Lecture 6: Xylem and how rings are formed

- General structure of softwood xylem
- General structure of hardwood xylem
- Cell types
- Meristems and gross structure
- The vascular cambium
- Stages in development of a woody cell
- Cell and ring development

Tuesday May 27, 2014, Dendroecology presession class

Malcolm K. Hughes, Laboratory of Tree-Ring Research, University of Arizona

Lecture 6: Xylem and how rings are formed

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General structure of softwood (conifer) xylem

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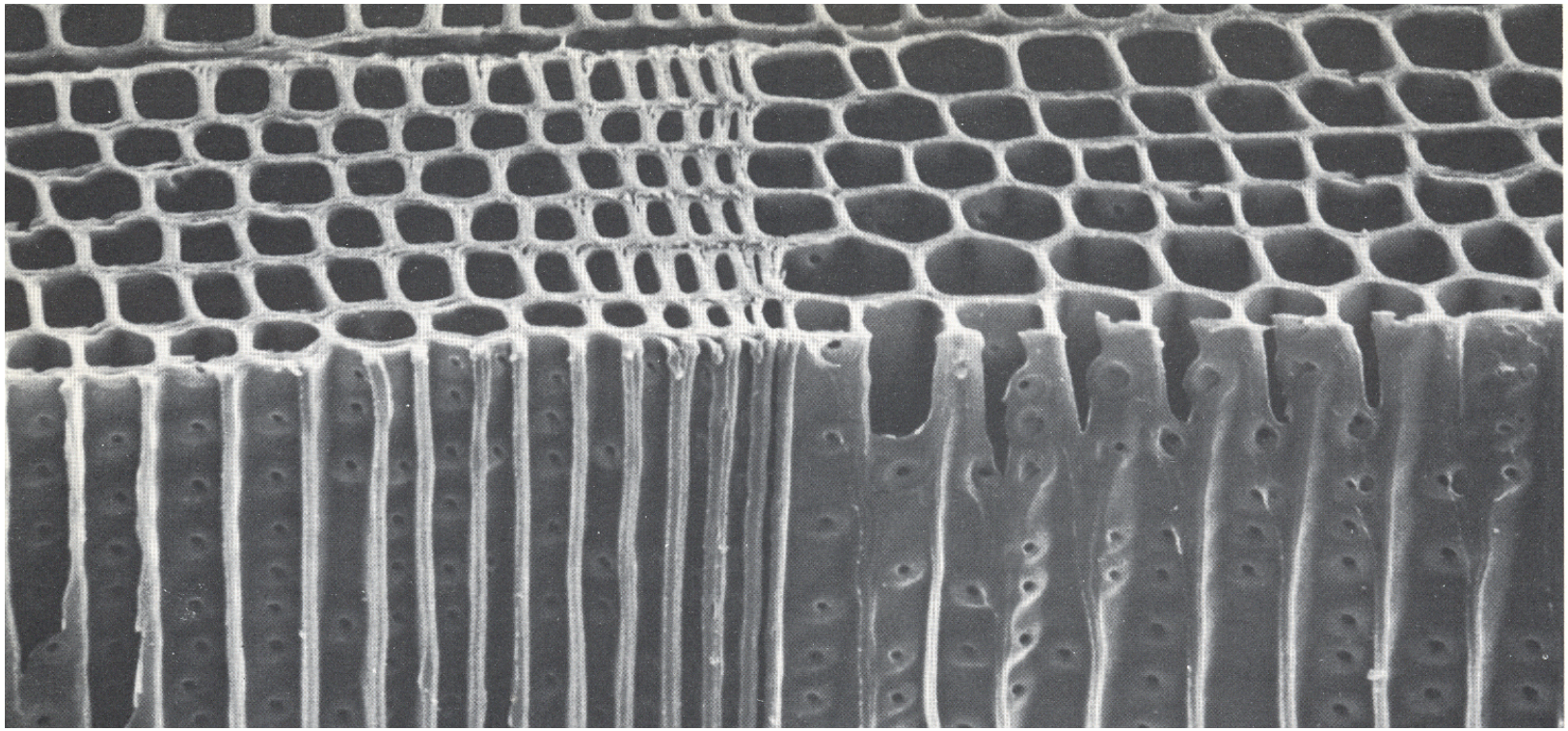
A growth ring boundary in *Chamaecyparis lawsoniana* – note bordered pits in tracheid walls.*All SEM pictures from Butterfield and Meylan, 1980.*



General structure of hardwood (angiosperm) xylem

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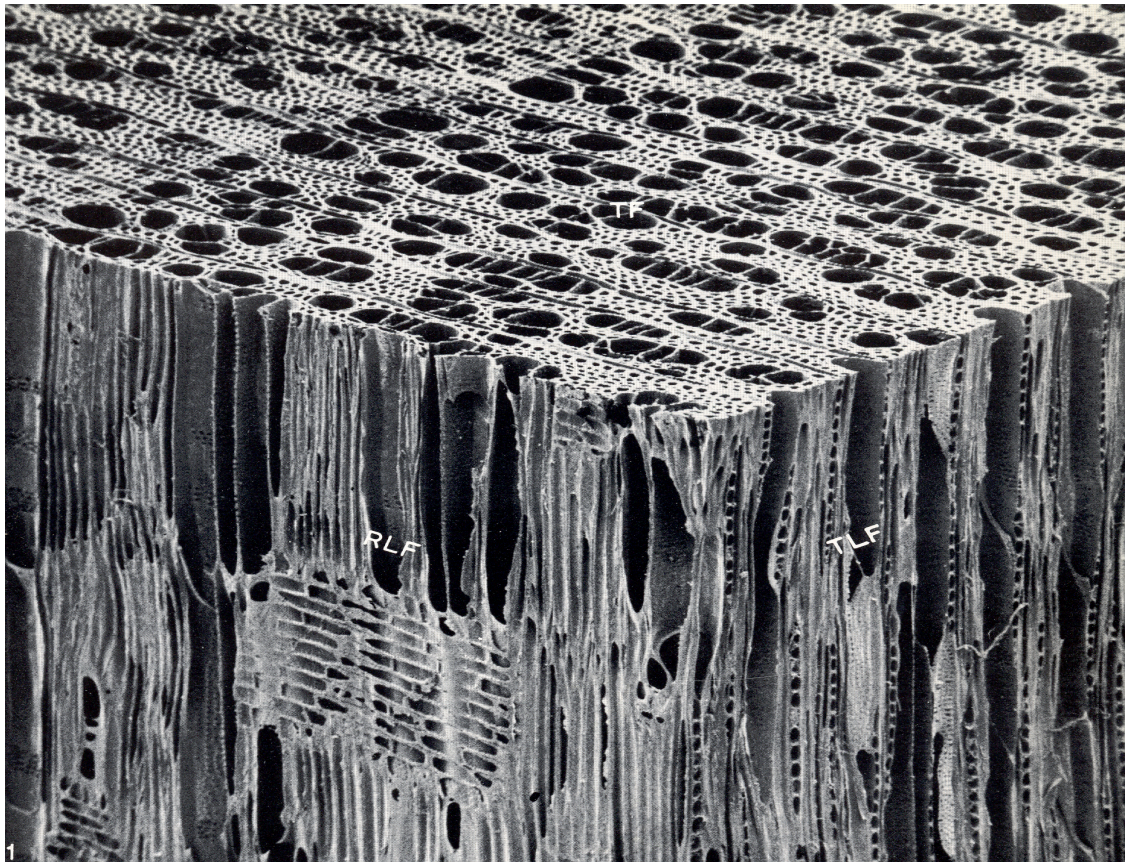
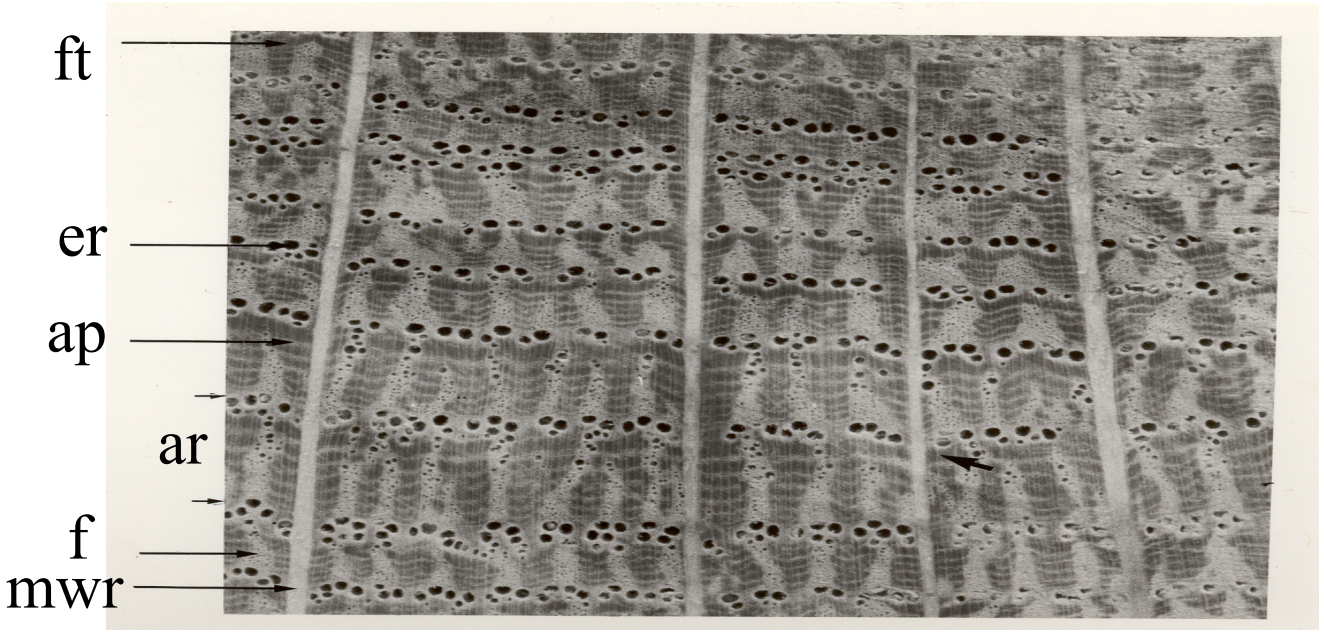
As can be seen in this *Nothofagus solandri*, the main difference between hardwood and softwood xylem is the presence of vessels, which may be much bigger than tracheids. They do have pits. *All SEM pictures from Butterfield and Meylan, 1980.*



OAK



Ft – fibers and fiber tracheids
Er - earlywood
Ap – apotracheal parenchyma
Ar – annual ring 2.77mm
F – ‘flame’ – bank of latewood vessels
Mwr - multiseriate wood ray

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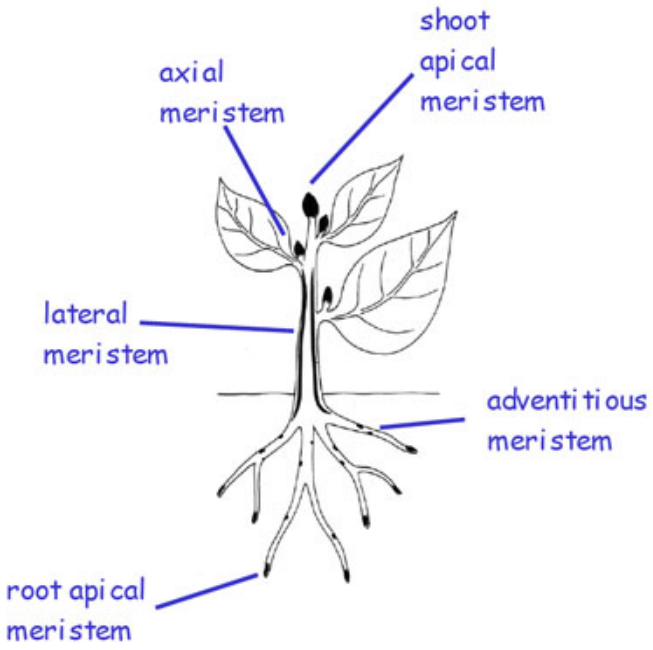
How rings are formed (xylogenesis)

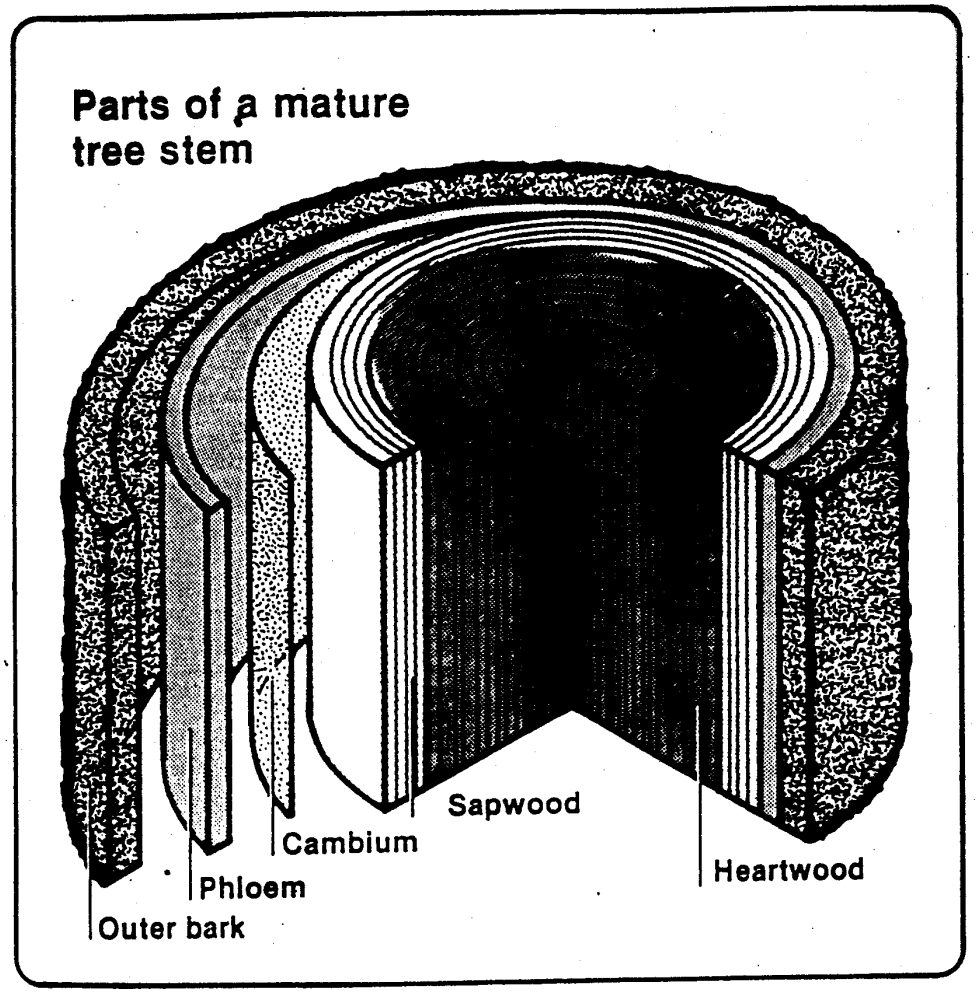
- Meristems and gross structure
- The vascular cambium
- Stages in development of a woody cell
- Cell and ring development

Meristems and gross structure

Meristems are tissues whose cells divide and differentiate to form other tissues. Main ones – apical meristem and vascular cambium (this is a lateral meristem).



http://vannocke.hrt.msu.edu/plb865/Meristem%20dynamics/meristems.html



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What's the sequence of events*?

* *In conifers*

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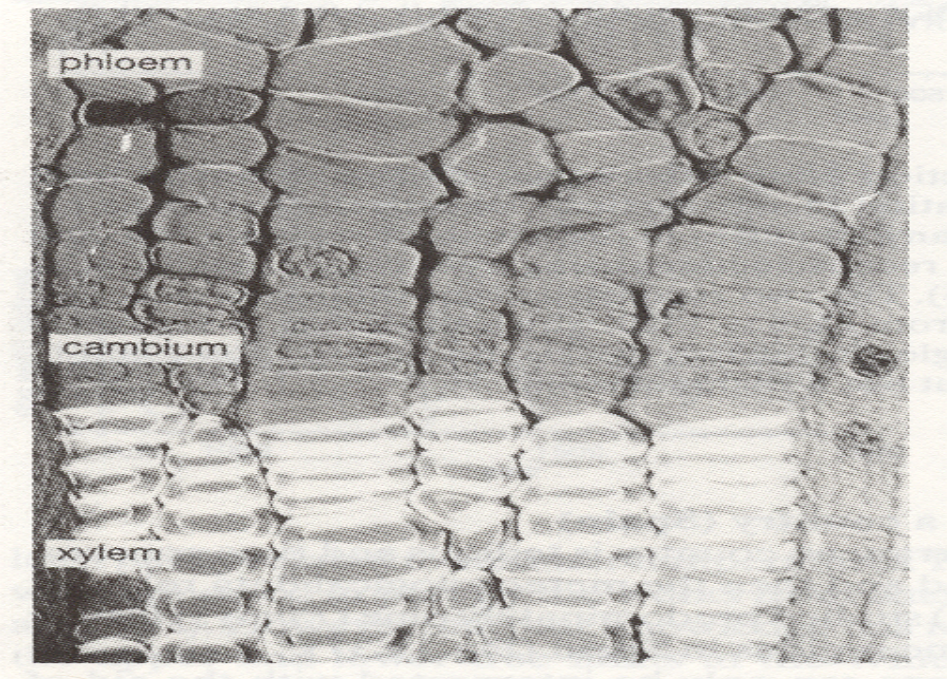
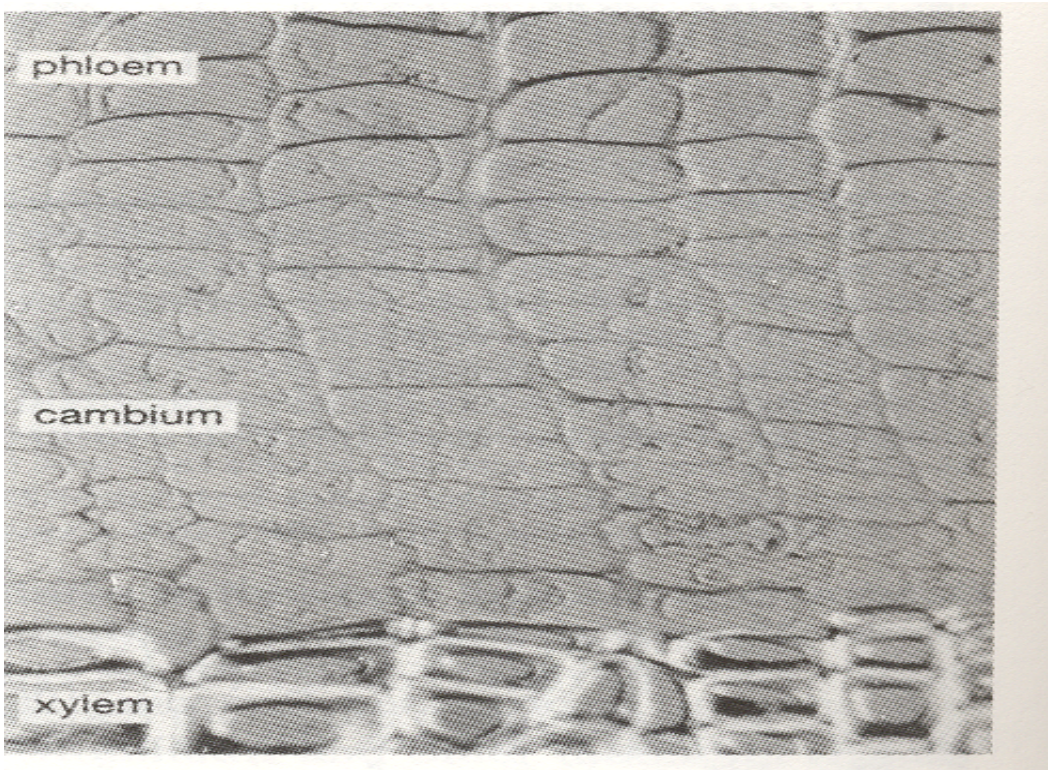
- In the dormant season, the vascular cambium is inactive, and the cambial zone consists of two to four layers of cells. These cells are rectangular in cross-section, contain protoplasm in a viscous state and have clearly defined walls.



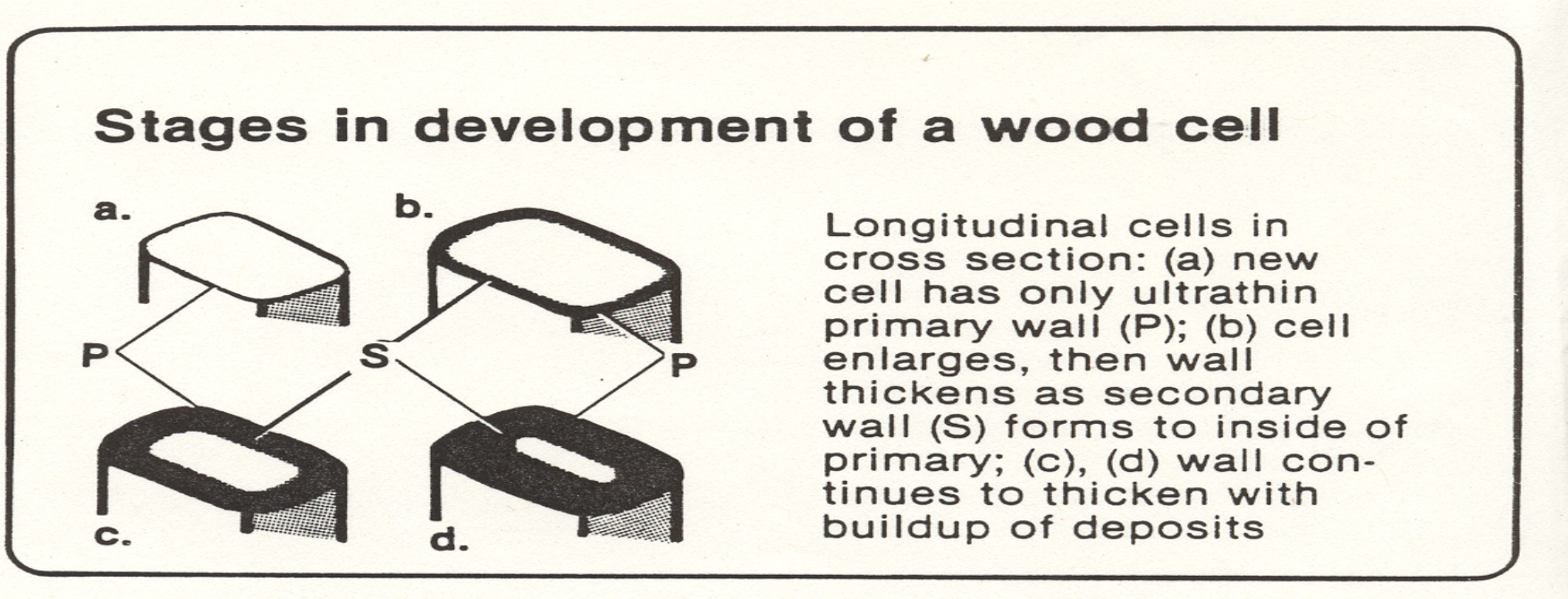
From Richter, 1988

In the spring, the walls become semi-transparent, the protoplasm more fluid, the cells extend radially, and the cambium may double in thickness



From Richter, 1988

Stages in the development of a woody cell



Courtesy R. Wimmer

How does this make a conifer ring?

http://dendro.cnre.vt.edu/forestbiology/cambium2_no_scene_1.swf

When do these developments occur?

IAWA Journal, Vol. 27 (4), 2006: 383–394

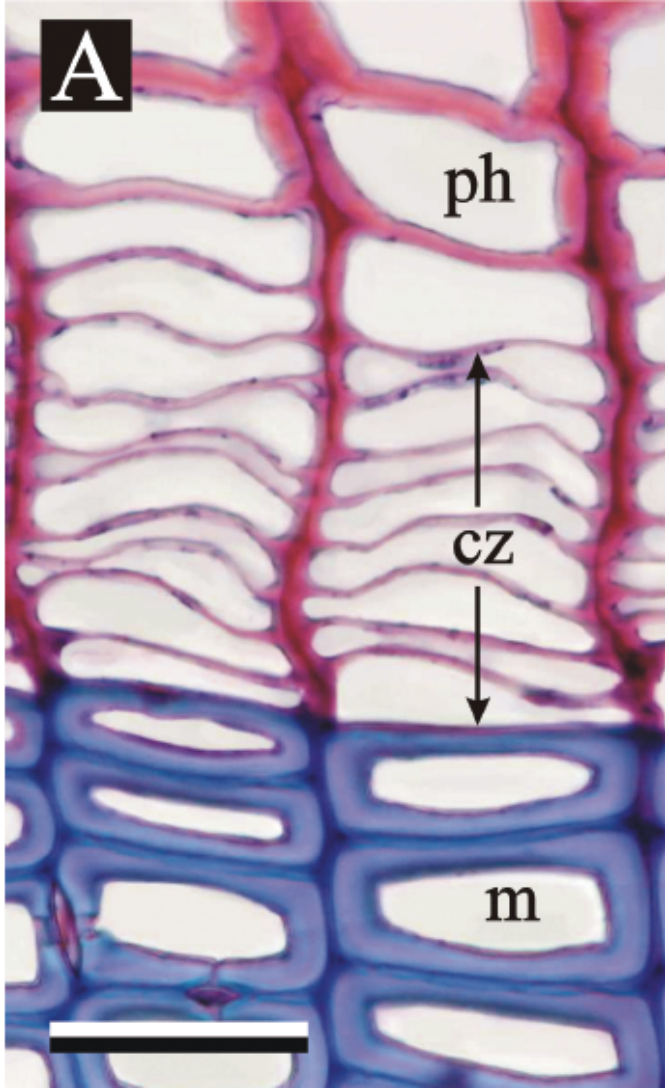
ASSESSMENT OF CAMBIAL ACTIVITY AND XYLOGENESIS BY MICROSAMPLING TREE SPECIES: AN EXAMPLE AT THE ALPINE TIMBERLINE

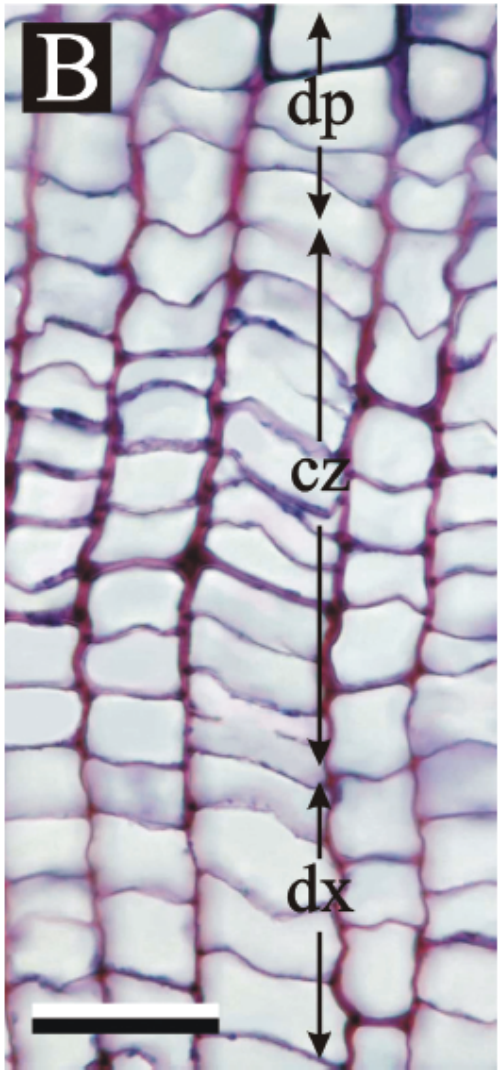
Sergio Rossi*, **Annie Deslauriers** and **Tommaso Anfodillo**

Take repeated (usually weekly) microcores of the outside of the stem.

http://www.tesaf.unipd.it/Sanvito/trephorEn.asp#

Thin sections





From Rossi et al 2006.
Scale bar 20µm

Fig. 1. – A: Cross section of *Pinus cembra* stem in winter; mature tracheid (m), cambial zone (cz), phloem cell (ph). – B: Cambial zone (initial cells and derivatives) during the growing season in *Picea abies*; developing xylem (dx), cambial zone (cz), developing phloem (dp). – C: Wall

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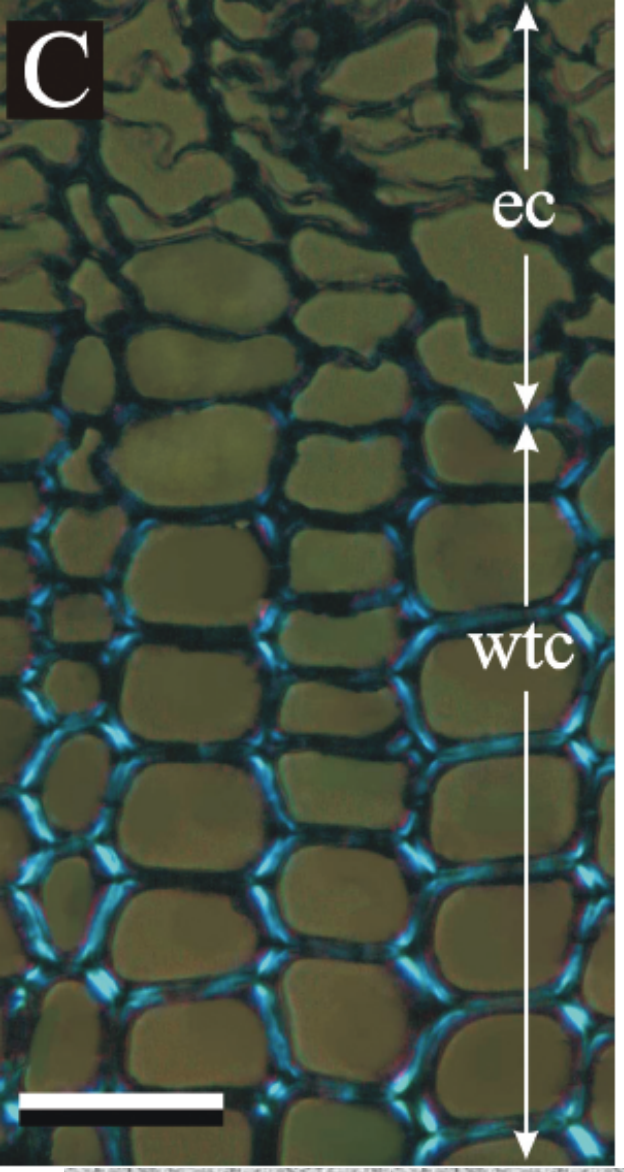
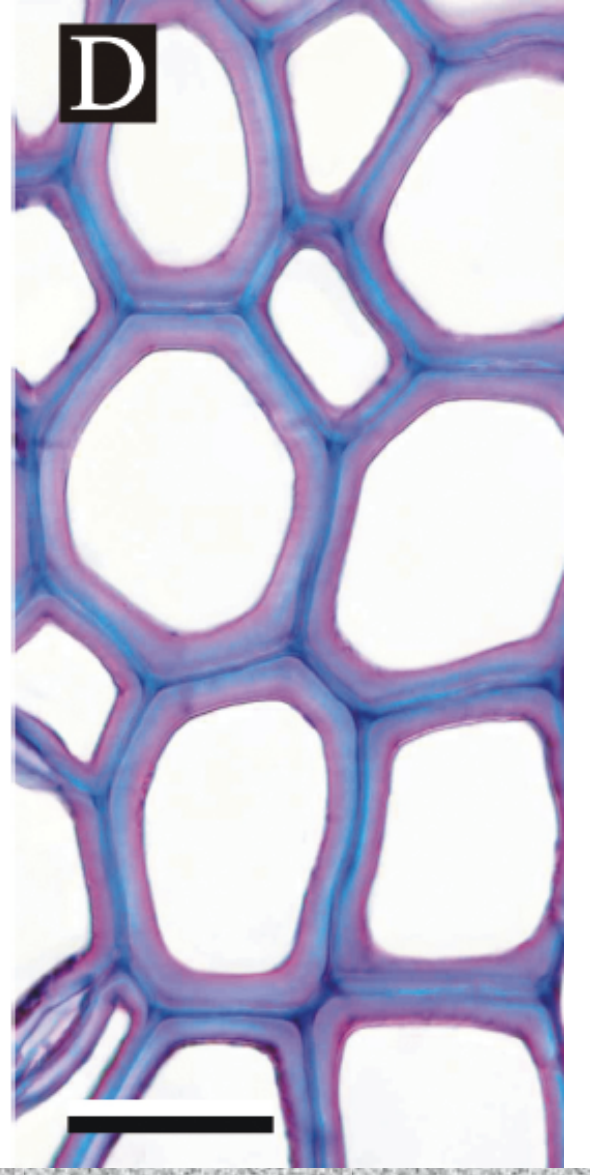
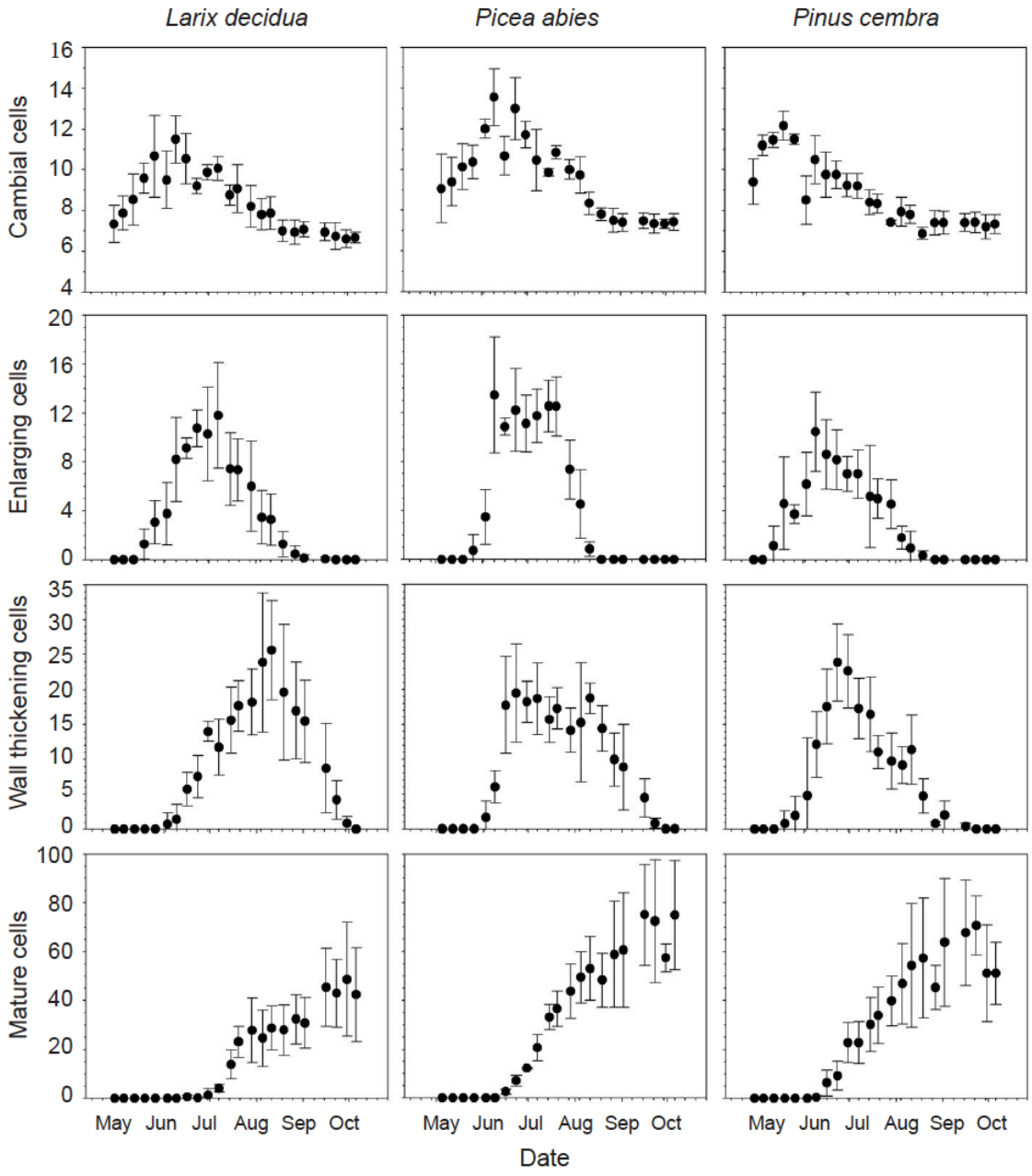




in *Picea abies* - developing xylem (dx), cambial zone (cz), developing phloem (dp). – C: Wall thickening and enlarging cells of *Picea abies* under polarized light; wall thickening cells (wtc), enlarging cells (ec). – D: Earlywood of *Larix decidua* with partially lignified cells. – E: Mature cells of latewood in *Larix decidua*. — Scale bars = 20 μm.

From Rossi et al 2006.



•Fig 2. Number of cells observed in:
•Cambial zone,
•Enlargement phase,
•Wall thickening phase,
•And number of mature xylem cells
in *Larix decidua, Picea abies* and *Pinus cembra* during 2003.

Dots and bars represent average number of cells and SD among 5 trees respectively.

From Rossi et al 2006.

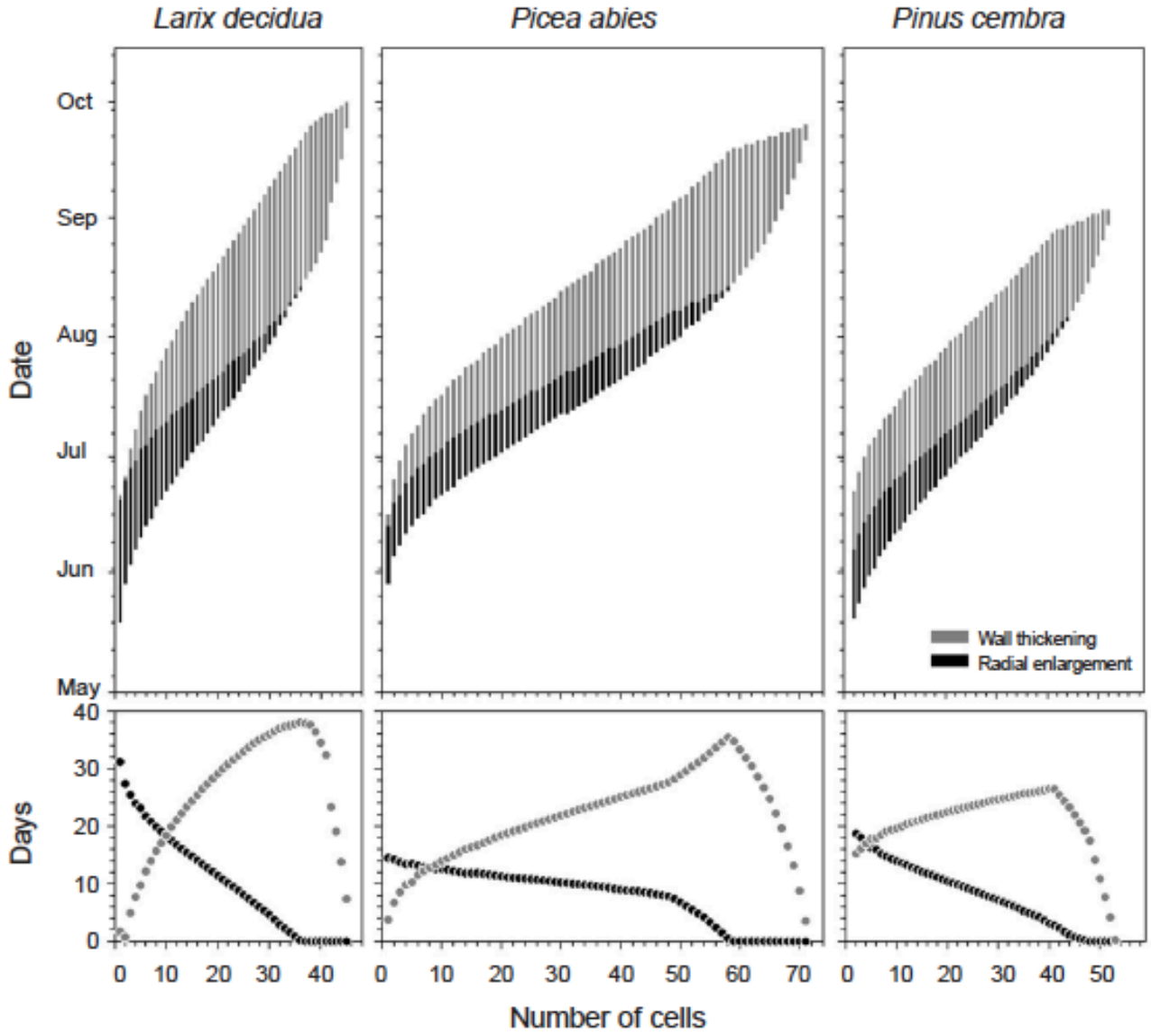


Fig. 4. Timings (above) and days spent (below) in radial cell enlargement (black) and cell wall thickening (grey) for each consecutive tracheid produced in 2003 in *Larix decidua*, *Picea abies* and *Pinus cembra*. From Rossi et al 2006.

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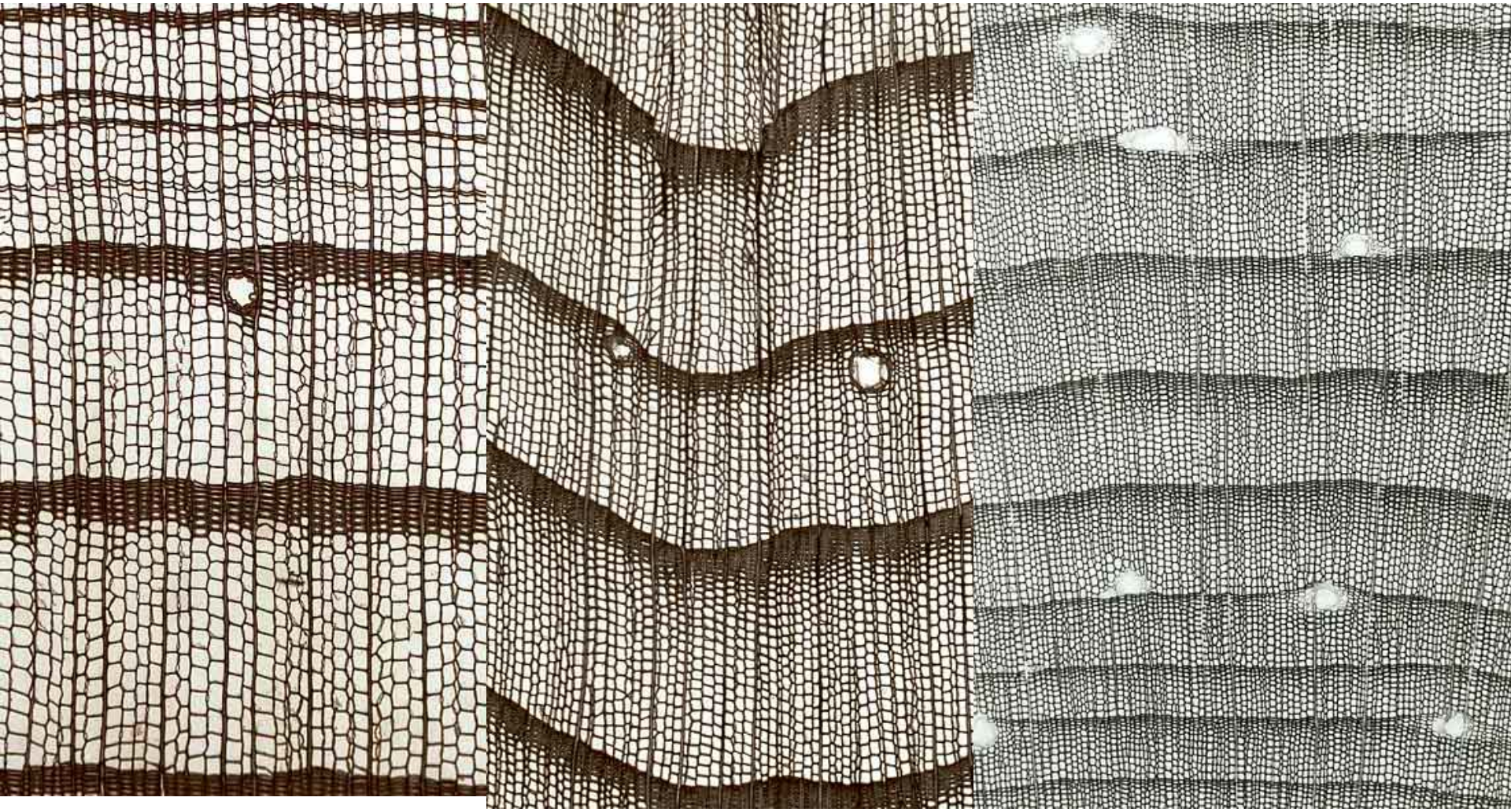
http://www.woodanatomy.ch/



1 mm

Larch Spruce Pine

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Ann. For. Sci. 66 (2009) 206

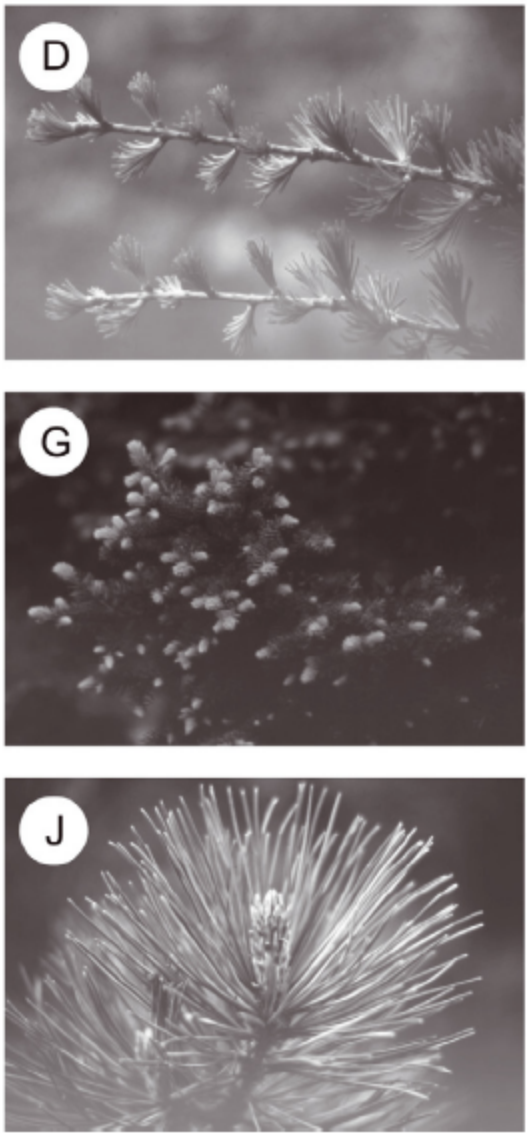
DOI: 10.1051/forest/2008088

Available online at:
www.afs-journal.org

Original article

Comparing needle and shoot phenology with xylem development on three conifer species in Italy

Sergio ROSSI[1]*, Cyrille B.K. RATHGEBER[2,3], Annie DESLAURIERS[1,4]



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Pine and spruce – needle and shoot growth at same time (mid-June – August);

Larch – needles first (late May) then shoot growth (late June);

All – cambium cell division mid-May to early August (mainly early), end of needle and shoot growth July/August, same time as beginning of latewood cell wall thickening.

Suggests switch of limited resources from needle and shoot lengthening to latewood cell wall thickening.

From Rossi et al 2009.

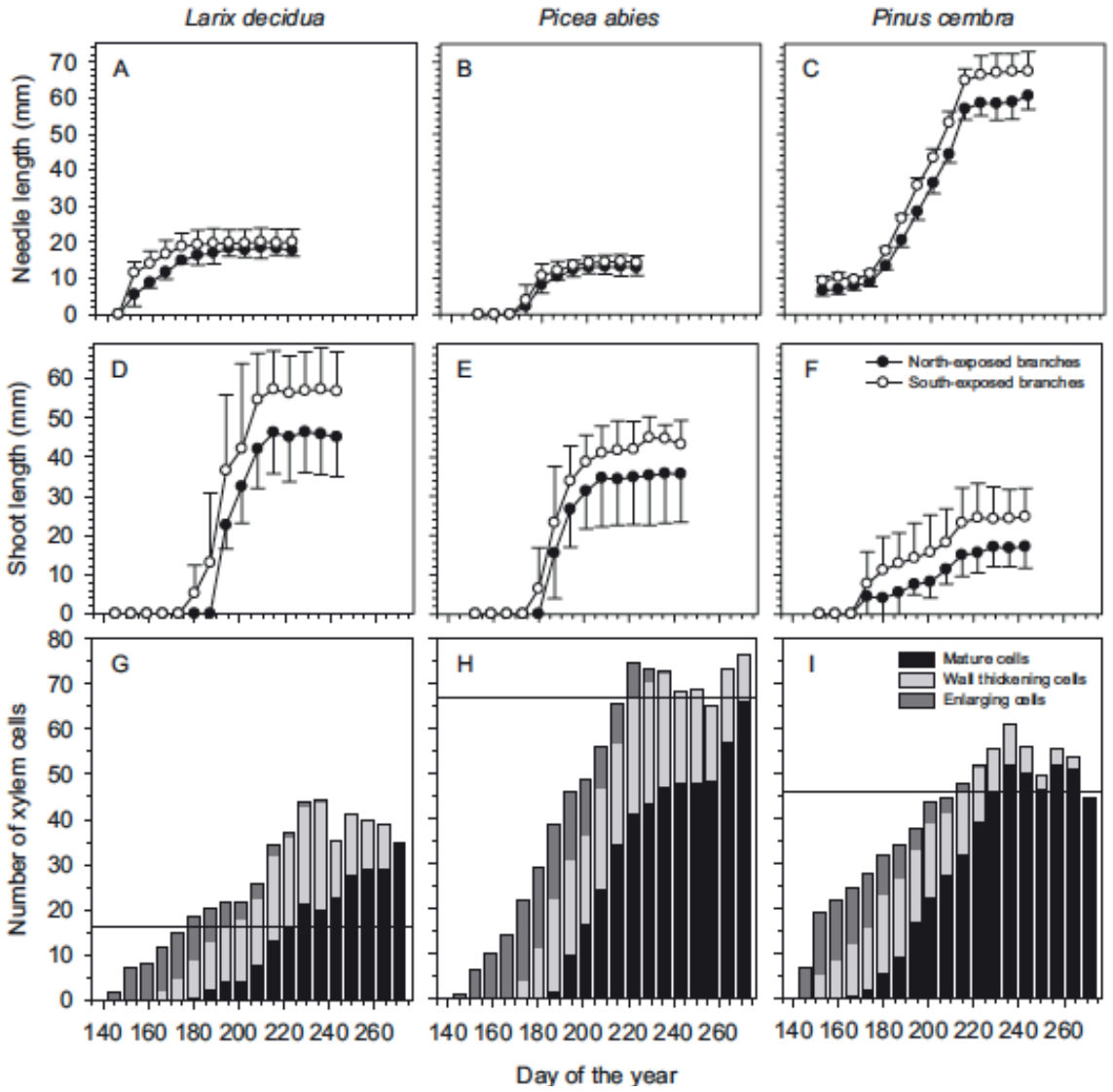

Figure 2. Needle (A–C) and shoot (D–F) length of north- and south-exposed branches and (G–I) accumulation of developing and mature cells in xylem of *L. decidua*, *P. abies* and *P. cembra* at Cinque Torri during 2001. Dots and error bars correspond to means and standard deviations. Horizontal bars separate earlywood from latewood. See next slide re: latewood.

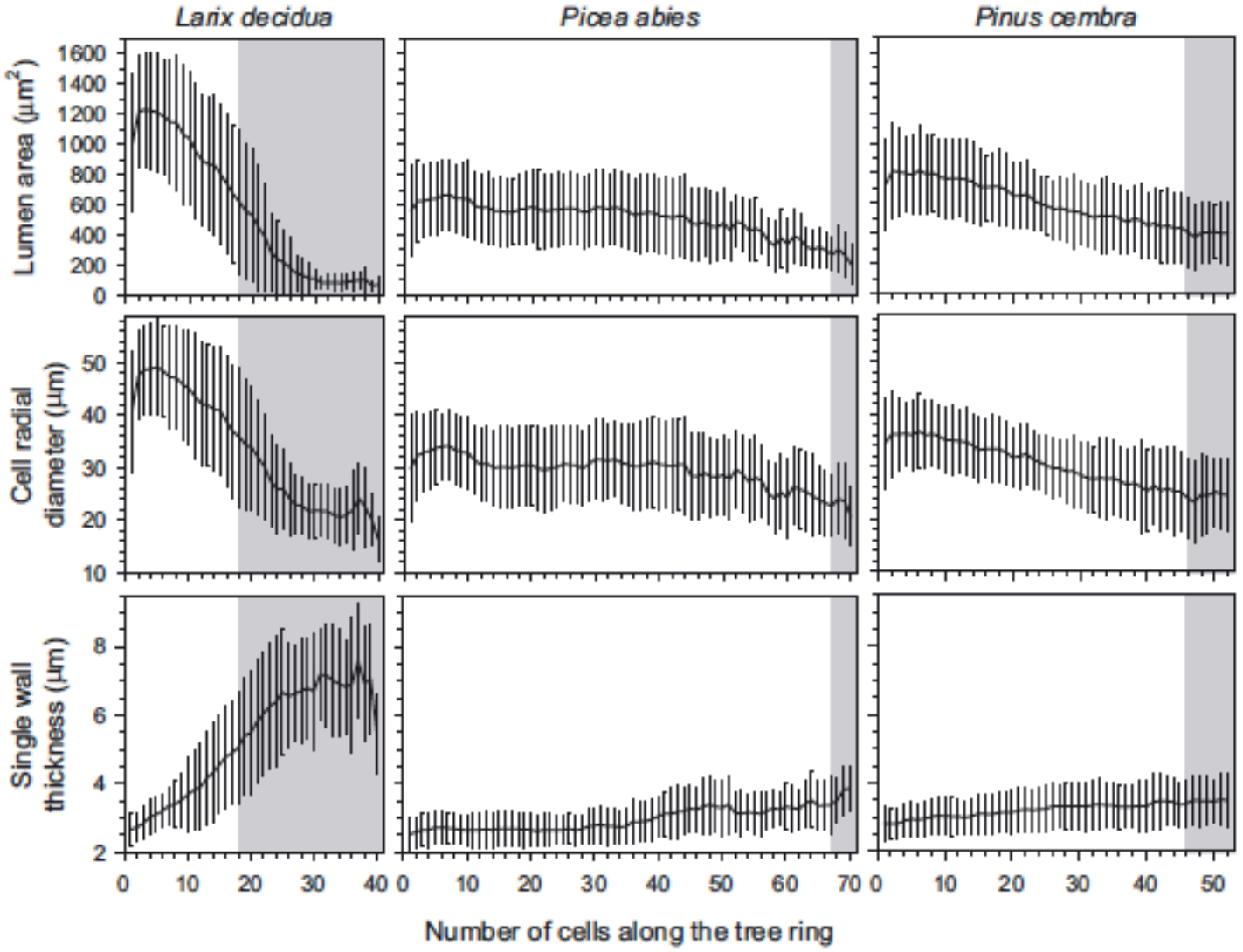

Figure 3. Cell lumen area (µm²), radial diameter (µm) and single wall thickness (µm) of tracheids produced in 2001 by *L. decidua*, *P. abies* and *P. cembra* at Cinque Torri. Vertical bars represent the standard deviation. Grey windows indicate cells belonging to latewood.

Latewood cells have lumen diameter half or less the double cellwall thickness (Mork's definition)

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Cell and ring development

- Back to movie

Final thoughts

•3 processes – cell division, expansion and maturation.
•Each marches to the beat of its own drum.
•Final form of ring determined by the combined effects of the rate and duration of each of these 3 processes, with respect to one another.
• Phenology (timing) is important to understanding how environment can affect ring formation.
•Useful in figuring out when in the season things (e.g. damage) happen to the cambium.
•RAPIDLY ADVANCING FIELD

Some places to start…

The animation we saw here:
http://dendro.cnre.vt.edu/forestbiology/cambium2_no_scene_1.swf

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Original article

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