From wood anatomy

to tree-biomechanics

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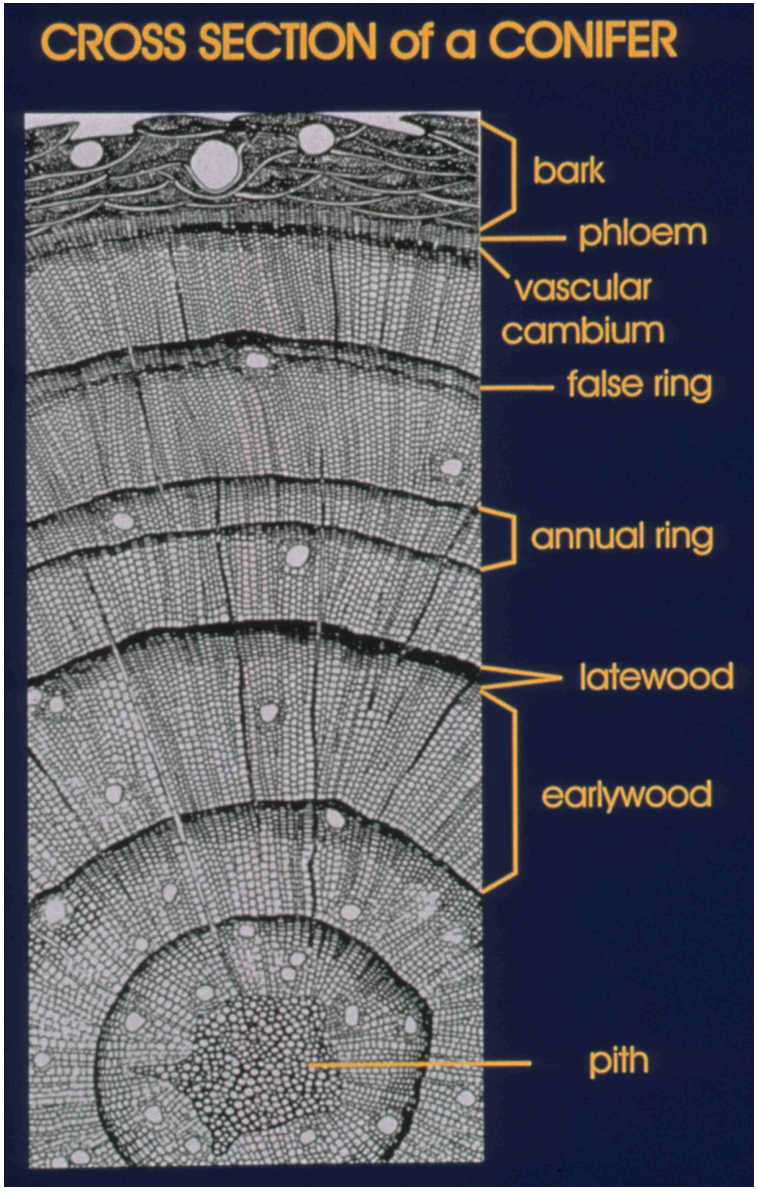


coniferous wood

is 'relatively' simple:

basically one kind of cell (tracheids) has to provide for

> water transport

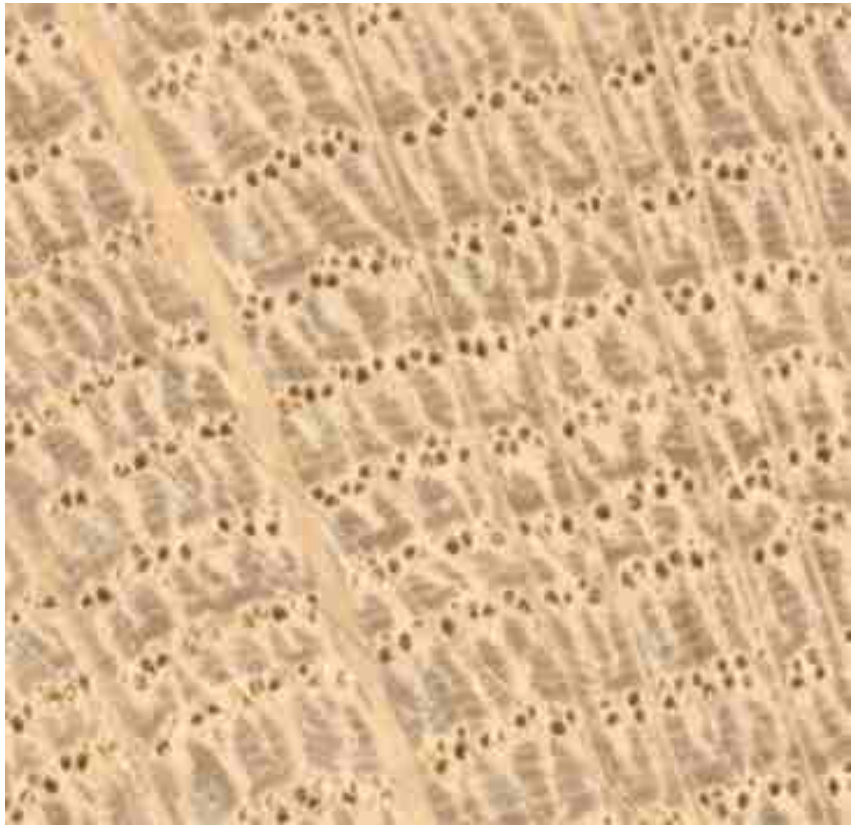
> storage

> stability

but is differently built

in earlywood and latewood

(picture from ITRDB Tucson)



ring porous wood

is more complex: it has different kinds of cells, each fulfilling specific purposes:

> vessles

> rays

> tracheids

=> large gradients of density and strength!

=> rays are required not only for radial transport but for stabilization!

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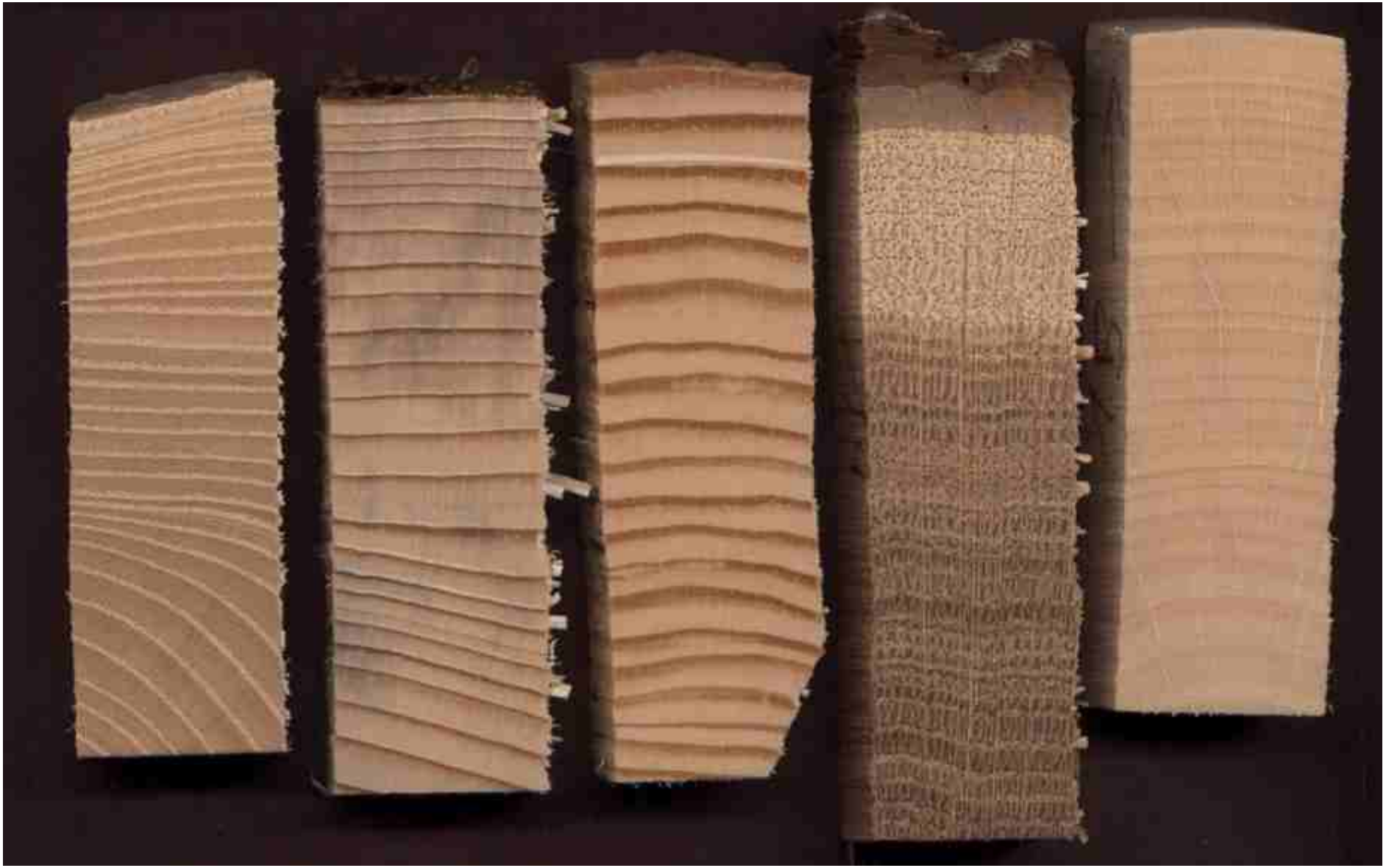
Diffuse porous wood

often does not show clear tree rings because latewood may be missing completely

=> it is more homogenous

=> and the trees are more flexible because they can build vessels within the vegetation period



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With decay, bio-mechanics is more complex:

> early stages of brown or soft rot, for example, can lead to 90% strength loss while having only 'eaten up' 10% of the wood (Wilcox 1978)

> such early stages of decay are difficult to detect with ALL machines measuring MOE (modulus of elasticity), such as sonic tomography or pull tests.

In addition to the variation on the cellular level, there is one additional factor, strongly influencing internal mechanical design of trees:

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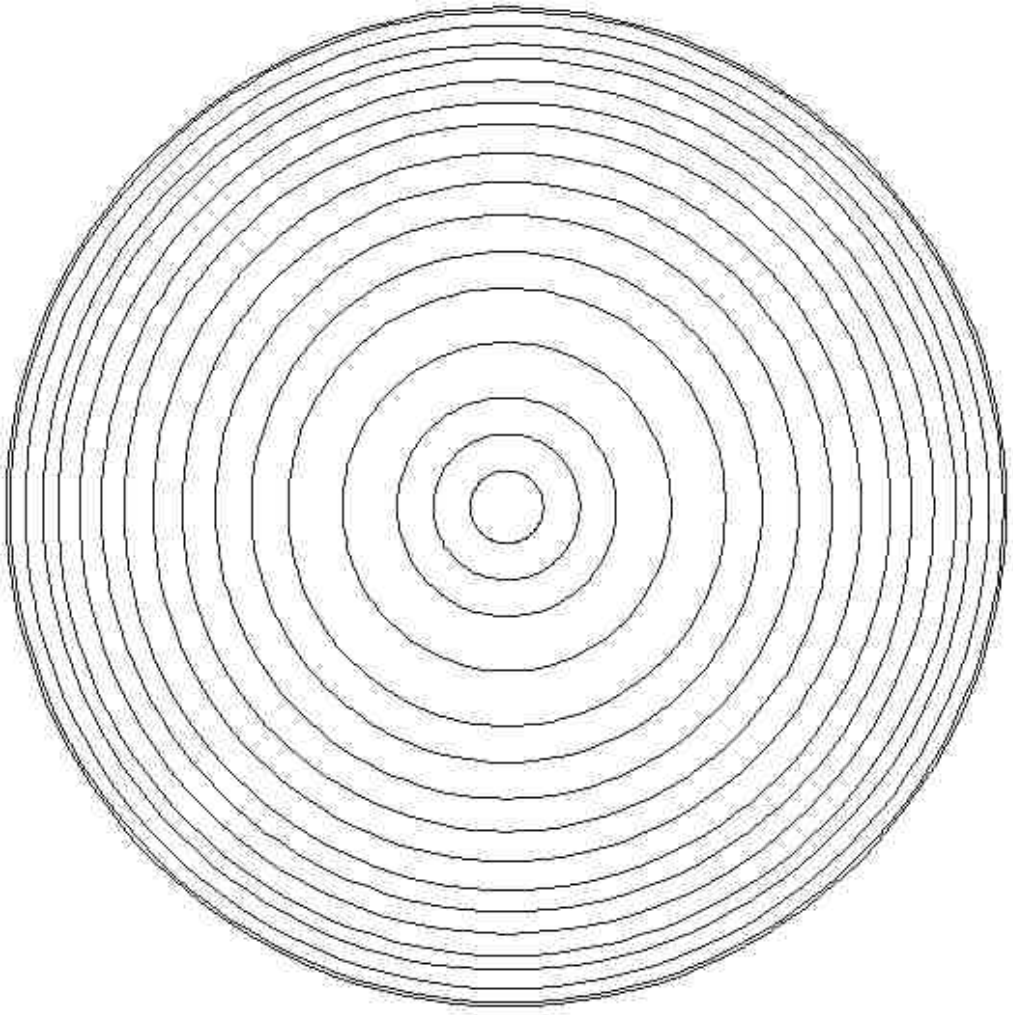
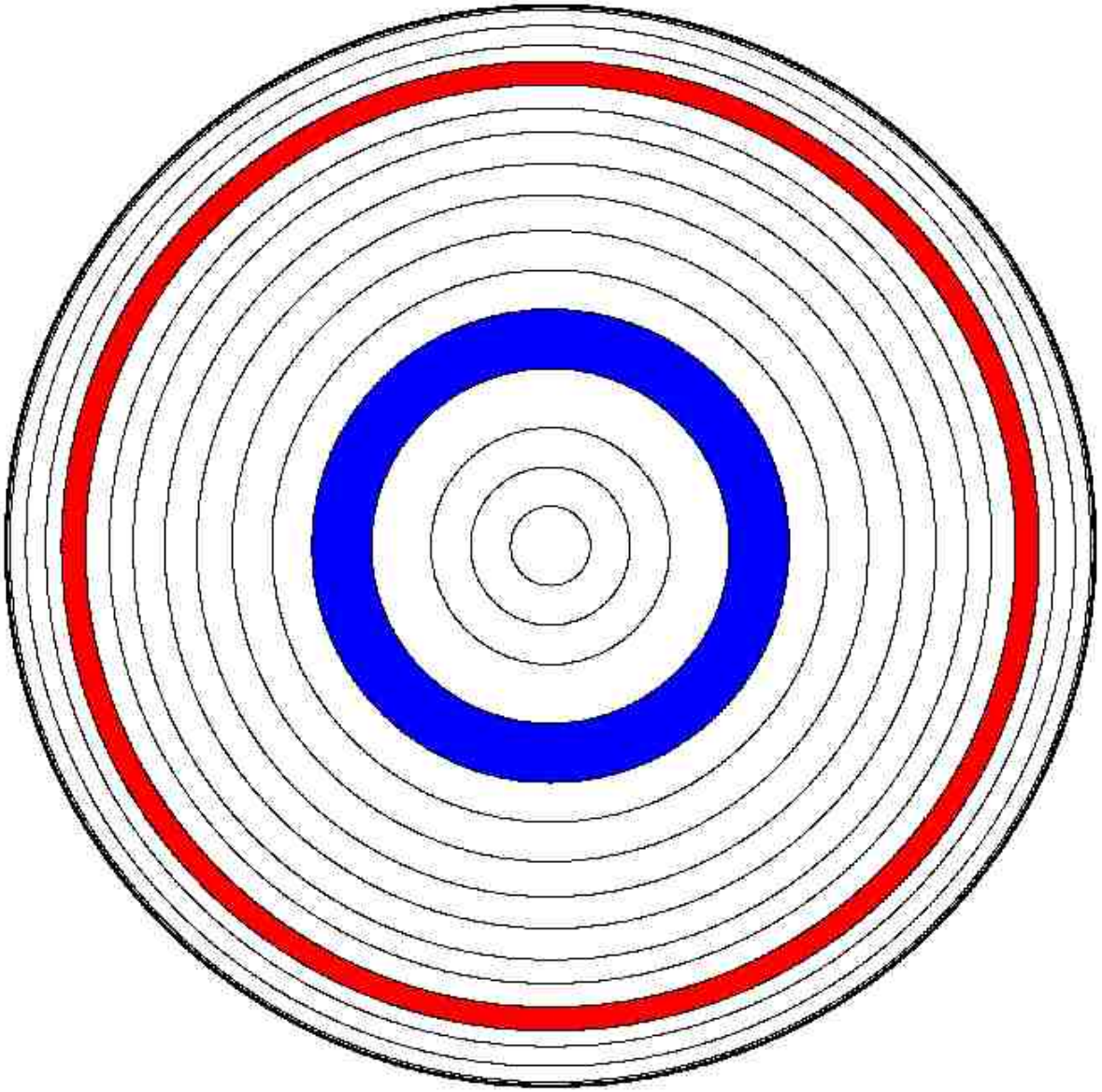
Age trend:



ring width typically decreases after the 'juvenile' phase.

After maximum height and girth growth was reached, ring width often stabilizes on a certain level.



A decreasing ring width does not mean vitality is decreasing!

A thinner ring outside can represent more wood production than a bigger ring in the center!

=>

Don’t condemn trees just because growth rates are decreasing!

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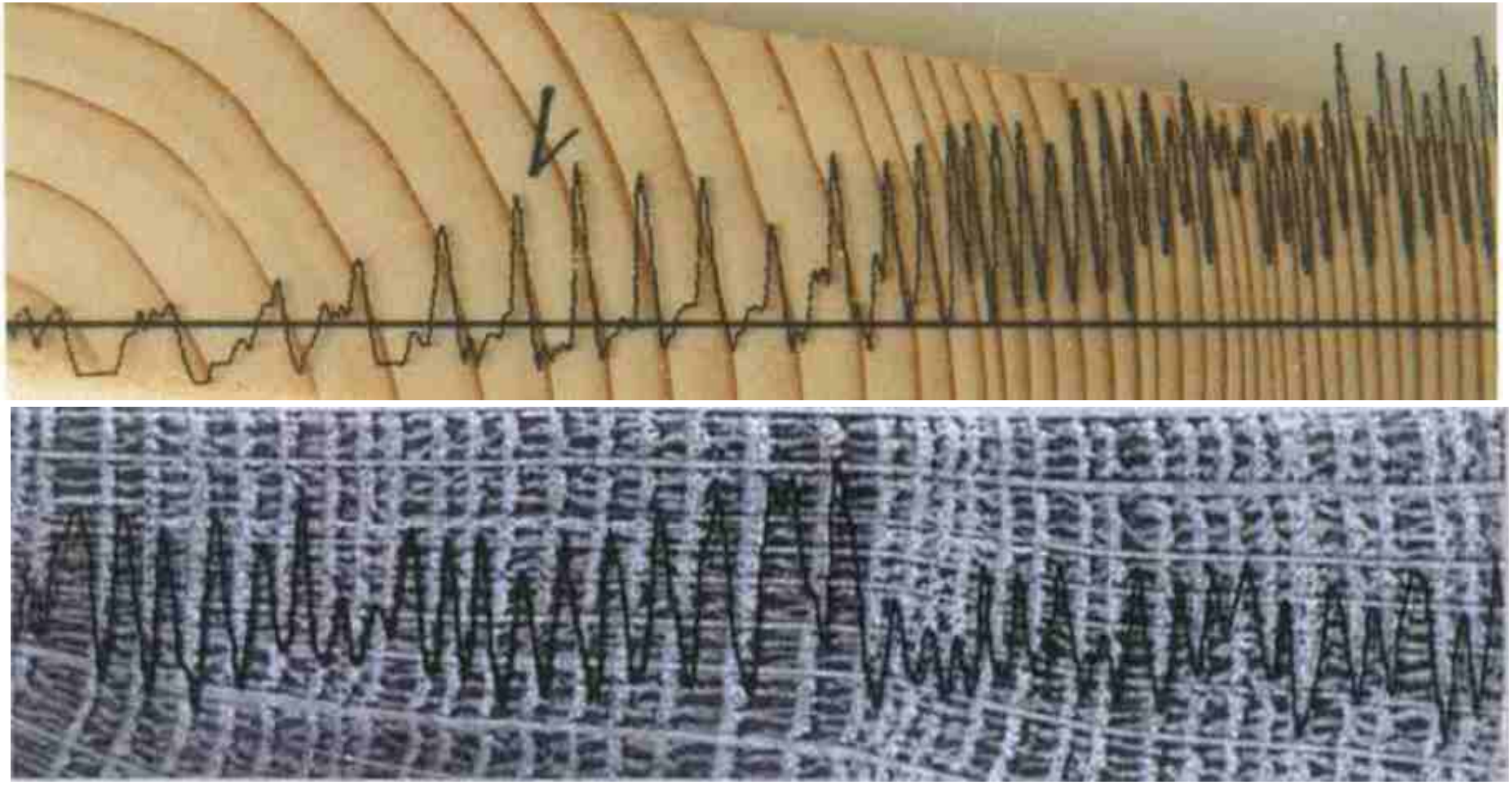
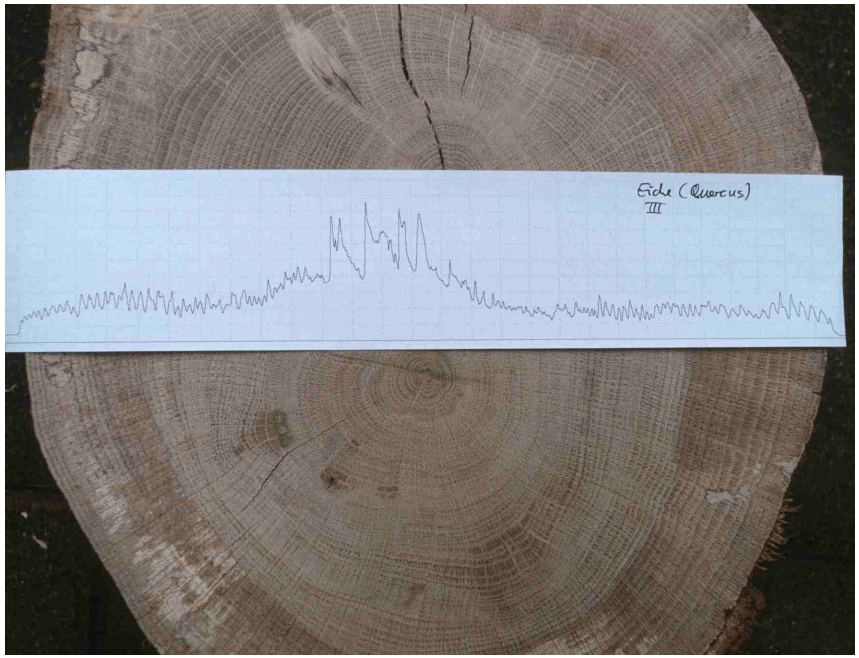
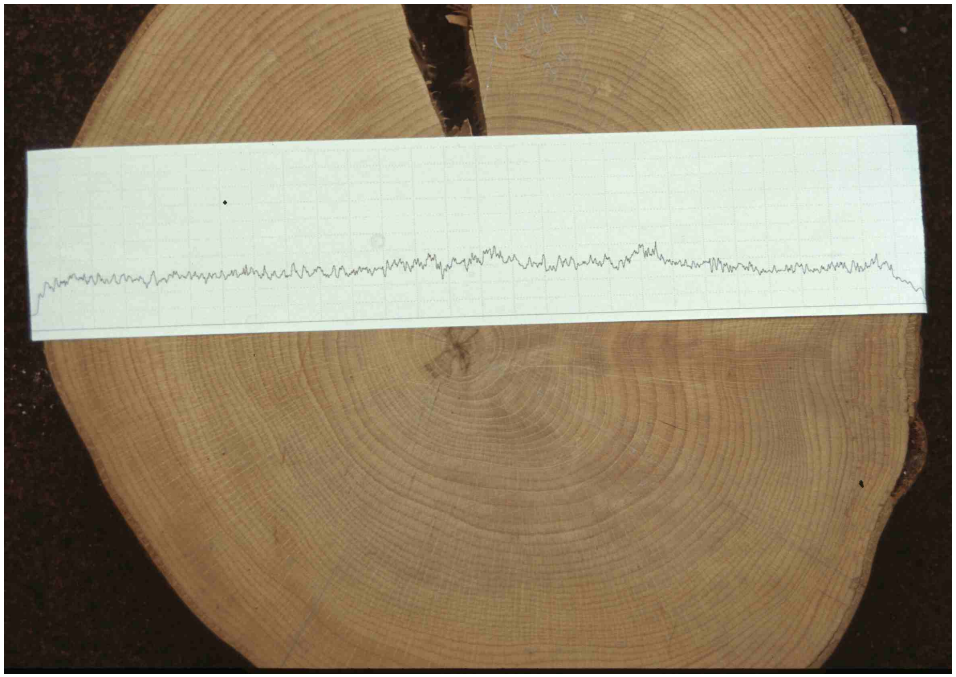
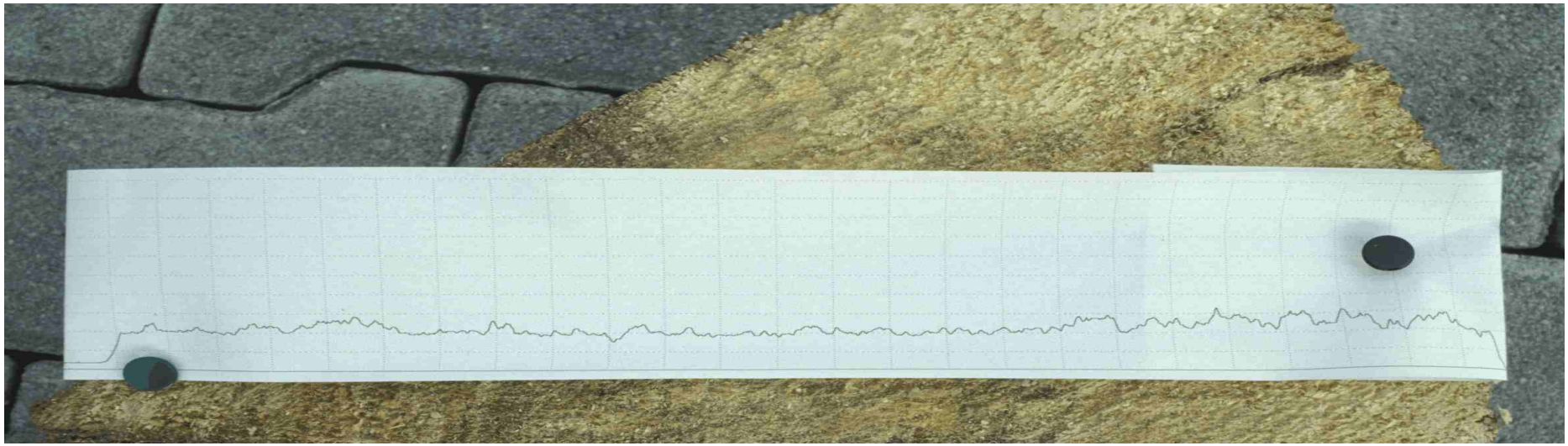
Changing ring with determines mechanical wood properties:

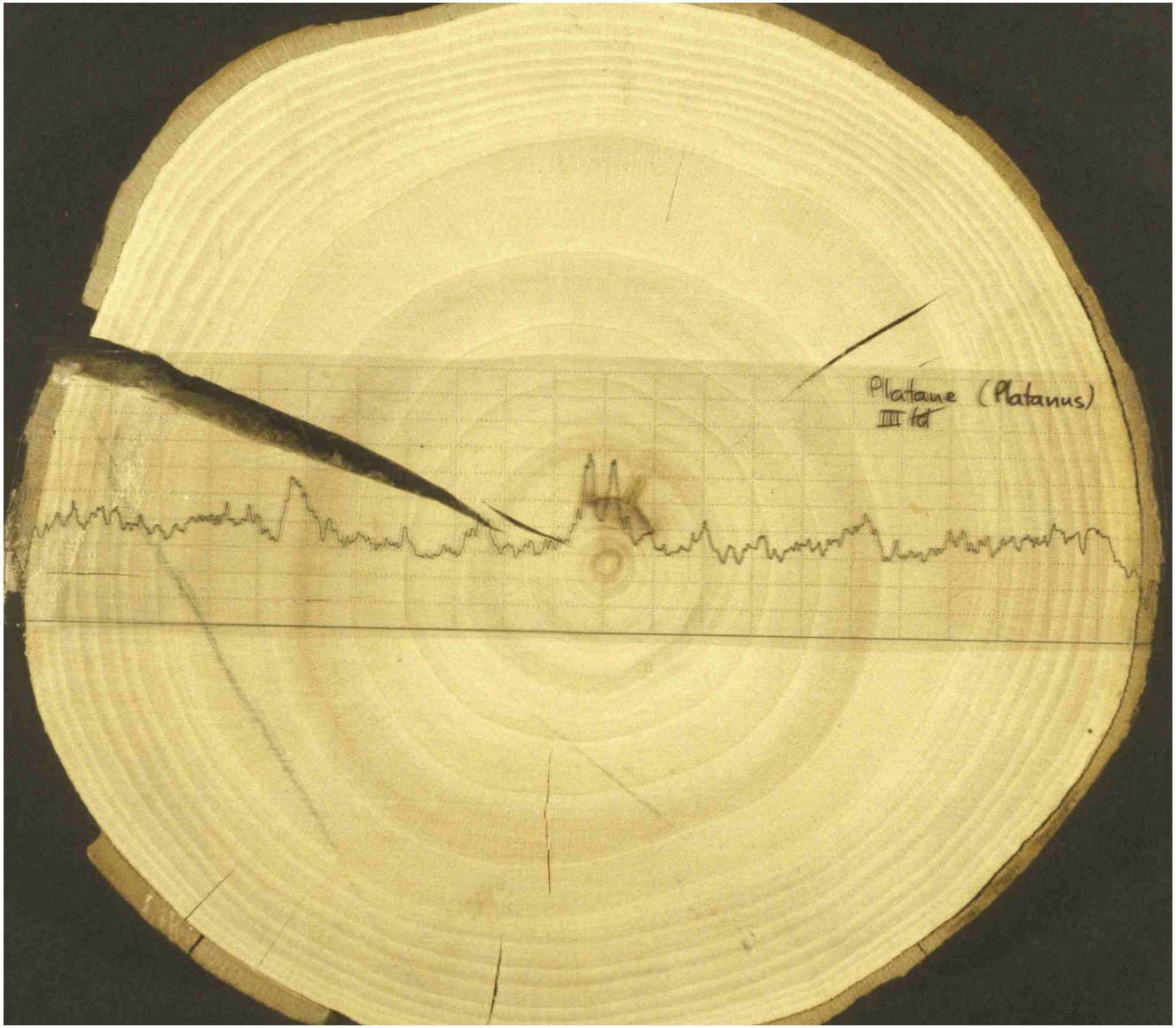
(in certain different ways in conifers, ring- and diffuse porous wood!)




Eiche (Quercus)
III





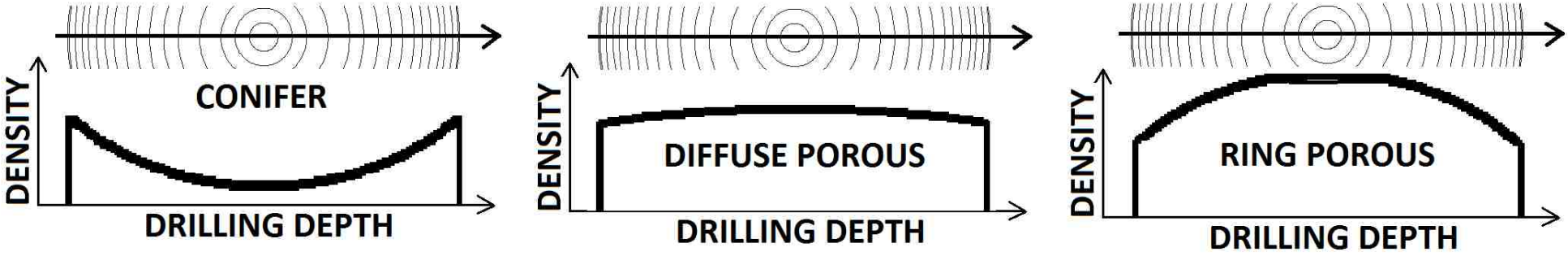


While conifers are mostly much softer in the center, ring-porous trees are much stronger in the center and diffuse porous trees are more homogenous in their density and strength distribution in a cross-section.

=> species matters!

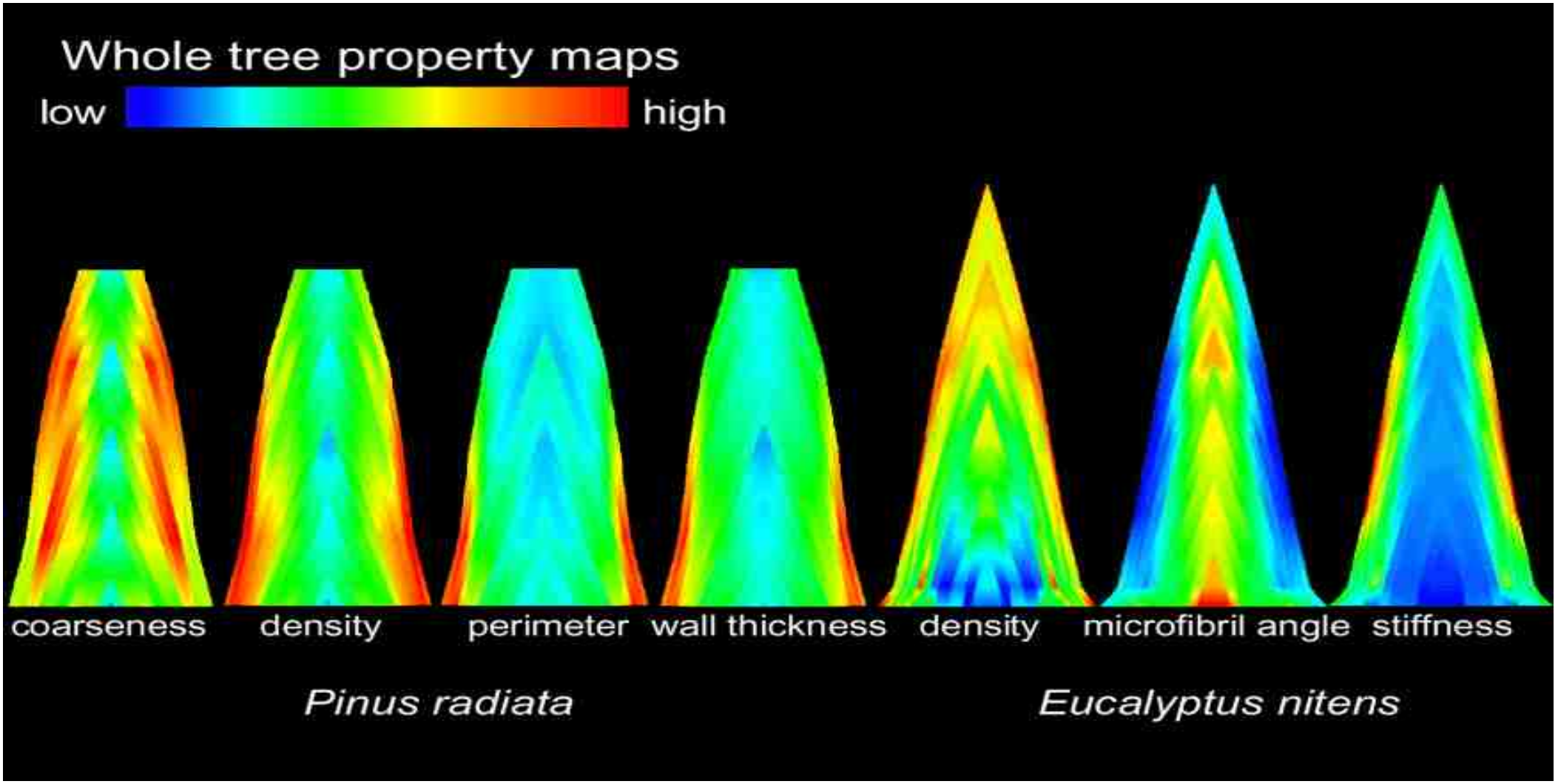
The cellular wood anatomy in combination with the age trend, leads to typical cross-sectional density and strength-distribution.

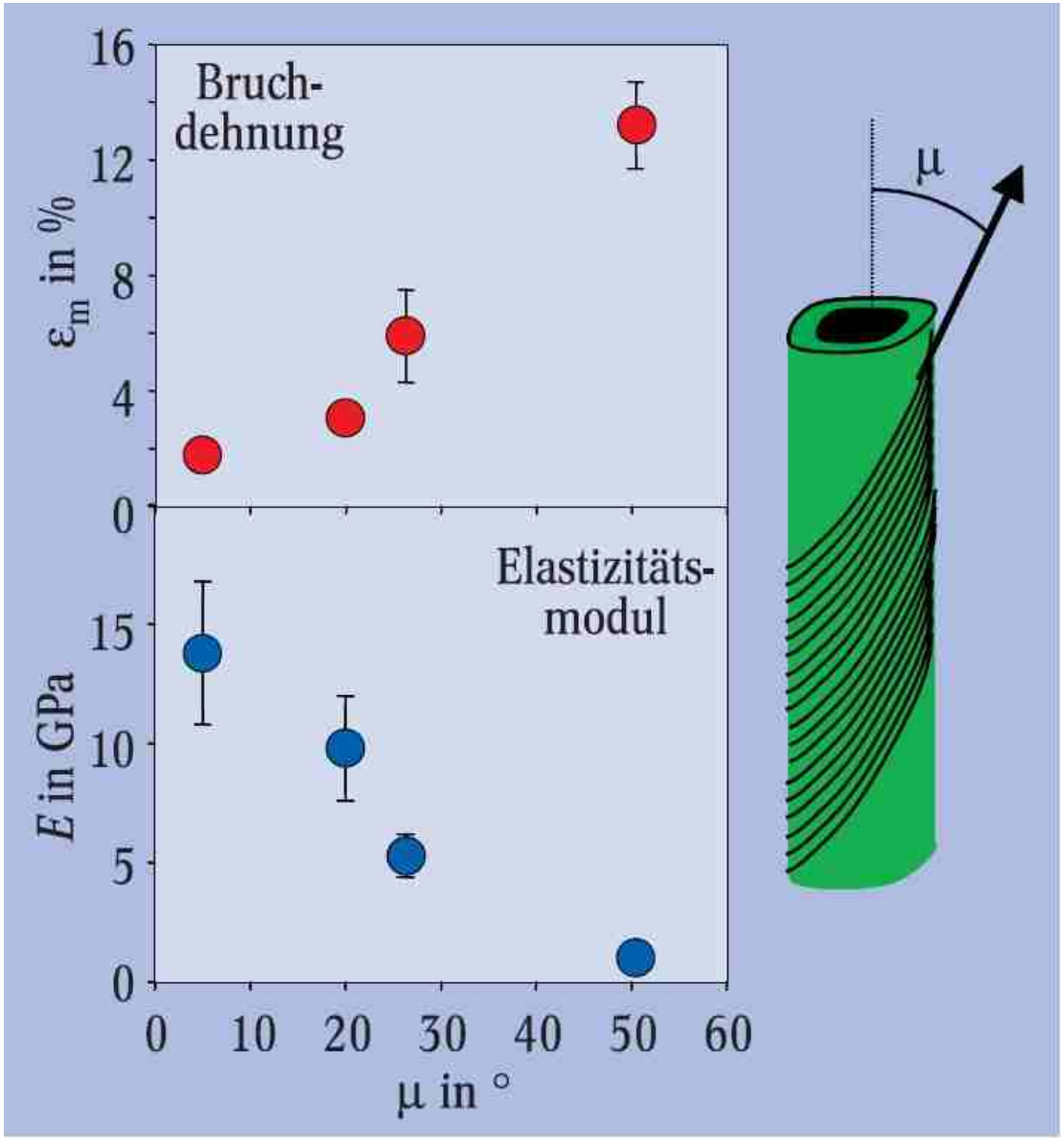
Radial density profiles of different species groups / kinds of wood:



(can be measured and correctly displayed by x-ray densitometry or, for example, by resistance drills, but only by calibrateable machines -versions)

Robert Evans, CSIRO/Melburne:

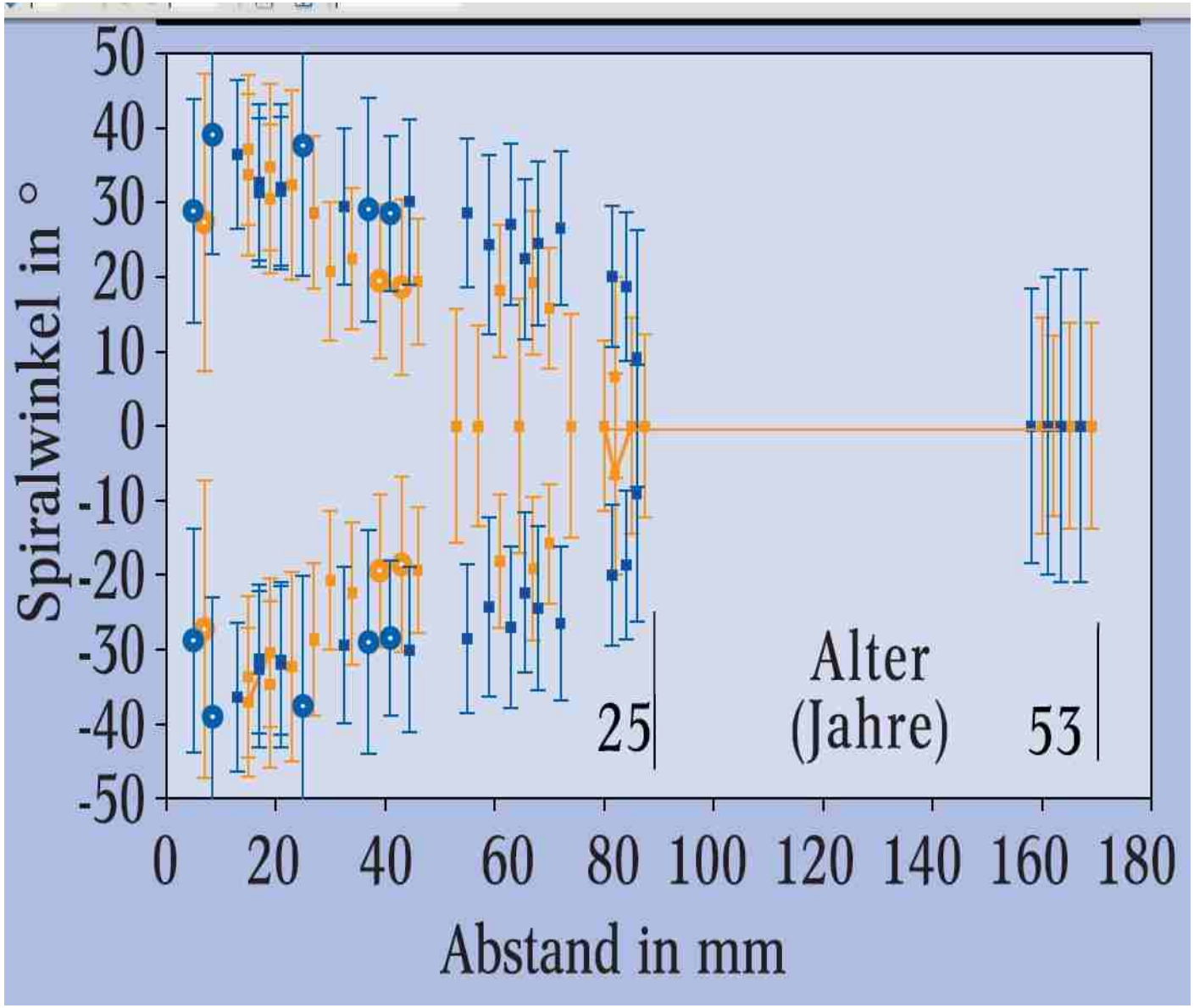




(Fratzl 2002)

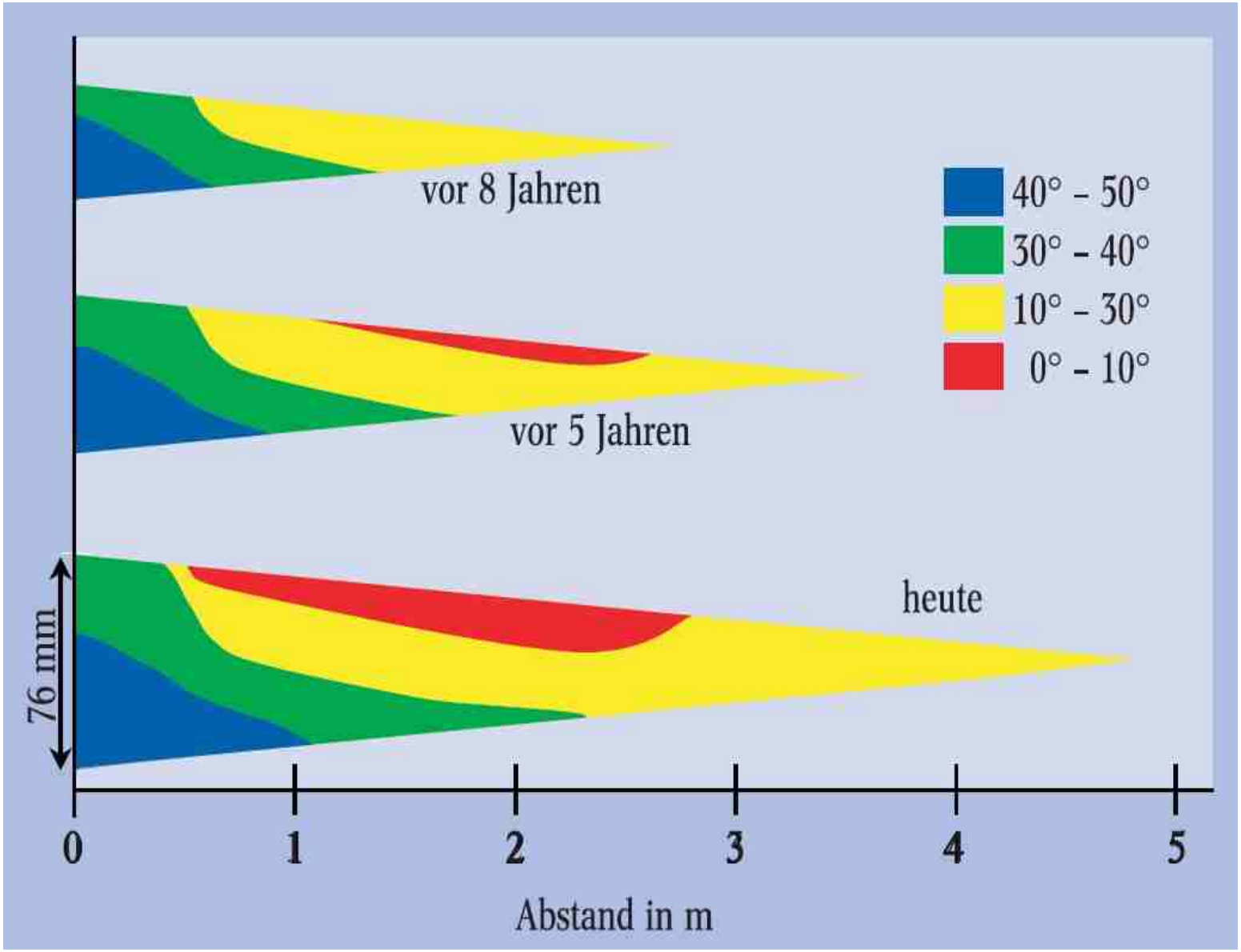
In addition to the overall variance in wood strength, trees are able to locally change material property by, for example, different fibre angels.

=> Modulus of elasticity
strongly depends on
fibre angle!



(Fratzl 2002)

Fibre angle typically decreases with age!



(Fratzl 2002)

=>

Wood stiffness changes with age!

(Climbers know that already since a long time)

Summary

- Mechanical properties of trees differ strongly between three major species groups:
  - conifers ring-porous trees diffuse porous trees
- in terms of trunk-internal mechanical 'design'
  - tropical trees are very much like diffuse-porous trees
  - palms are different but most similar to conifers
- Radial wood growth adapts to changing mechanical loads in different ways depending on an age-specific combination of:
  - bigger/smaller tree-rings
  - higher/lower wood 'quality' (density and/or stiffness/elasticity)

> Young trees react different to changing mechanical loads than mature trees!

> Structural stability of young and mature trees have to be evaluated differently!

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