Aim of the Action

Bringing together experimental and computational methods for a better understanding and higher predictability of wood properties.
Hierarchical structure of wood

Fahlen and Salmén (2005)
Biomacromolecules, modified

Tschegg (2001)
Côté (1965)

MFA

2.5 nm
Lignin
Xylan
Glucomannan
Cellulose microfibril
Micromechanics according to the hierarchical structure of wood

- Tissue mechanics
- Single fibre mechanics
- Cell wall mechanics
- Fibre-tissue interrelations

Hepworth & Vincent (1998)
Annals of Botany
Micromechanical tests can provide a high resolution regarding the mechanical relevance of structural features.

Thin tangential tissue sheets across one growth ring

Futo (1969), Holz als Roh- und Werkstoff, modified
Single fibre tests across a growth-ring

Eder et al. (2009)
Trees
Problems!

Material

Techniques

Heterogeneity
Complexity

Heterogeneity
Complexity
Tissue and Fibre Mechanics

How should we deal with complexity and heterogeneity?

For softwoods

- Xylem
  - Juvenile wood
  - Adult wood
    - Earlywood
    - Latewood
    - Compression wood
    - Opposite wood
      - Tracheids
      - Rays
      - Ax. Parenchyma

For hardwoods even more complex
Complexity of wood

Bramwell (1976), modified
Stress-strain curves of pulped fibres with different microfibril angle

Mechanical properties of chemically isolated fibres with respect to tree height and age

Size effects in micromechanical studies

Different mechanical behaviour of fibers and tissue

Size effects in micromechanical studies

Tensile strength of earlywood and latewood tissues tested perpendicular to the grain

Futo (1969), Holz als Roh- und Werkstoff, modified
Size effects in micromechanical studies

Stress-strain diagrams of wood specimens strained longitudinally

Tissue mechanics in the transverse direction

Jernkvist & Thuvander (2001) Holzforschung
Radial strain as a function of radial position in the growth ring

Jernkvist & Thuvander (2001) Holzforschung
Tangential contraction upon radial straining as a function of radial position in the growth ring

Jernkvist & Thuvander (2001) Holzforschung
Methods - Single fiber tests

Important parameters

- Fibre fixation
- Fibre length
- Strain rate
- Fibre rotation
- Force and strain measurement


Burgert et al. (2003) Holzforschung
Eder et al. (2009)
Trees
Combine microtensile testing with ESEM technology


**Fig. 2** Characteristic deformation pattern of an earlywood fibre and corresponding force-displacement curve; *bar 50 μm*. *a-f* in the diagram refer to the corresponding micrographs which are plotted below; *arrows* in *b* point at incipient folding/collapse of the cell wall.
Fig. 5 Characteristic deformation pattern of a latewood fibre and corresponding force-displacement curve, bar 50 μm
Drawbacks of micromechanical studies

- Complexity of the material (cell types)
- Natural variation
- Complexity of variability (several parameters changed)
- Inhomogeneity of samples (pits, MFA)
- Influence of testing techniques
- Geometrical and size constraints

Measurement of highly specific data

Comparability? Usability?
What can we do to make wood more predictable?

- standardize micromechanical testing techniques
- use genetically modified material (compensation strategies!)
- establish a pool of structural and mechanical data
- become more analytic rather than descriptive
- combine micromechanical testing and modelling towards a mechanistic model
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Wood cell wall

Fengel & Wegener (1984) modified

Hemicelluloses & Lignin

3 nm
In-situ tensile tests combined with Raman spectroscopy

Individual mechanically isolated tracheid of spruce (*Picea abies*)

- **Cellulose, C-O-C**
- **Lignin, C=C**

Gierlinger et al. (2006) Biomacromolecules

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In-situ tensile tests combined with X-ray measurements

Change of cellulose microfibril orientation

Wet compression wood tissue of spruce

We need to get more information about the matrix properties and the interactions of the macromolecules!

Approaches:

• Lennart Salmén‘s talk „Softening – transverse direction“

• Mechanical characterization of genetically modified material (Ingela Bjurhager, Lars Berglund)

• Perform in-situ testing techniques on genetically modified material!
How can we contribute to this COST-Action?

• Provide structural and mechanical data (pool of data) to the modelling community

  ➔ „Iterative approach“

• Approach the level of molecular interactions and its transfer to higher hierarchical scales in a combined actions of experimental and computational characterization.

  ➔ „Back and forth approach“