Hope to learn a little about:

Cambium

Differentiation (cell division, enlargement, maturation)

Xylem
Phloem
Vessels
Tracheids
Rays
Resin ducts
Earlywood ("springwood")
Latewood ("summerwood")
Heartwood
Sapwood
Juvenile wood
Reaction wood

Historical aside……

the journal called

http://treeringresearch.org/

A Product of the Tree-Ring Society

Formed 84 years ago (established 1934)

ca. 250 members including institutions

Supports international meetings and fieldweeks

Membership $50 regular, $25 students
[information at http://www.treeringsociety.org]

Publishes 2 issues of a journal each year
Current (2015) Impact Factor: 1.769
5-year Impact Factor: 1.966

TREE-RING RESEARCH

An International Journal

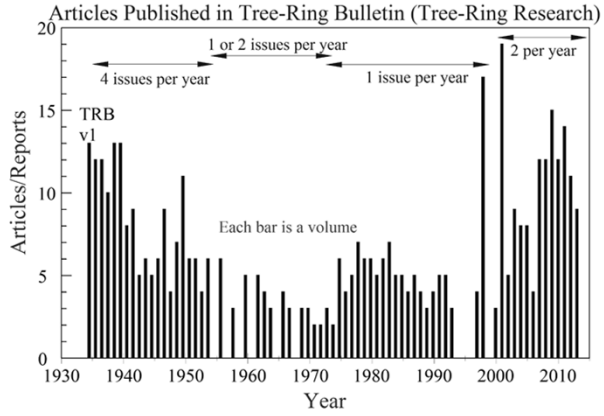
First issue (Volume 1, No. 1) published in 1934 as "**TREE-RING BULLETIN**"

Volume 57 (2001), name changed to "**TREE-RING RESEARCH**"

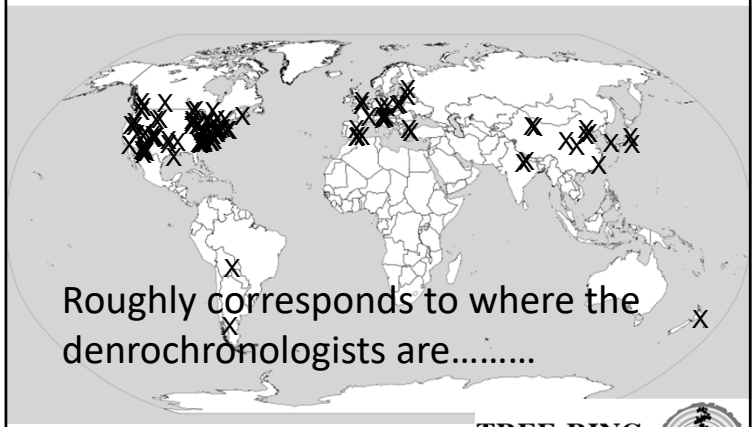
Volume 74 now being published in 2018

175 manuscripts submitted over the last 10 years

Approximately 80% of submissions in last 10 years have been published



Tree-Ring Research First Authors since 2002



Roughly corresponds to where the denrochronologists are……

TREE-RING RESEARCH

TRR Features

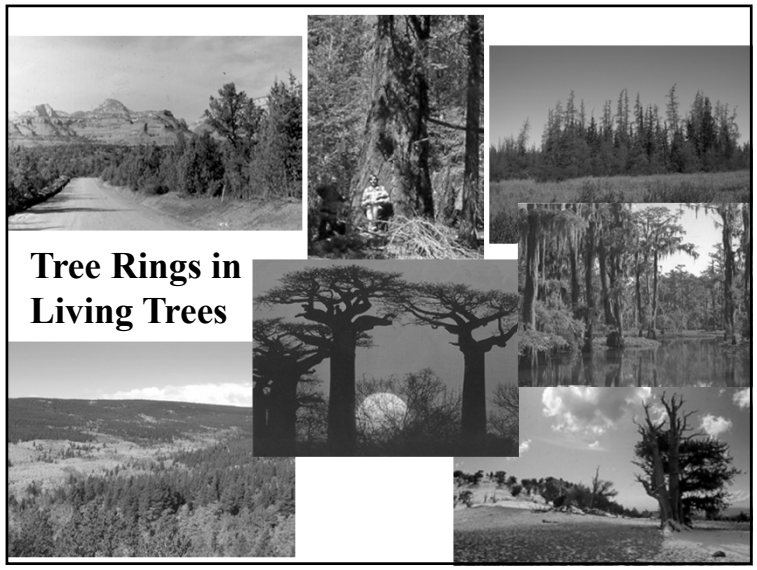
- **Associate Editorship**

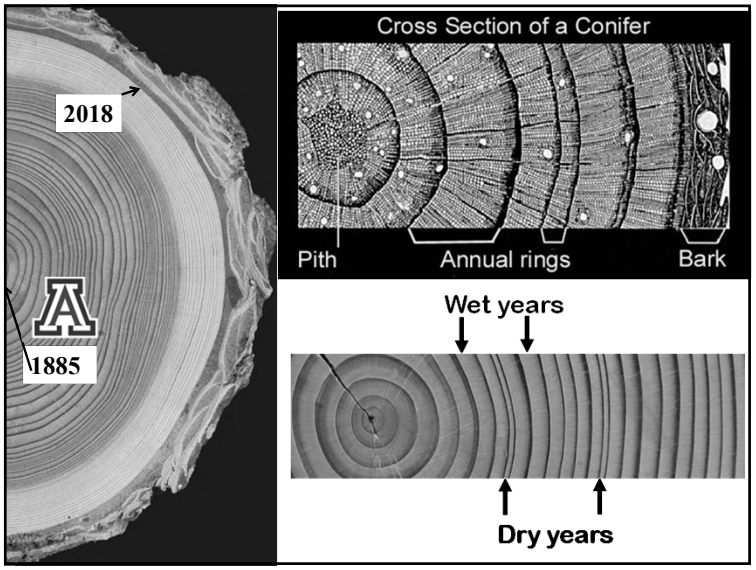
Gretel Boswijk	**Malcolm Hughes**
Étienne Boucher	**Alex Kirdyanov**
Carolyn Copenheaver	**Iain Robertson**
Malcolm Cleaveland	**Greg Wiles**
Katarina Cufar	**Qi-Bin Zhang**
Jeffrey Dean	

- **Visibility**- TRR has appeared in the **Thomson Reuters (formerly ISI) Master List of Journals** since 2005 and is indexed and abstracted in **Science Citation Index Expanded** (also known as **SciSearch**), **Current Contents**/Agriculture, Biology, and Environmental Sciences, Biological Abstracts, BIOSIS Previews, and in **Elsevier Bibliographic Databases**. Access to full digital content of Tree-Ring Research is now provided through BioOne (www.bioone.org/loi/trre)

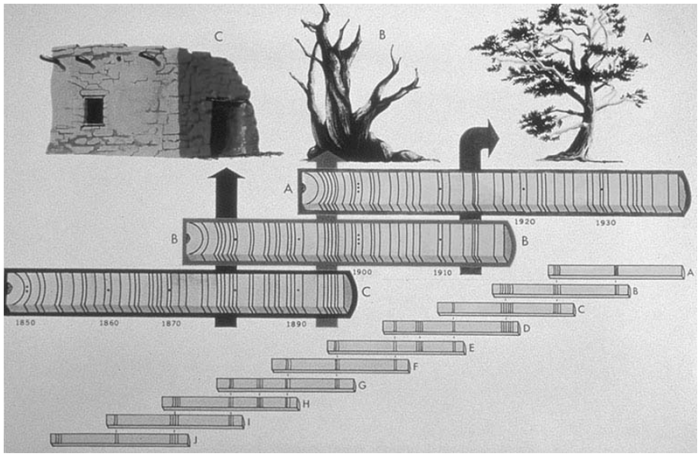
- **Web access of TRB/TRR articles for TRS members**-
  - Low-resolution PDFs of past issues from 1934 to 2006 are available from the Society's web pages at treeringsociety.org
  - High-quality PDFs (1934-2011) are available at http://arizona.openrepository.com/arizona/handle/10150/223317
  - TRR is now a Digital-only journal

Back to tree rings, the topic……..

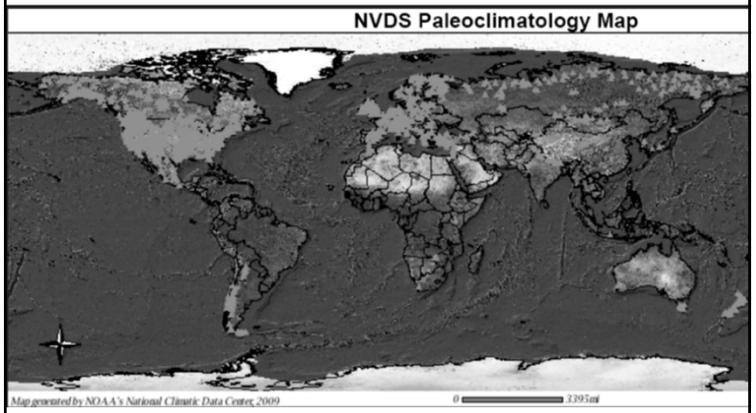




Developing Tree-Ring Chronologies



Tree-Ring Chronologies Around the World, ITRDB



87 chronologies 1000+ years world-wide, of which 59 are in U.S.

http://www.ncdc.noaa.gov/paleo/treering.html

Historical wood

Buildings: churches, castles, houses, barns.

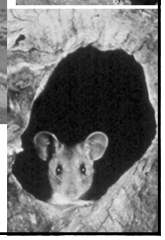
Other: bridges, fences, walkways, tombs, frames.

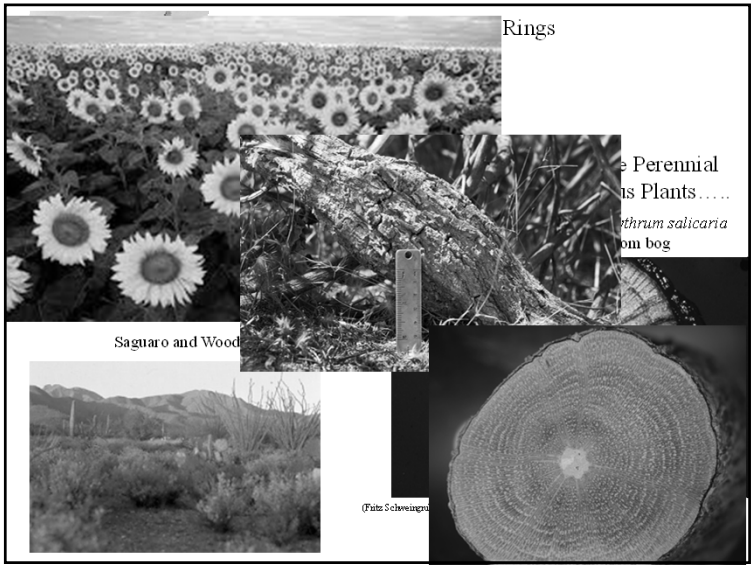

Archaeological wood

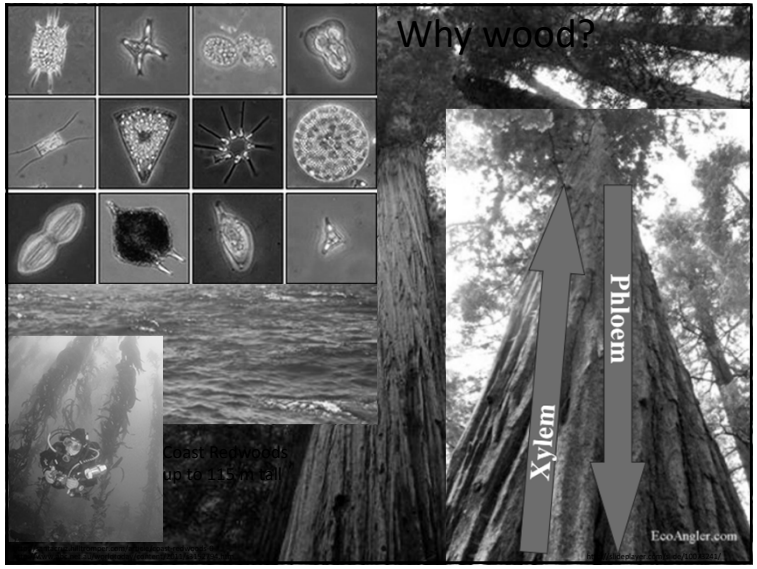
(1) primary and secondary roof support beams
(2) window and door timbers
(3) hearths and firepits (often charcoalized)

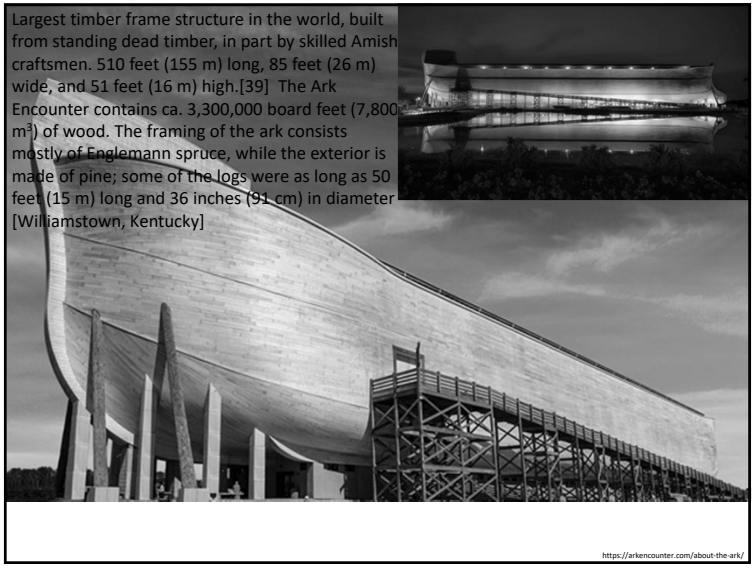

Wood from biological and geological deposits

alluvial deposits
lake deposits
bog deposits
packrat midden macrofossils
glacial deposits





Metropol Parasol: The World's Largest Wooden Structure, Seville

Gliwice Radio Tower: The World's Tallest Wooden Structure, Poland
118 m

https://www.quora.com/What-is-the-worlds-largest-tallest-wooden-structure

Todaiji, the world's largest wooden building, Nara, Japan

ANDERS BERENSSON ARCHITECTS PROPOSES 113M MASS TIMBER CENTRE PIECE FOR STOCKHOLM

26/4/2016 0 Comments

Mass Timber projects are popping up around the globe but this one takes on some exceptionally interesting ideas. Anders Berensson Architects have proposed a skyline changing Wood Skyscrapers for downtown Stockholm. The projects is 113 m tall and built above an

But strength of wood has its limits…

http://www.woodskyscrapers.com/blog

Plyscraper city: Tokyo to build 350m tower made of wood

The $5.6bn cost of the 70-storey W350 Project is expected to be twice that of a conventional building

▲ The W350 tower will be mostly wood, and 10% steel. Photograph: Sumitomo Forestry Co

LONDON CONSIDERING WORLD'S TALLEST MASS TIMBER SKYSCRAPER

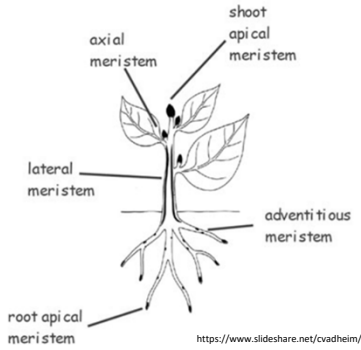
11/4/2016 0 Comments

PLP Architecture has teamed up with the University of Cambridge to propose the tallest free standing Mass Timber structure in the world. The 80-story building, centred in London, would be 300-m high and house roughly 1000 residential units.

Tree growth needs wood cells, and cells produced by meristems:

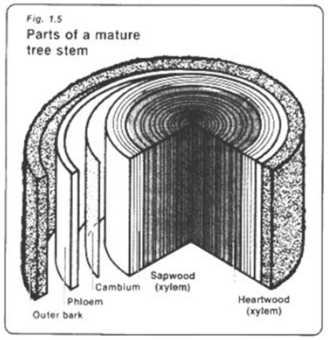
Meristems and gross structure

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



https://www.slideshare.net/cvadheim/botany-for-gardeners-2014final

Major Tissues in the Tree Stem



Outer Bark
- Protection

Phloem (Inner Bark)
- Transport (down)

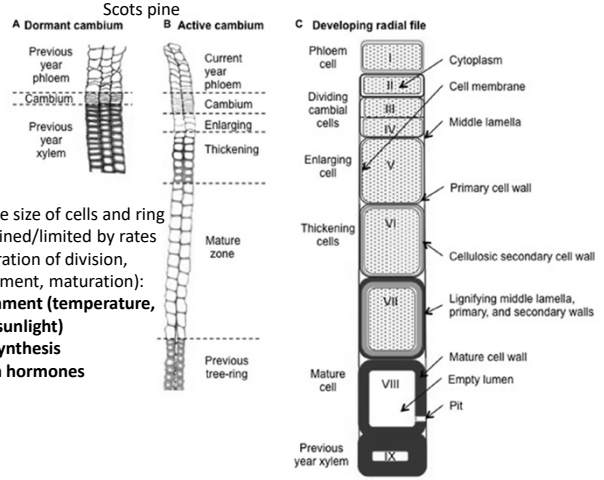
Cambium
- Radial growth

Xylem (Wood)
- Transport (up) and mechanical support

http://slideplayer.com/slide/5225443/

Division, Enlargement, Maturation

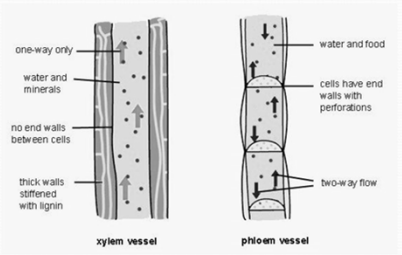
Scots pine

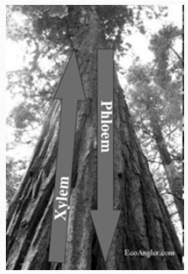


Ultimate size of cells and ring determined/limited by rates and duration of division, enlargement, maturation):
Environment (temperature, water, sunlight)
Photosynthesis
Growth hormones

Rathgeber et al. 2016

Phloem and Xylem

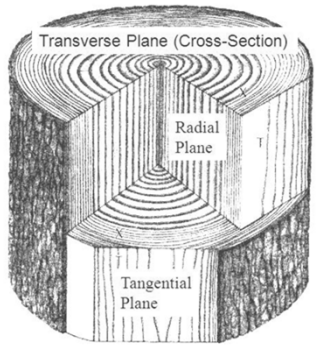




Xylem-System of tubes in a plant that **transport water and dissolved minerals**. The xylem distributes the water throughout the plant.
Phloem-Transport **sugars and molecules created by the plant**. Transports food made during photosynthesis.

http://slideplayer.com/slide/3563770/

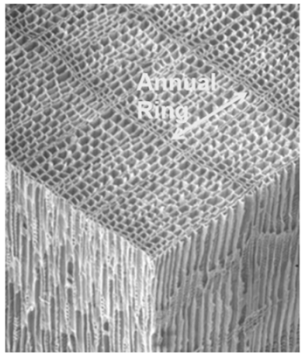
Planes-of-View in Wood Samples



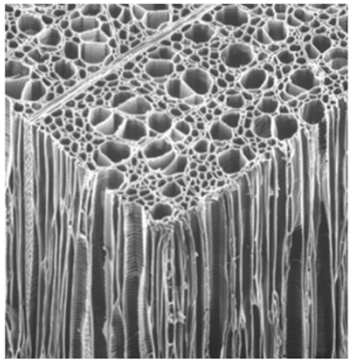
http://slideplayer.com/slide/5225443/

Basic Wood Anatomy

Microanatomy



Softwood

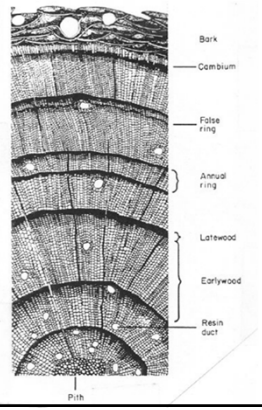


Hardwood

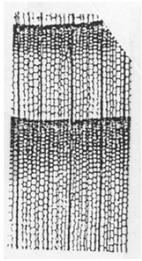
http://slideplayer.com/slide/5225443/

Basic Anatomy of Growth Rings

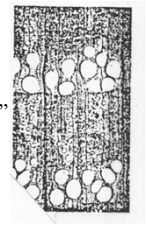
Terminology



Conifer
"non-porous"

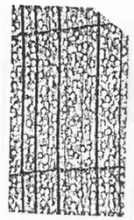


"ring-porous"



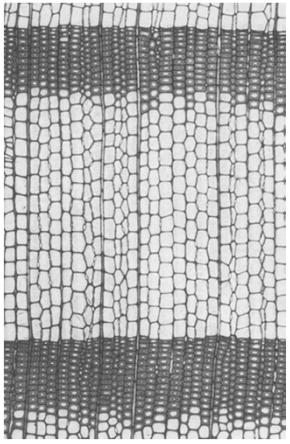
Angiosperms

"diffuse-porous"

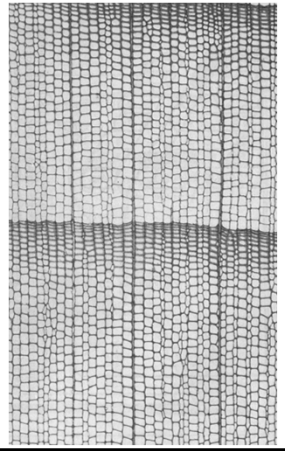


Earlywood / Latewood Transition

Abrupt



Gradual



Cell Wall

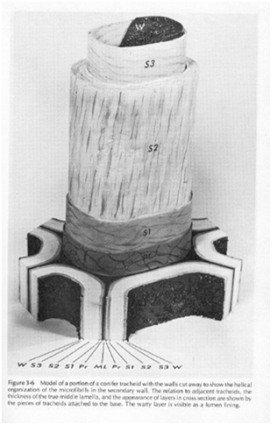


Figure 3-6 Model of a portion of a conifer tracheid with the walls cut away to show the helical organization of the microfibrils in the secondary wall. The relation to adjacent tracheids, the thickness of the true middle lamella, and the appearance of layers in cross section are shown by the pieces of tracheids attached to the base. The warty layer is visible as a lumen lining.

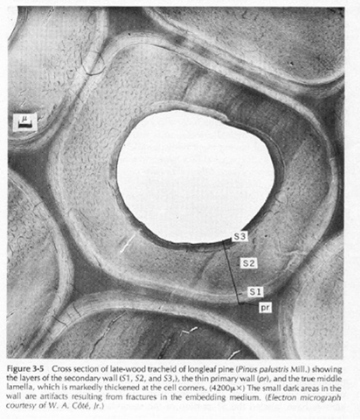
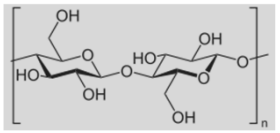
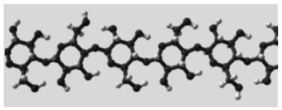


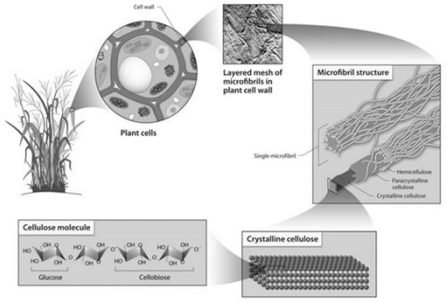
Figure 3-5 Cross section of latewood tracheid of longleaf pine (*Pinus palustris* Mill.) showing the layers of the secondary wall (S1, S2, and S3,), the thin primary wall (pr), and the true middle lamella, which is markedly thickened at the cell corners. (4200x.) The small dark areas in the wall are artifacts resulting from fractures in the embedding medium. (*Electron micrograph courtesy of W. A. Côté, Jr.*)

(Panshin& Zeeuw 1980)

Cellulose is the dominant constituent of wood: Long polymers of repeating $C_6H_{12}O_6$ units that are assembled together a **microfibrils**







http://en.wikipedia.org/wiki/Cellulose

http://www.treehugger.com/files/2008/03/zymetis-cellulosic-ethanol.php

Cell Walls

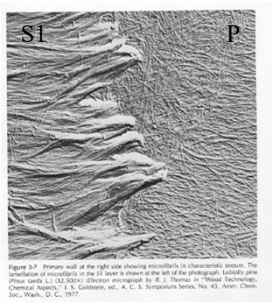


Figure 3-7 Primary wall at the right side showing microfibrils in characteristic texture. The lamellation of microfibrils in the S1 layer is shown at the left of the photograph. Loblolly pine (*Pinus taeda* L.) (32,500×) (Electron micrograph by R. J. Thomas in "Wood Technology: Chemical Aspects," I. S. Goldstein, ed., A. C. S. Symposium Series, No. 43, Amer. Chem. Soc., Wash., D. C., 1977.

Wall Layer	Relative Thickness (%)	Avg. Angle of Microfibrils
PW	±1	random
S1	10-22	50-70°
S2	40-90	10-30°
S3	2-8	60-90°

(Panshin& Zeeuw 1980)

Cell-Wall Chemistry

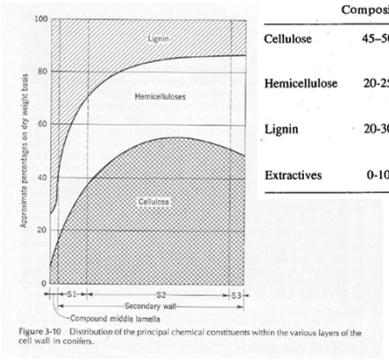
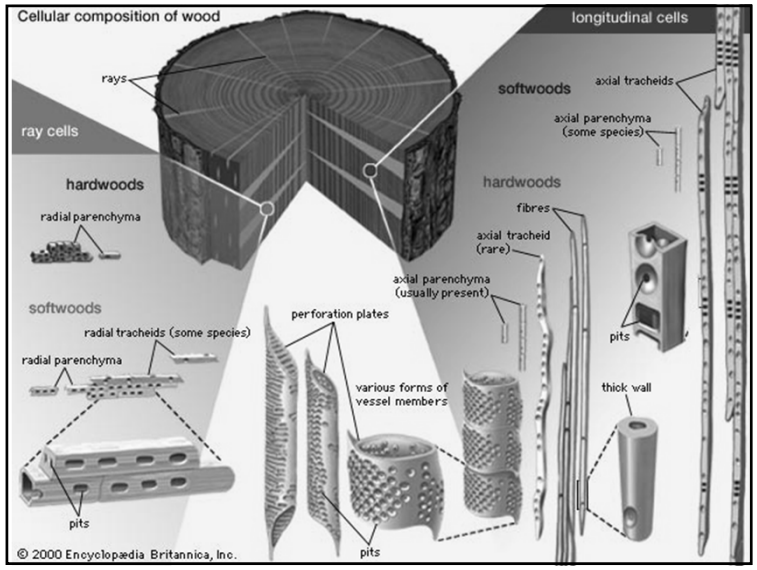


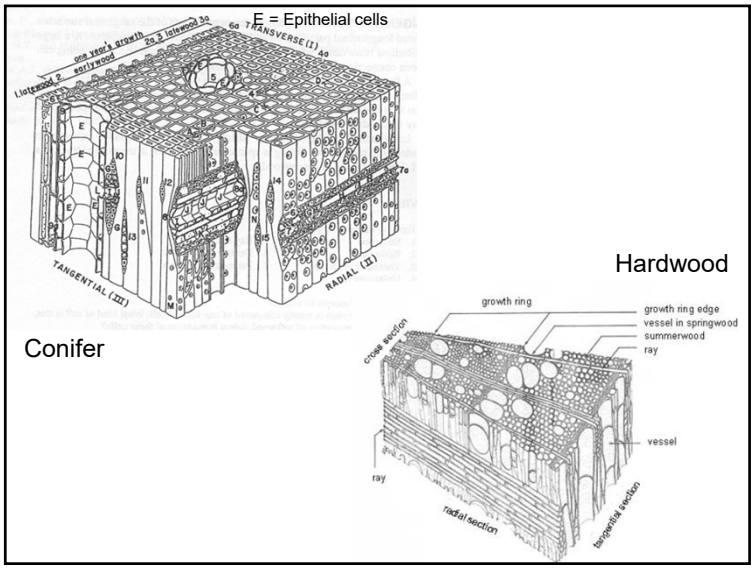
Figure 3-10 Distribution of the principal chemical constituents within the various layers of the cell wall in conifers.

Table 3 Chemical Constituents of Wood

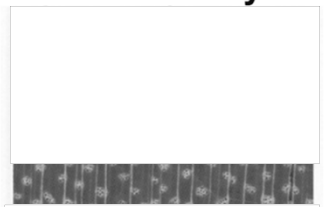
	% Composition	Polymeric nature	Degree of polymerization	Molecular building blocks	Role
Cellulose	45–50	linear molecule crystalline	5,000–10,000	glucose	framework
Hemicellulose	20-25	branched molecule amorphous	150-200	primarily nonglucose sugars	matrix
Lignin	20-30	three-dimensional molecule	100-1,000	phenolpropane	matrix
Extractives	0-10	polymeric	—	polyphenols	encrusting

(Panshin& Zeeuw 1980)



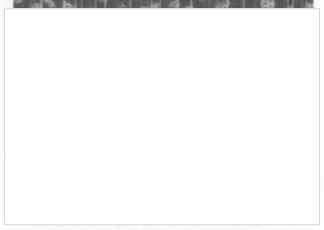


Rays in Wood

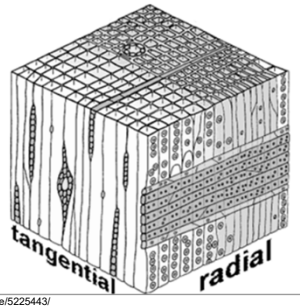


Function: Transport from the phloem towards the pith.

- Ray cells are elongated in the radial direction
- Width, height, density, and appearance vary - useful for ID

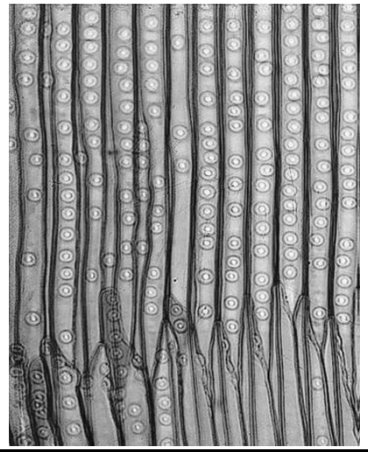


KENTUCKY COFFEETREE
Gymnocladus dioicus



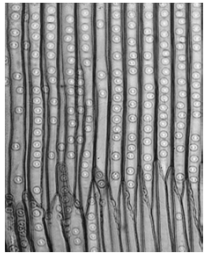
http://slideplayer.com/slide/5225443/

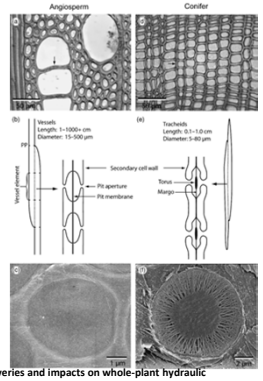
Longitudinal Tracheids



- Compose the bulk of xylem (90-95%)
- Shape and proportions are similar amongst softwood species
- Radial diameter varies with position in growth ring
- Tangential diameter remains constant and leads to judgements of **texture**
- Conductive and support functions

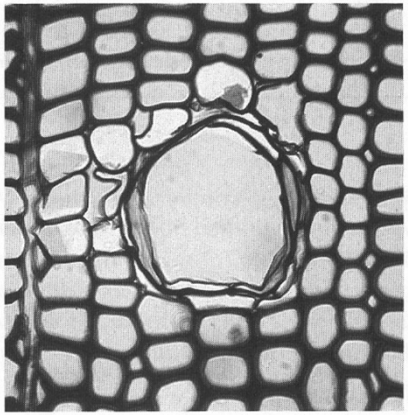
Bordered pits are cavities in the lignified cell walls of xylem conduits (vessels and tracheids) that are essential components in the water-transport system of higher plants. The pit membrane, which lies in the center of each pit, allows water to pass between xylem conduits but limits the spread of embolism and vascular pathogens in the xylem.





Choat, B., Cobb, A.R., Jansen,S.,2008. Structure and function of bordered pits: new discoveries and impacts on whole-plant hydraulic function.New Phytologist 177: 608–626.

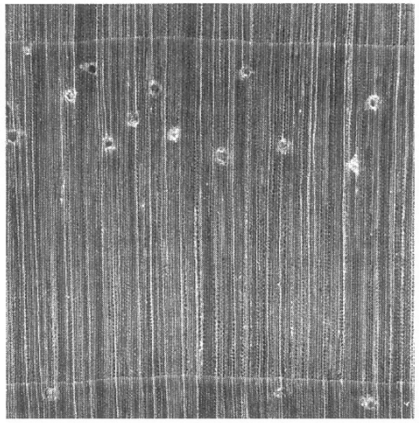
Resin Canals



- Conduct resin secreted by specialized parenchyma cells called epithelial cells lining the canal opening
- Seals wounds from insects or mechanical damage
- Occur oriented in the longitudinal direction and in the radial direction (within fusiform rays)

38

Resin Canals



- Occur in:
  - *Pinus* spp.
  - *Larix* spp.
  - *Picea* spp.
  - *Pseudotsuga menziesii*
- Useful for wood ID
- May need hand lens to see
- Appearance varies with presence/absence of resin

39

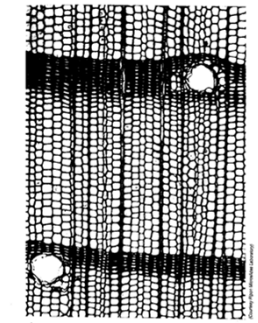


FIGURE 4.6. Resin canals characteristic some softwoods. Transverse view of ponderosa pine (*Pinus ponderosa*). ×85.

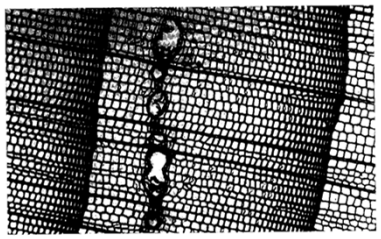
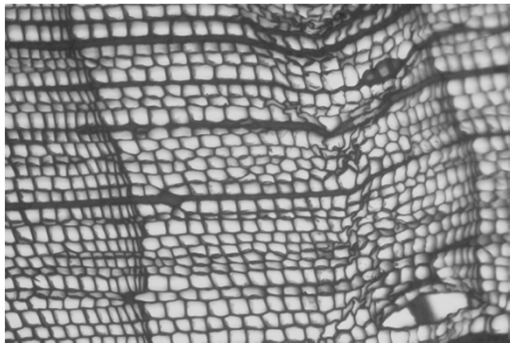


FIGURE 4.7. Traumatic resin canals. Transverse view of incense cedar (*Calocedrus decurrens*). ×80.

Lecture notes and graphics by V. Trouet, with contributions from M.K. Hughes and T.W. Swetnam

Frost rings



Heartwood vs. Sapwood

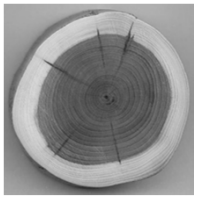
Sapwood

- only living (parenchyma) cells in xylem
- Not all sapwood cells are living
- Conduction function
- Size is relative to size of tree crown

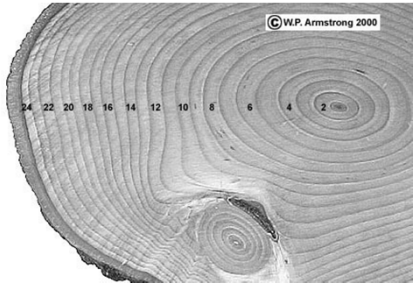
Heartwood vs. Sapwood

Heartwood

- Reduced water and oxygen availability: death of parenchyma cells
- Mechanical support only
- Does not follow tree-ring contours
- Extractives
  - Coloring
  - Decay resistance
  - Low water permeability



Juvenile Wood



- Short fibered xylem with high microfibril angles and low specific gravity.
- Wood produced during the first 5-15 years of growth
- As tree grows, the SG increases and the fibers lengthen.
- Gradual transition from juvenile wood to mature wood
- Caused by effects of hormones from apical meristems on cambium
- As cambium in stem becomes farther from and less influenced by the apical meristem, transition to mature wood

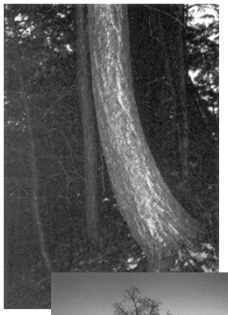
Physical Characteristics of Juvenile Wood that Affect its Use

- Cells are shorter than mature wood
- Thin cell walls and less latewood
  - Leads to lower density and strength
- More spiral grain

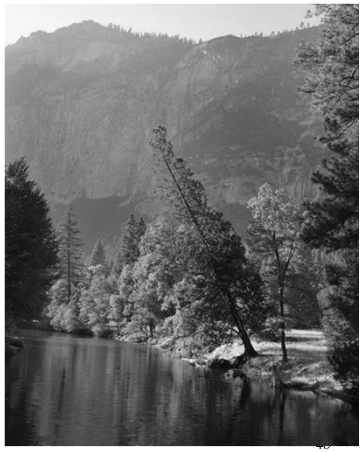
For Softwoods in Particular:

- Density
  - 10-15% lower than mature wood
- Strength
  - 15-50% lower than mature wood

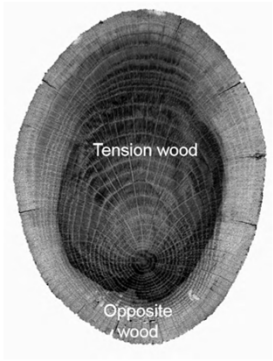
45



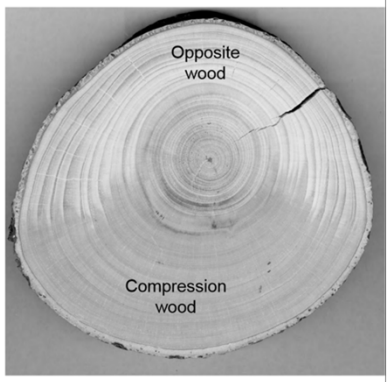
Reaction Wood



Reaction Wood



White Oak (*Quercus alba*)

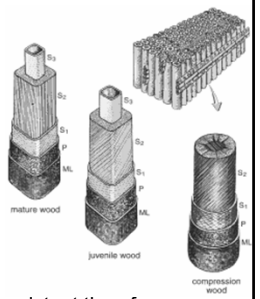


Eastern White Pine (*Pinus strobus*)

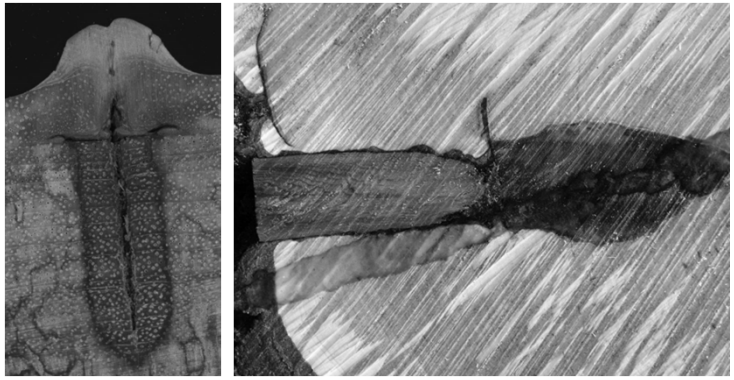
https://ag.purdue.edu/fnr/associations/IAA/Documents/BiomechanicsOfTreesTelewski.pdf

Reaction Wood in Softwoods and Hardwoods

- **Compression Wood**
  - Softwoods
  - Underside of branches or leaning stem
  - Commonly in juvenile wood
  - Appearance is similar in most species
- **Tension Wood**
  - Hardwoods
  - Top of branches or leaning stem
  - Common in juvenile wood also
  - Appearance and microanatomy is less consistent than for compression wood



Wound formation



http://www.lvm.lv/en/news/2849-it-s-time-for-maple-tree-sap

Lecture notes and graphics by V. Trouet, with contributions from M.K. Hughes and T.W. Swetnam

Do all trees have rings?
Tropical and subtropical wood