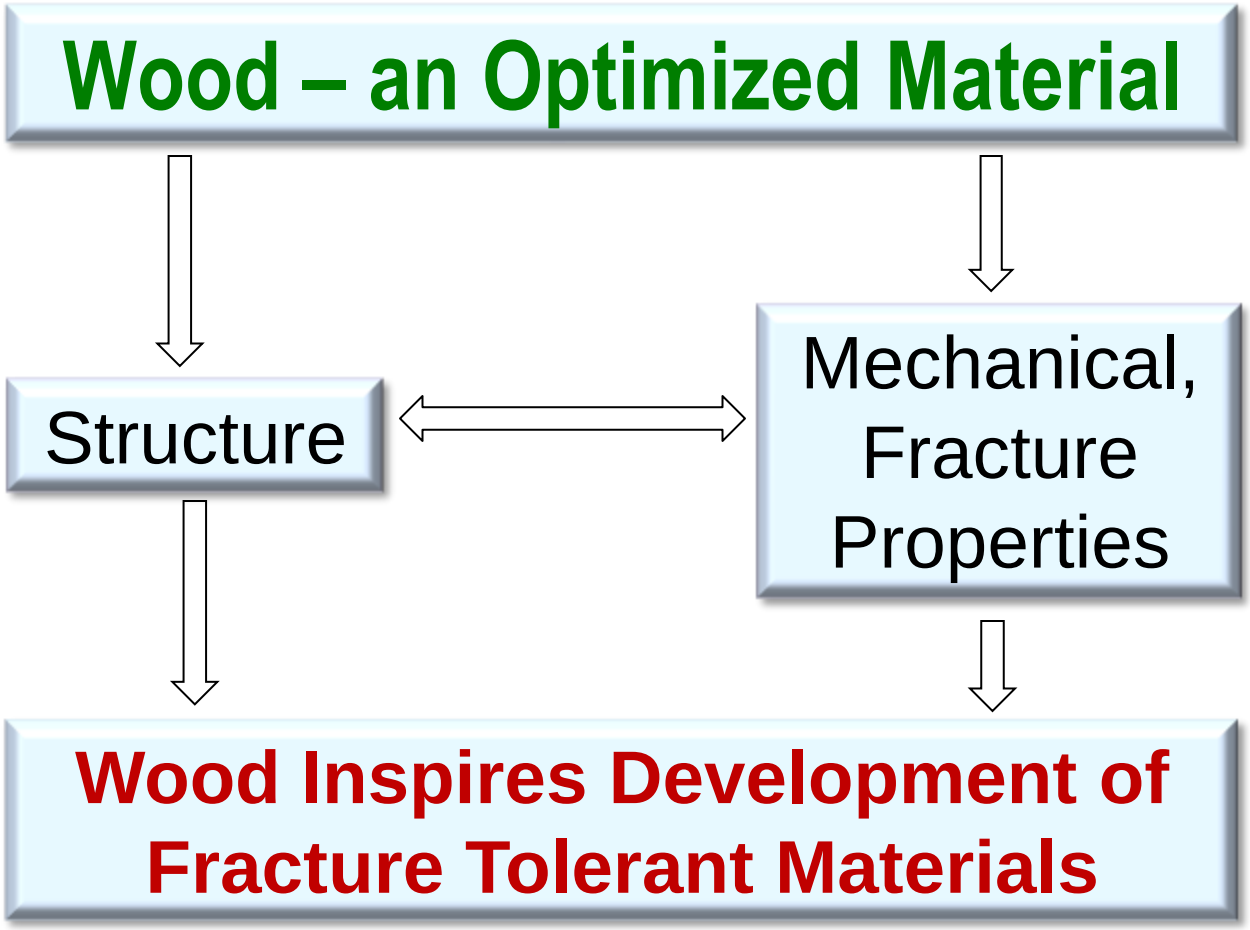
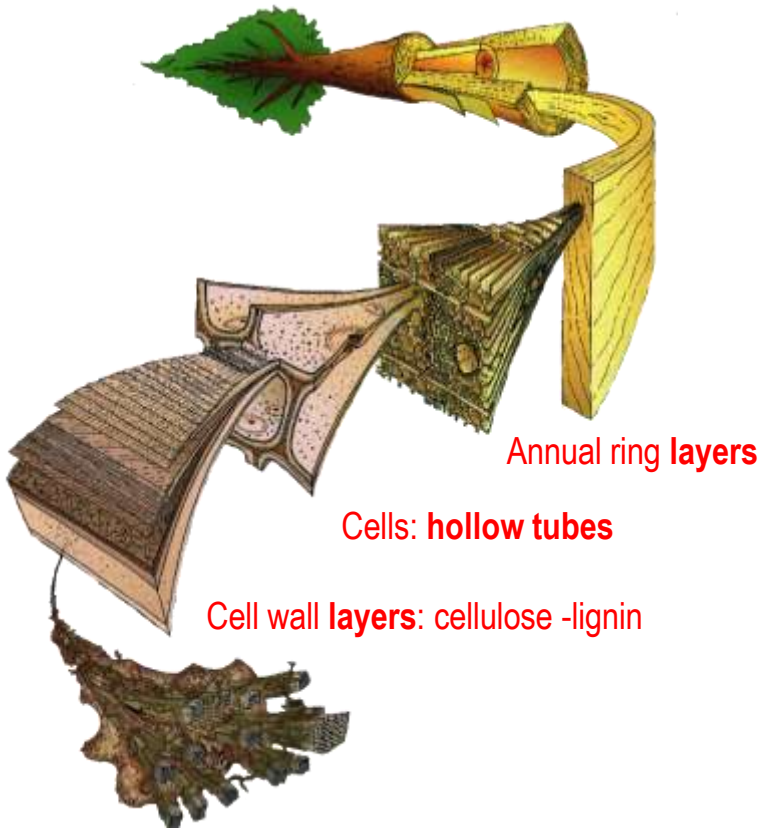
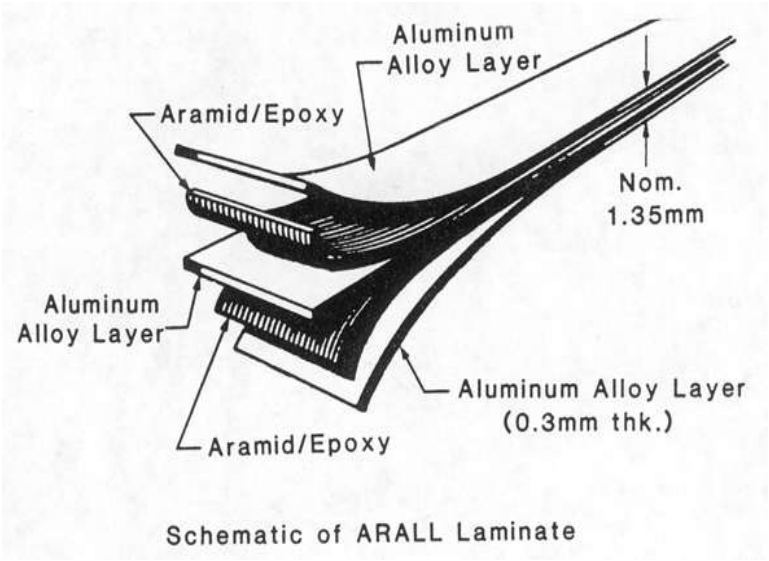

Wood – an Optimized Material
Structure
Mechanical, Fracture Properties
Wood Inspires Development of Fracture Tolerant Materials

Wood – Complex hierarchical structure
Layered and cellular composite

Layers: Annual rings, cell walls



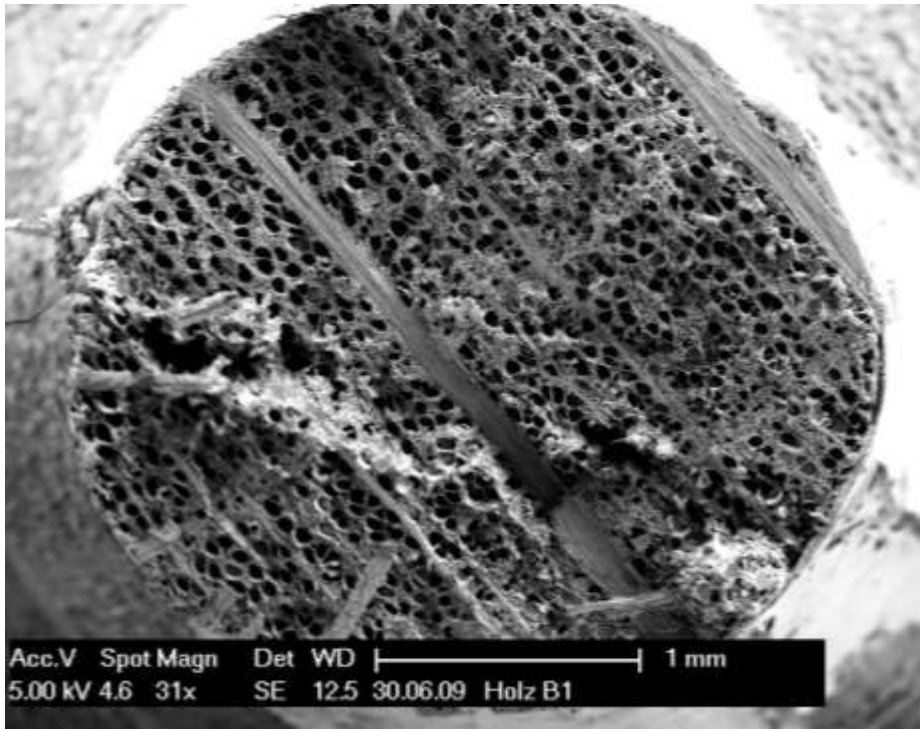
Al-alloy –
Epoxi layers –
Aramid / Glass reinforcing fibres



Cellular composites

Wood – cells: Hollow tubes

Low density AND High stiffness

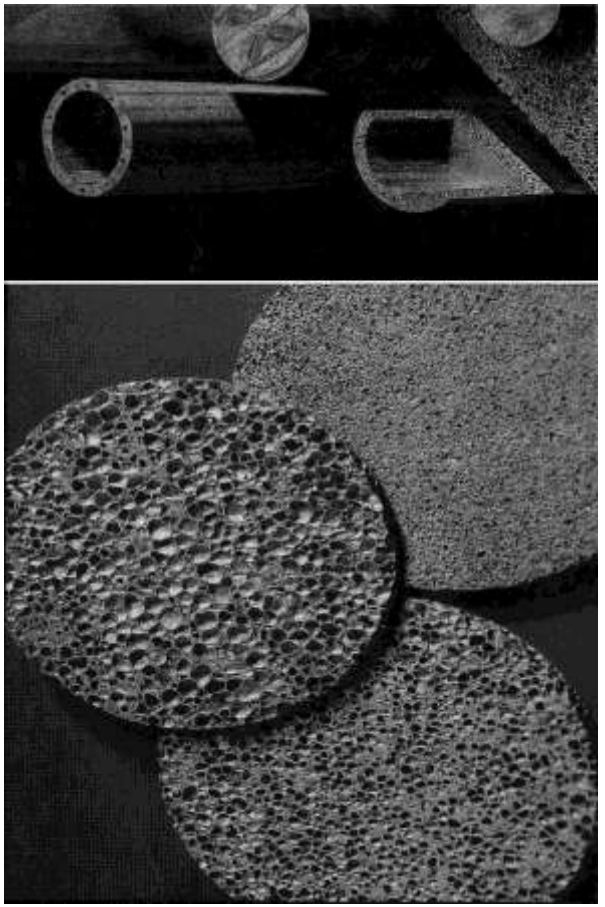


Beech microstructure Differing cell sizes

Wood rays perpendicular to longitudinal tracheids

Fatigue fracture: $\varepsilon = 2.5 \times 10^{-3}$, $N_f = 1.24 \times 10^{7}$

Metallic foams – open and closed cells - low weight….

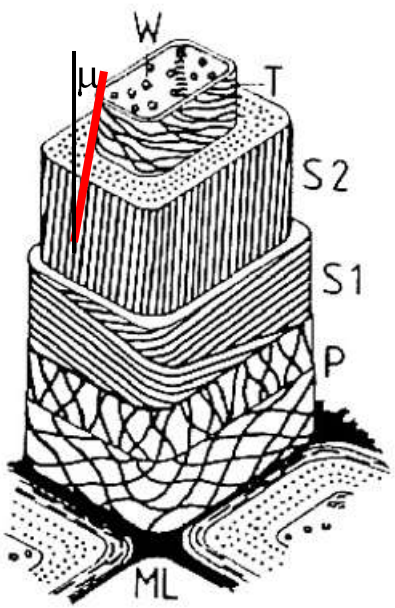


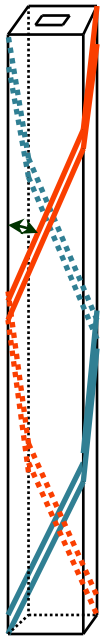
Orientation and angle of fibres

Flexibilty: Elementary fibril angle

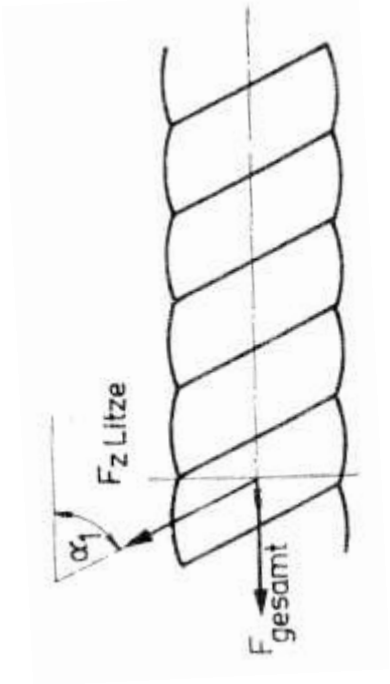
Strength: Spiralic bundles of fibrils

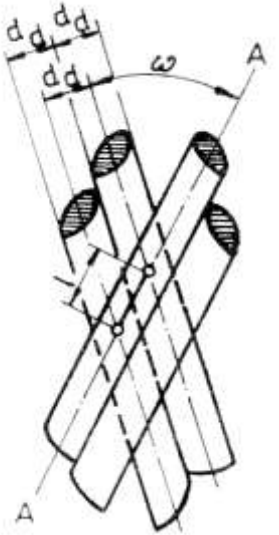
Nature: wood



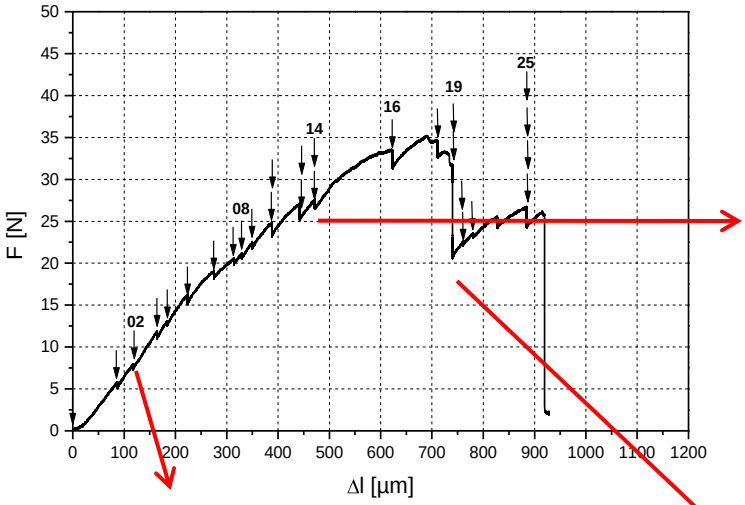


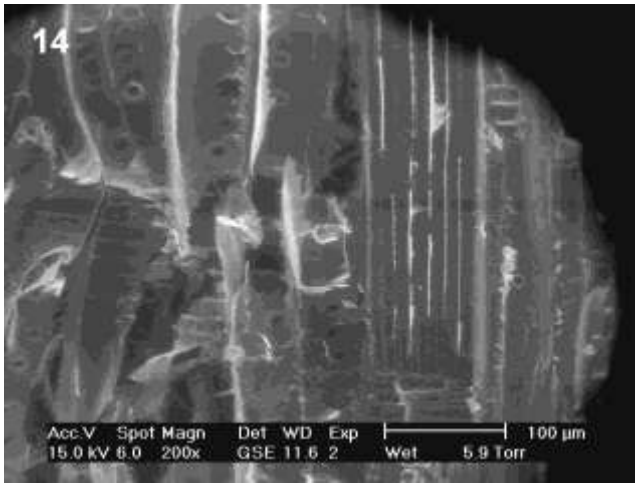
Man-made rope

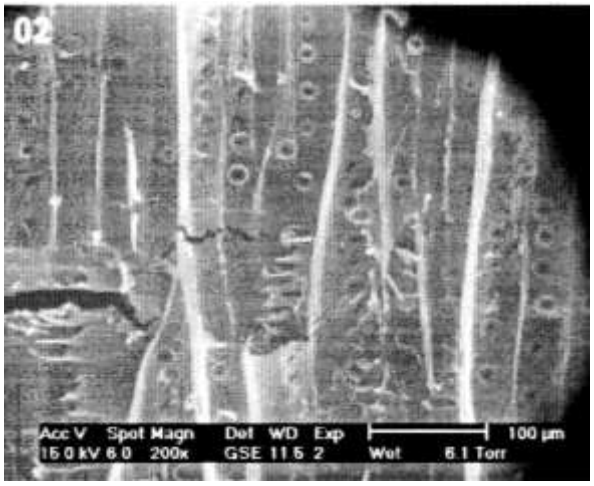


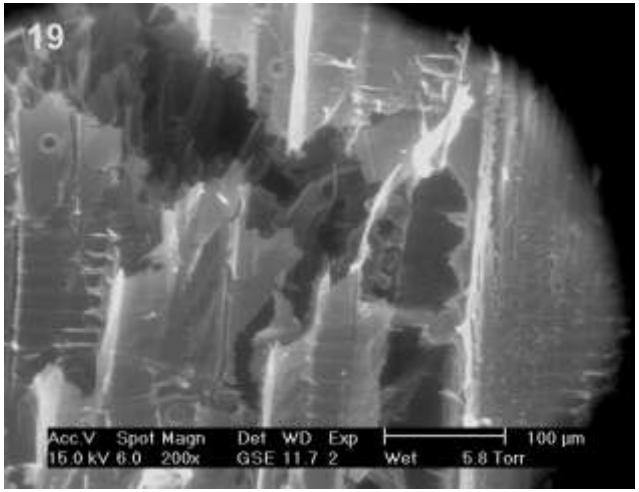


Fracture tolerance – high fracture resistance
Non- LEFM









In situ splitting

ESEM

Spruce LR (R-)

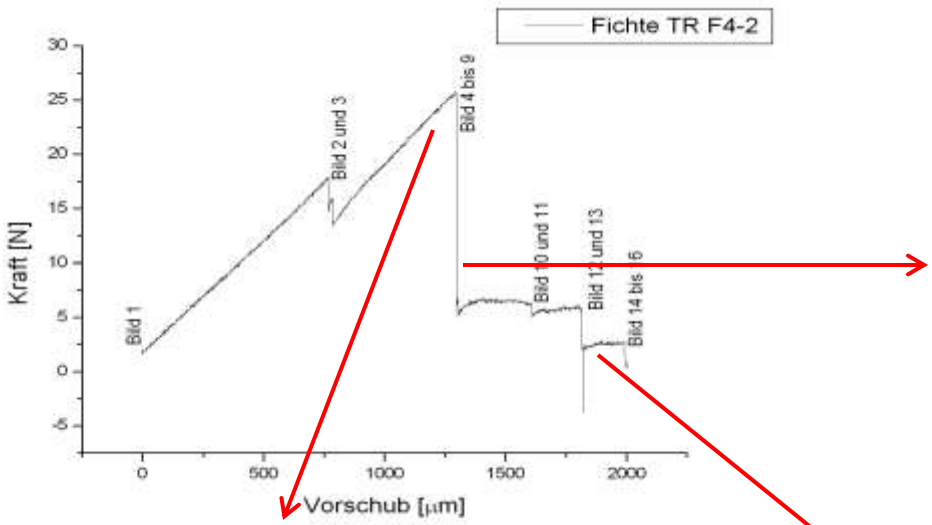
WHY no brittle fracture?

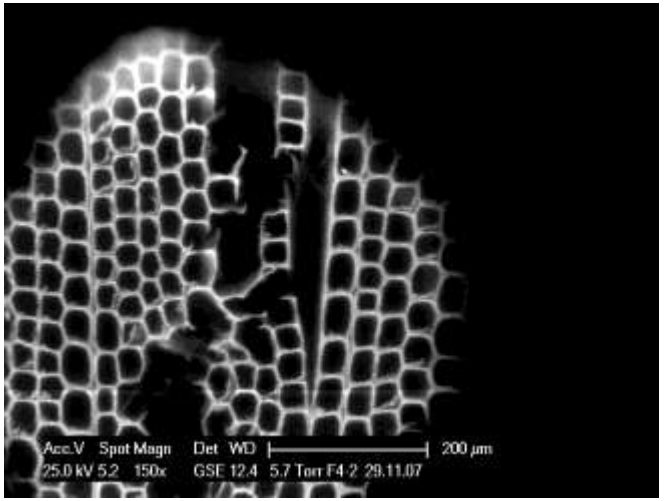
- **Crack branching**
- **Fiber reinforcement**
  by thicker walled late wood cells
- **Fiber bridging**

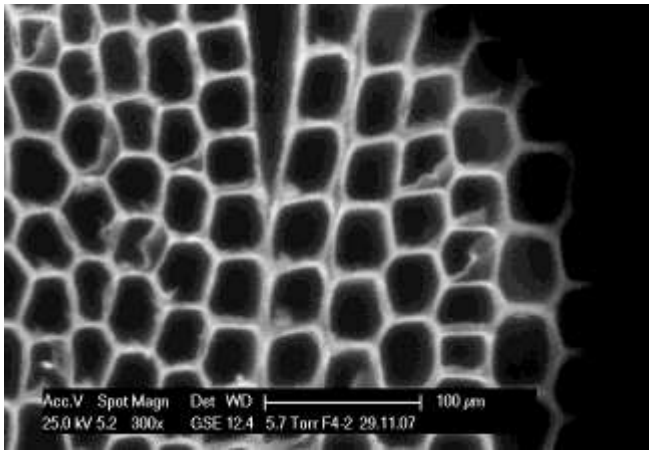
Frühmann et al., CD-Labor 2003

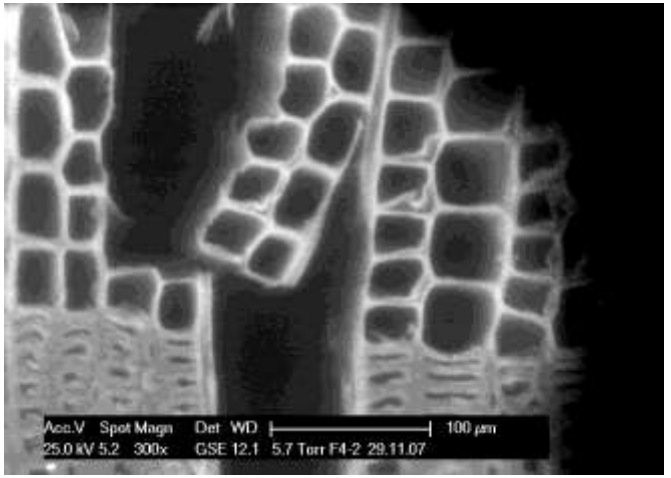
Brittle fracture in TR (R-) orientation but final fibre bridging of crack

ESEM *in-situ* fracturing Spruce





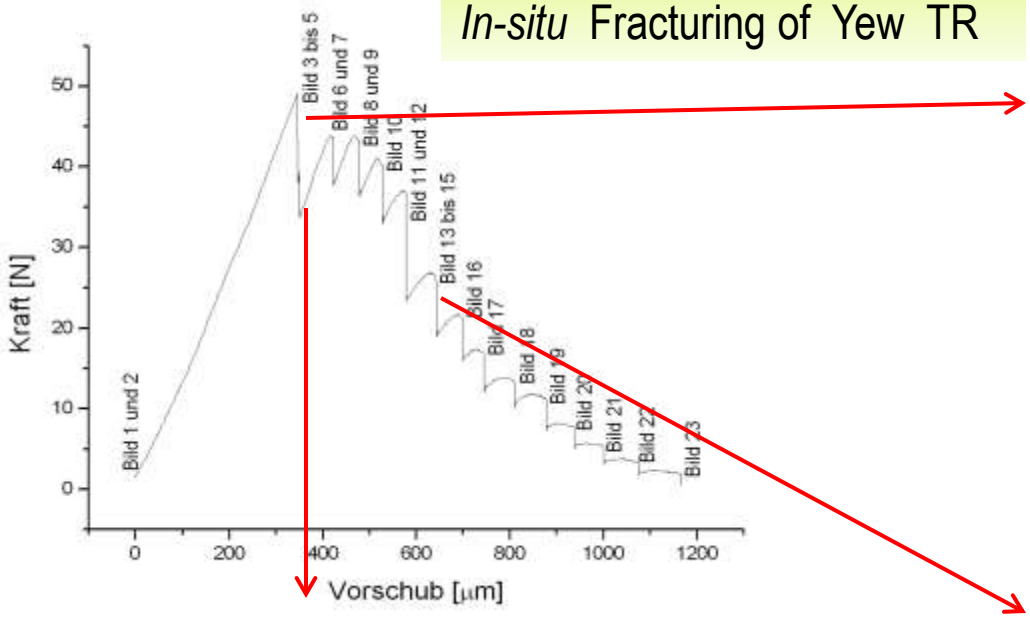


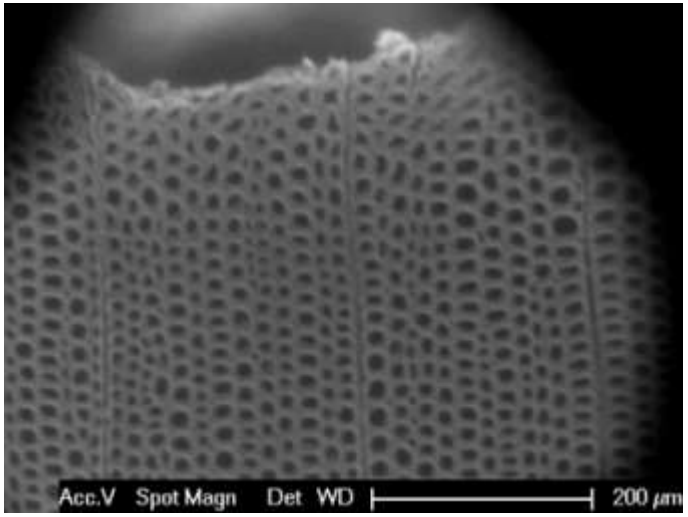


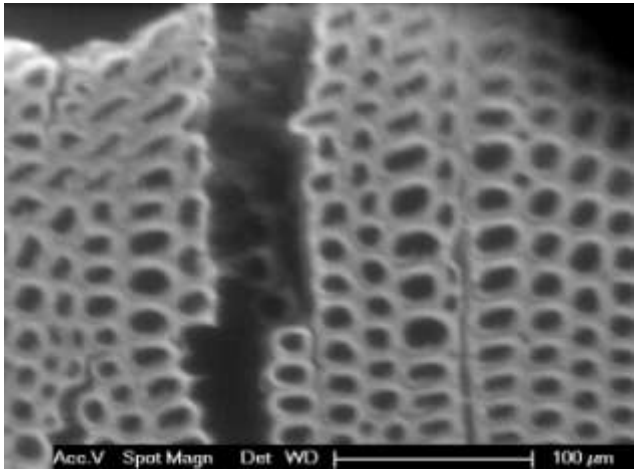
Perlega et al 2007

Further Improvement Compression Wood

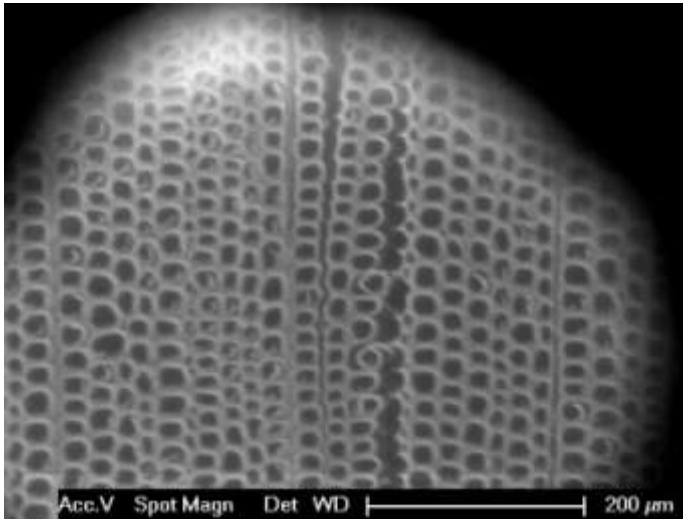
In-situ Fracturing of Yew TR



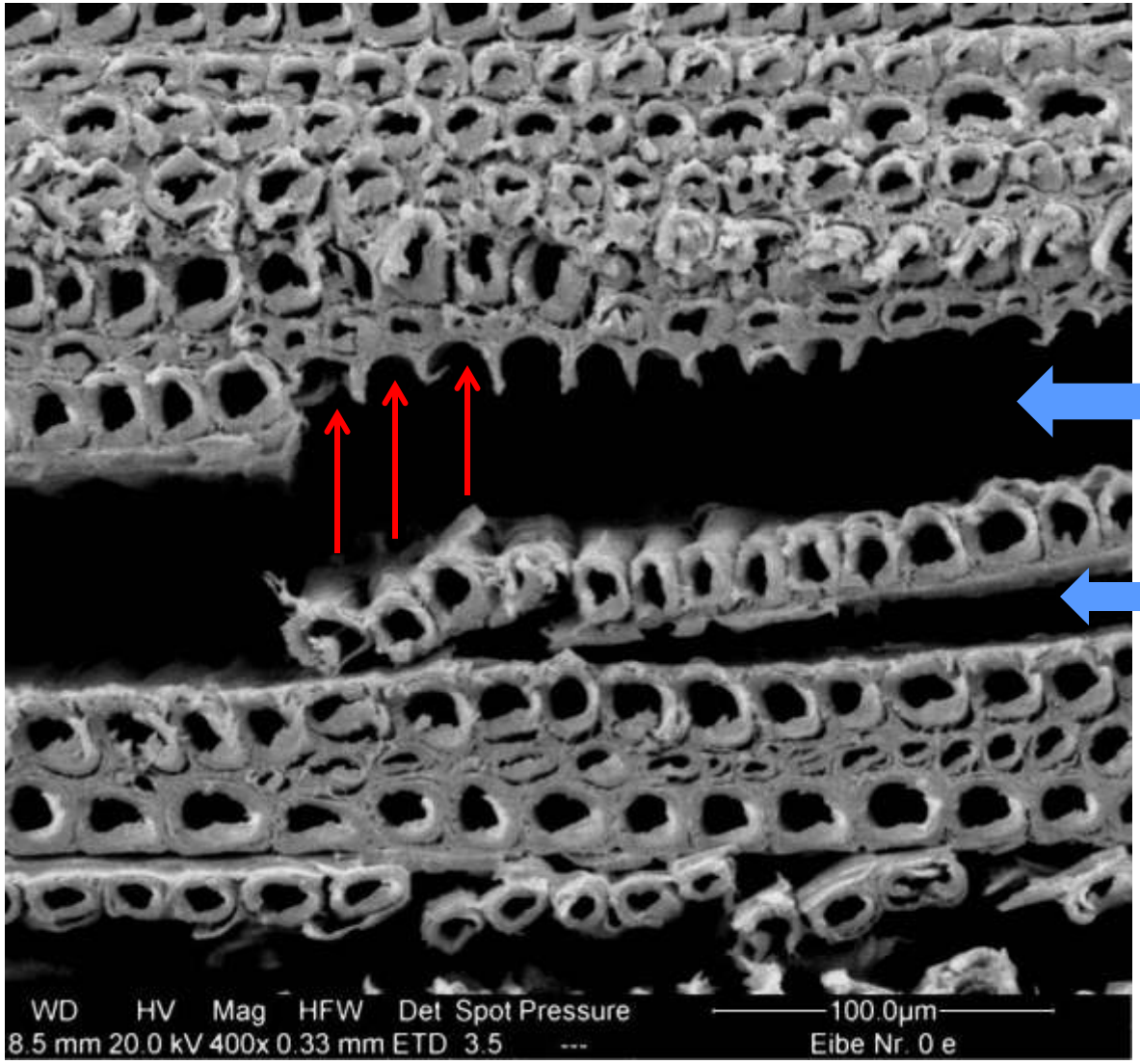




Perlega et al, 2007



Change of Fracture Mode - Yew Compression Wood

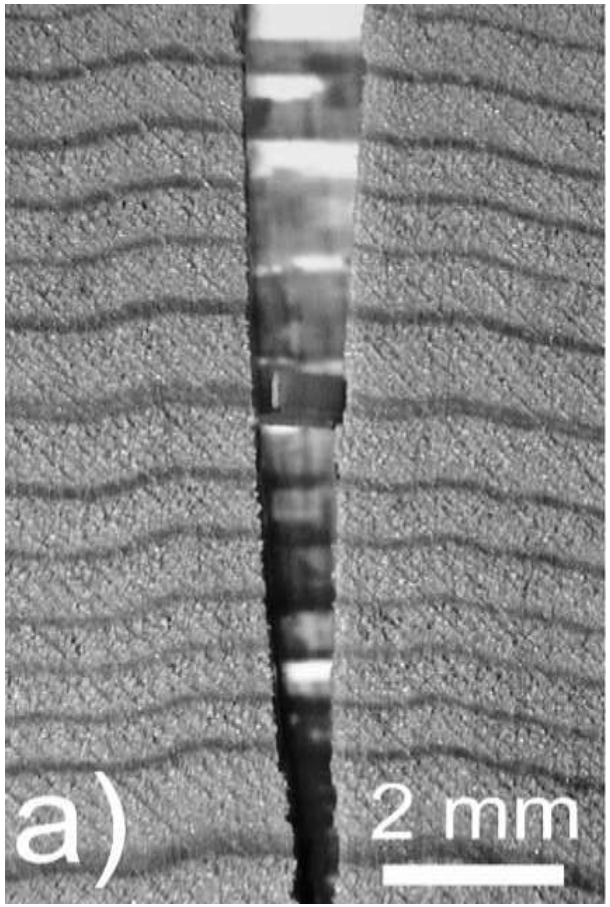


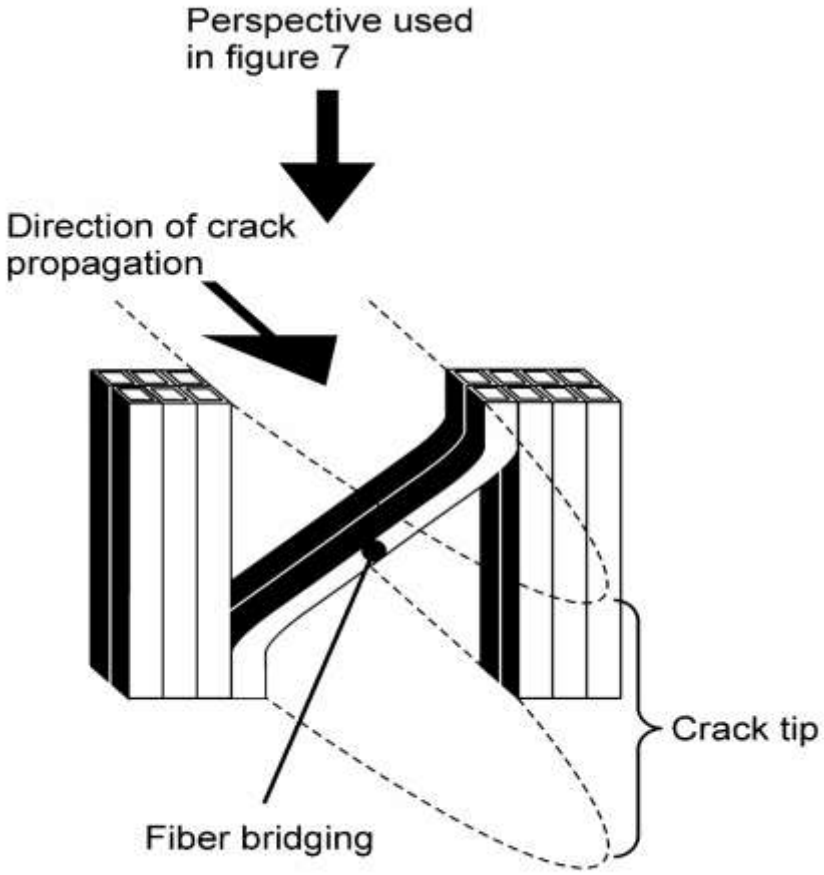
Lower load:
- **Intercellular (S2 – CML)**

High load:
- **Ray fracture - brittle**

Keunecke et al 2007

Fibre Bridging in Yew Compression Wood





Keunecke et al. 2007

Summary: Fracture Tolerance by Shapes and Dimensions of Structure

Several Mechanisms of Crack Arrest

Elongated fibres

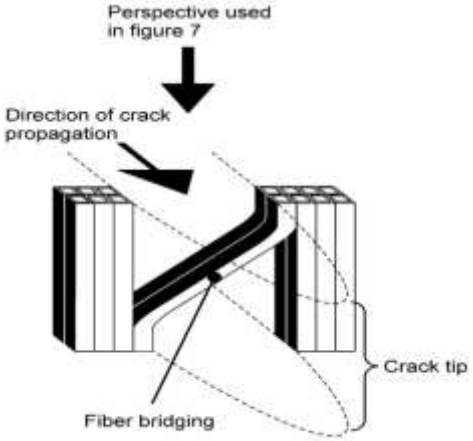
reinforcing

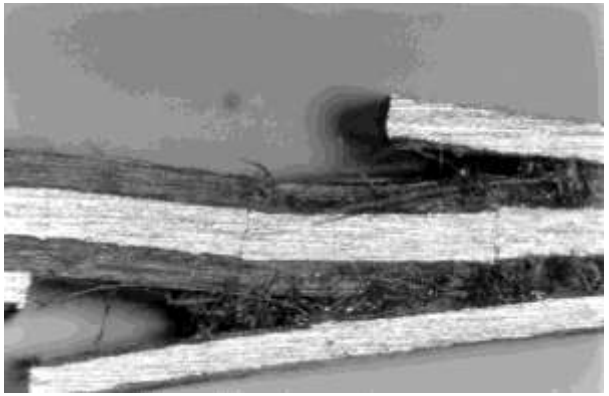
braching, bridging

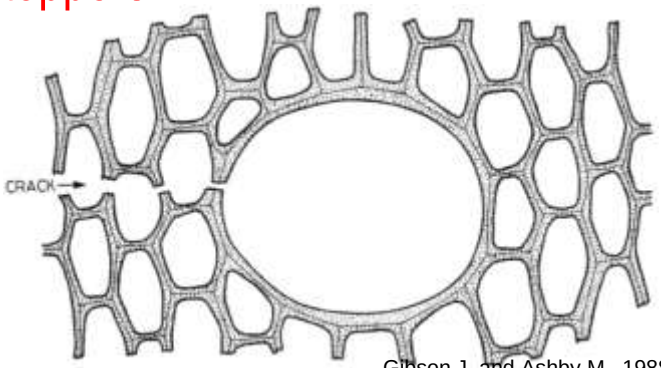
Layers

Cells and holes

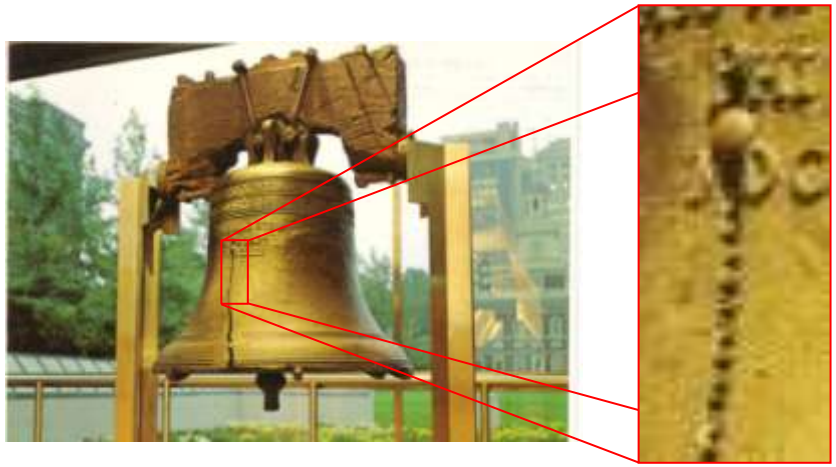
crack stoppers







Gibson J. and Ashby M., 1988



Several mechanisms → fracture tolerant