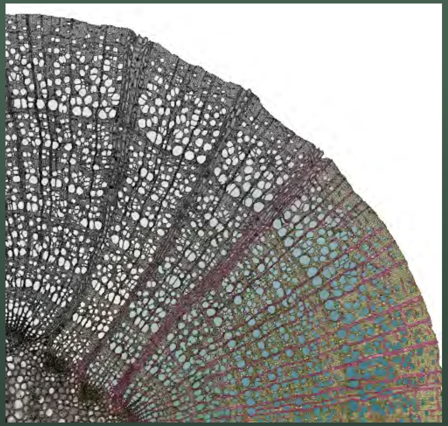


Microscopic Marvels in Wood

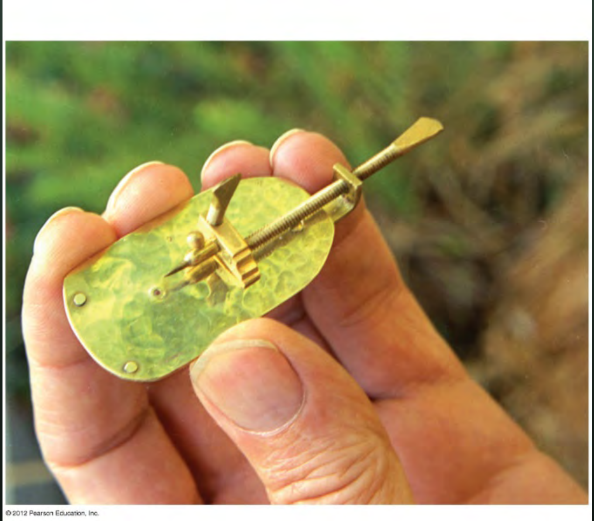
Presentation to Suncoast Wood Crafters Guild
Sept. 19th, 2023, Chatelech School

Michael Bradley

Image: https://arboretum.harvard.edu/stories/wood-under-the-microscope/

Introduction

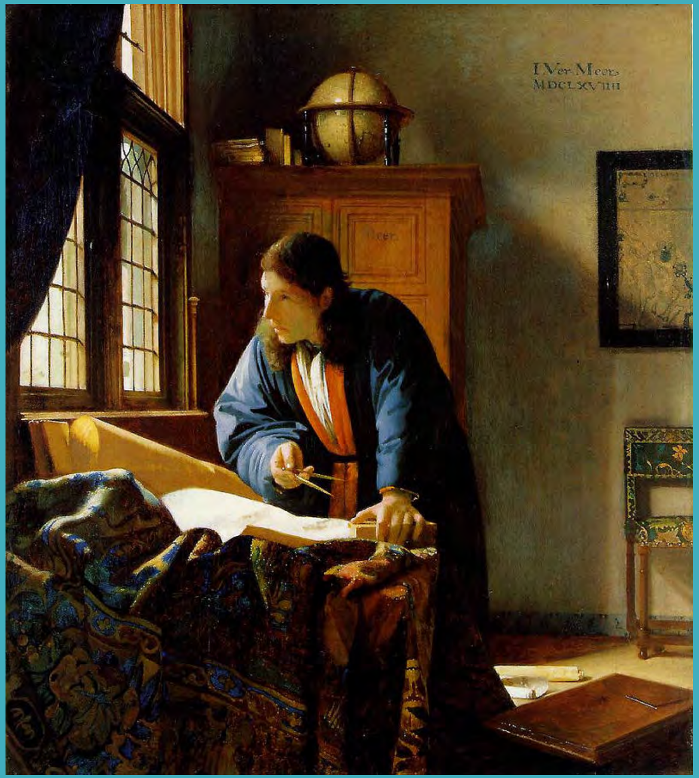
- I’ve been preparing this presentation as an amateur microscopist, not as a wood expert nor as a tree expert – please excuse any mistakes !
- Does anyone here have a microscope at home?
- Do you use it?
- At Elder College we’ve been offering annual “Introduction to Microscopy” classes recently, one is planned for 2024 Spring.



Antonie van Leeuwenhoek

The Astronomer

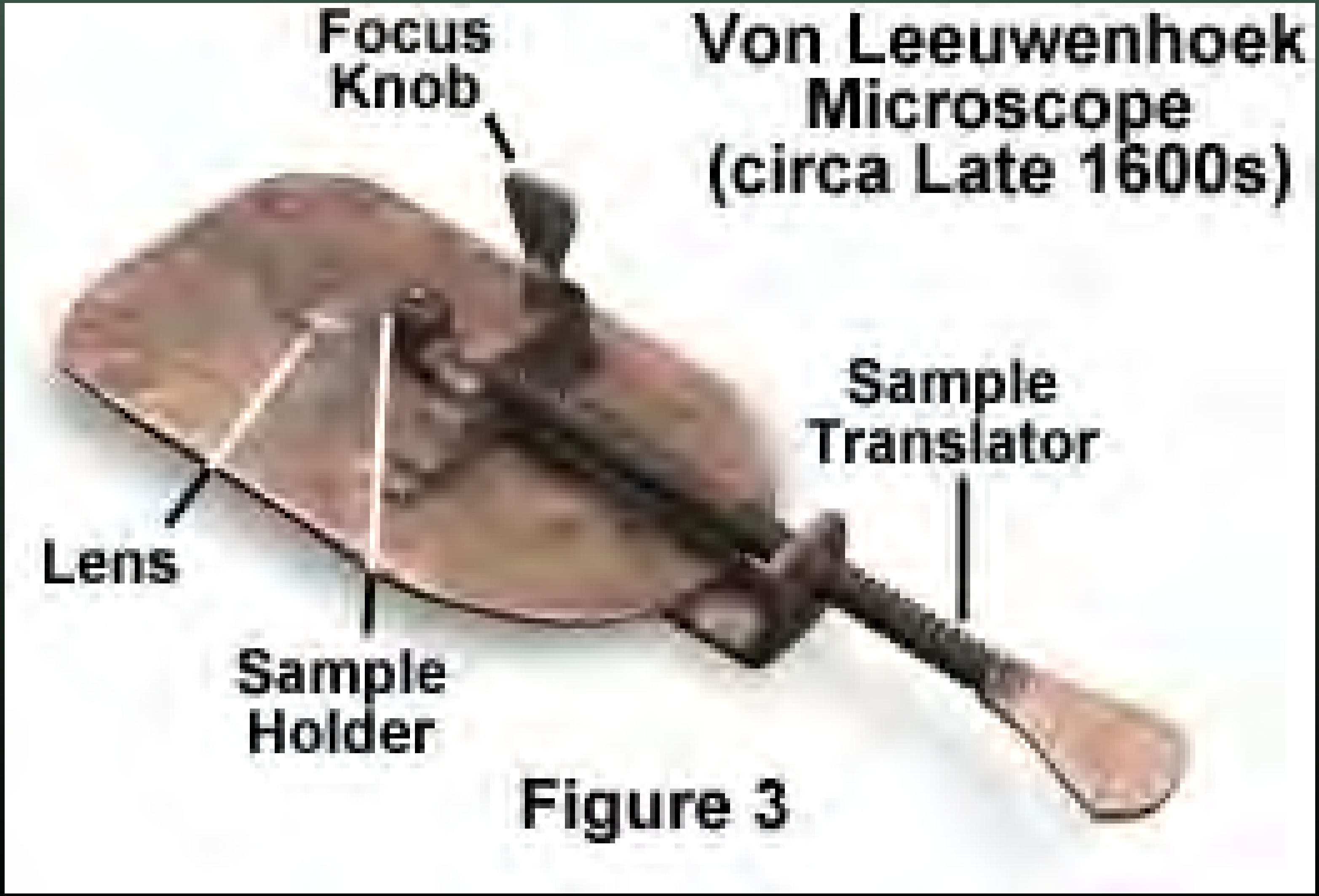
The Geographer



- He was a contemporary and acquaintance of Johannes Vermeer. He was also Vermeer's executor. It is believed that the paintings *The Astronomer* and *The Geographer*, portray van Leeuwenhoek.

- He interests us today because he manufactured deceptively simple hand lenses for examining the weave of his fabrics and he developed a proprietary approach to making high magnification, optically clear, lenses.

Antonie van Leeuwenhoek (1632-1723)



Source: BigPicture@welcome.ac.uk

Tree wood anatomy Antonie van Leeuwenhoek,

In this 1680 letter van Leeuwenhoek sketched the anatomy of the internal vessels from oak, beech and elm.

His observations were made using his single lens microscope. The resolution he was able to achieve is quite remarkable.

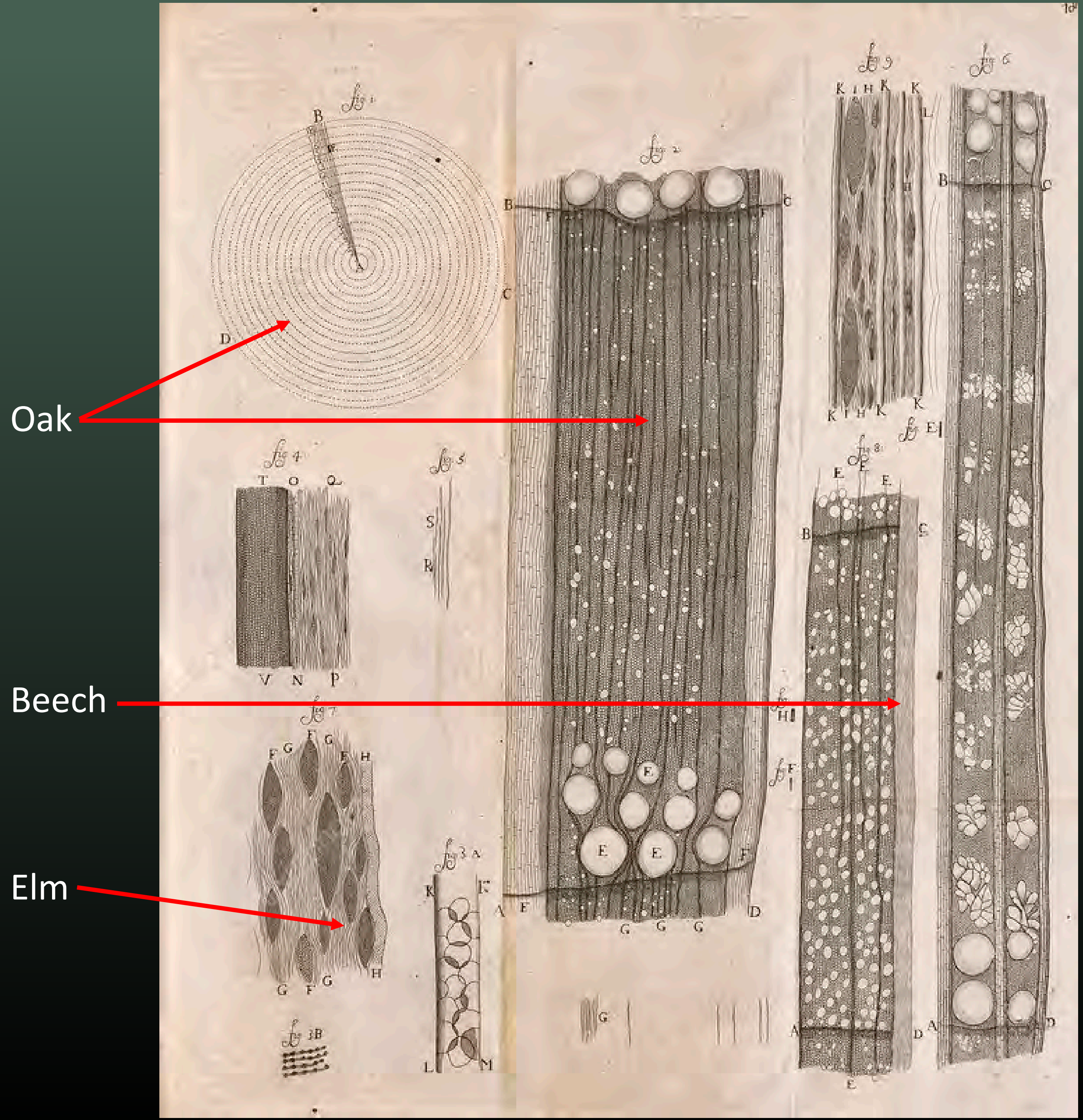
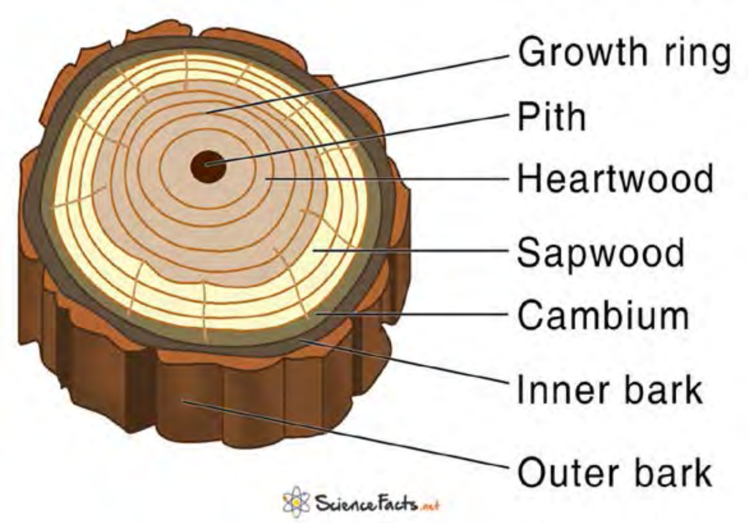


Image: Library of Congress, Rare Book and Special Collections Division

Questions?

"The great thing about studying tiny things is that no one knows what the hell you're doing."

Characteristics of wood



- Tree growth takes place in a thin tissue layer between the inner bark and the sapwood - the *Cambium* layer. Fresh *Xylem* **cells** (sapwood) are produced towards the inside and *Phloem* (living bark) towards the outside.
- As the fresh xylem cells in the sapwood age they harden, fill with *lignin* and resins and form the heartwood.
- The xylem cells form as thin-walled, tapering, tube-like *Tracheids* (fibres) in spring and denser, thicker-walled, darker ones in fall. Deciduous trees also possess another type of cell, the *Vessel* .
- These cellular features can be easily seen with simple microscopes.

Macroscopic view of wood-transverse

1 mm (1000 µm)

Conifer

Tracheids dia. 20-40 µm

Macroscopic view of wood-transverse

—— 1 mm (1000 μm)

Conifer

Hardwood (diffuse porous)
(i.e. Maple, Birch)

Tracheids dia. 20-40 μm

Vessels dia. 30-130 μm

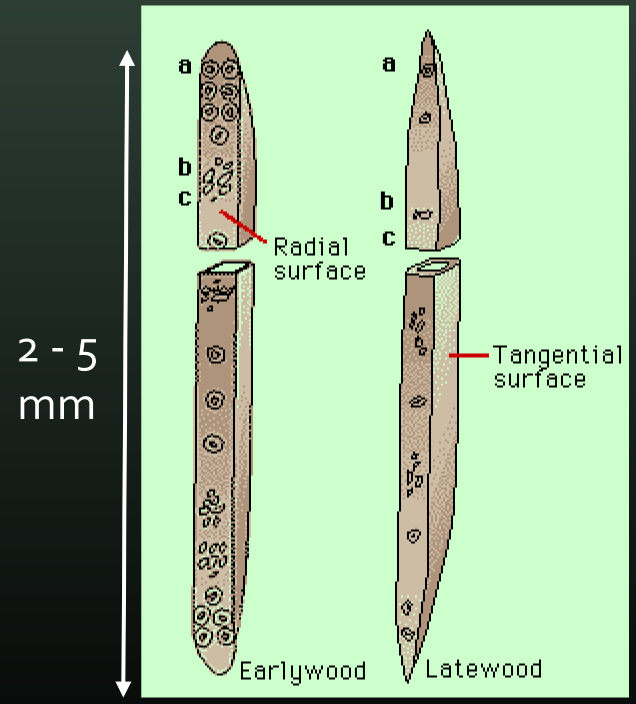
Macroscopic view of wood-transverse

1 mm (1000 µm)

Conifer	**Hardwood** (diffuse porous) (i.e. Maple, Birch)	**Hardwood** (ring porous) (i.e. Oak, Elm)
Tracheids dia. 20-40 µm	Vessels dia. 30-130 µm	Vessels dia. 150-350 µm

Wood through a microscope - Tracheids

- When we observe wood or wood fibres through a microscope we are looking at its cellular components.



SW Tracheid

- In softwoods (SW) the cells we see are the “tube like” *Tracheids.* They provide **both water-conduction and reinforcement**. Water moves longitudinally through endplates and laterally through pits.
- Tracheids are aligned axially, parallel to the length of the tree trunk. In SW the length is typically 2-5 mm.
- The term “tracheid” is from the same Latin root as “trachea”, ie related to “windpipes”.

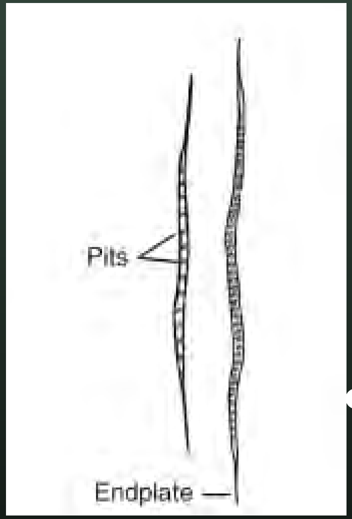
Image:Adapted from Koch, Peter. 1972. Utilization of the Southern Pines, USDA Forest Service

Wood through a microscope - Fibres

- In hardwoods (HW) the primary function of these cells is different from that in softwoods. Here their sole function is to **provide the mechanical structure of the wood**. Hence we usually refer to them as *Fibres* and not as *Tracheids*.

- Fibre lengths are typically between 0.8-2.0 mm.

0.8 - 2 mm

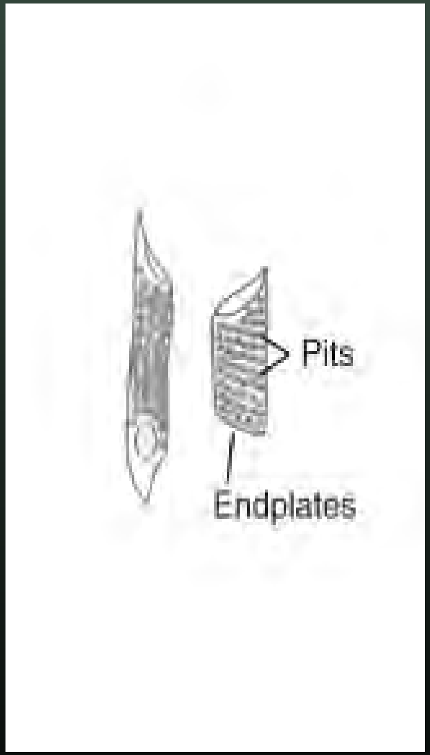


HW Fibre

Image: Patten et al, Am. J. Bot. **2007**, *94*, 912–925, copyright 2007

Wood through a microscope - Vessels

0.2 – 1.3 mm



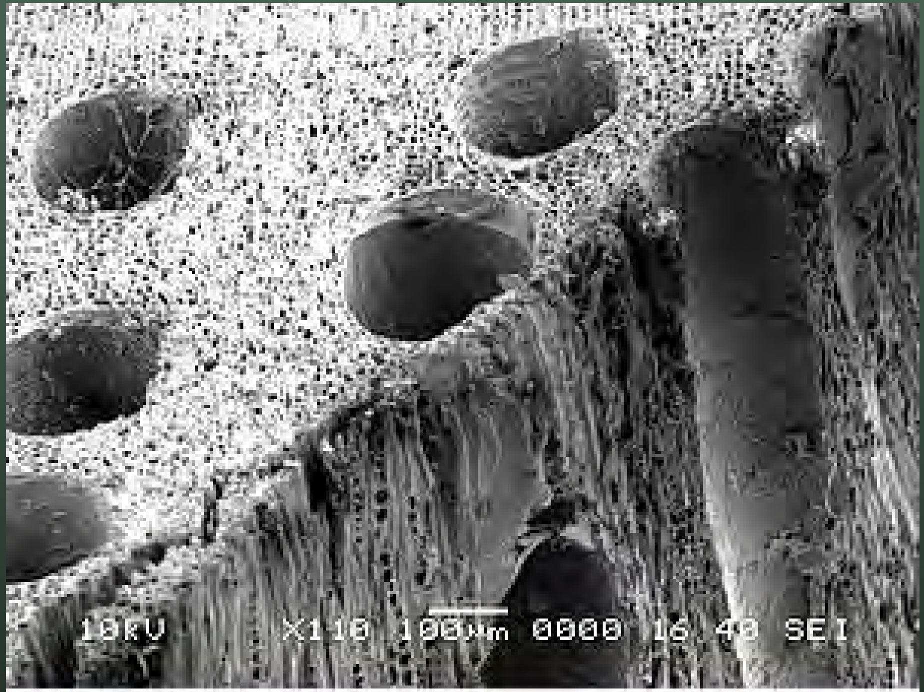
HW Vessels

The transport of water in hardwood species is via the *Vessel elements*. The separation of water conduction and reinforcement in HW species is considered as an evolutionarily advancement.

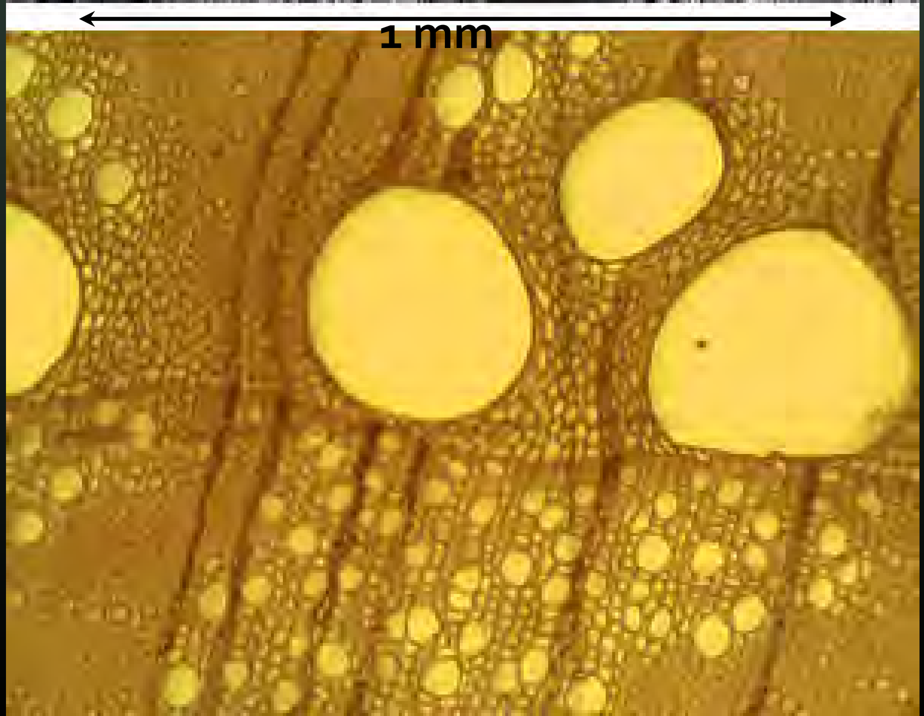
Individual vessel elements can reach 30 cm however in some species, combining into very long structures, ie 2 metres in Live Oak. (McDougal et al, 1929)

Image: Patten et al, Am. J. Bot. **2007**, *94*, 912–925, copyright 2007

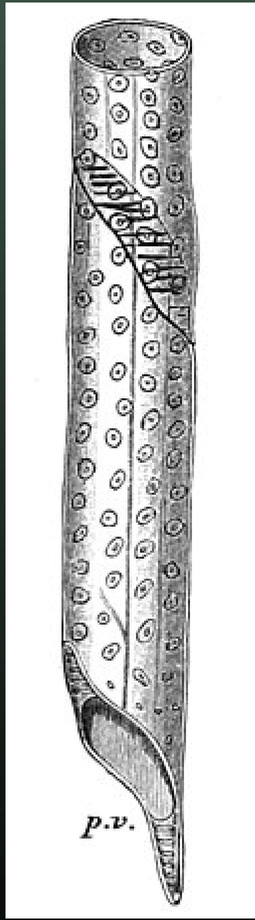
Vessel elements in Oak



Scanning Electron Microscope
x110



Light Microscope



(Images: Wikipedia)

Fibres and Vessels in Hardwoods

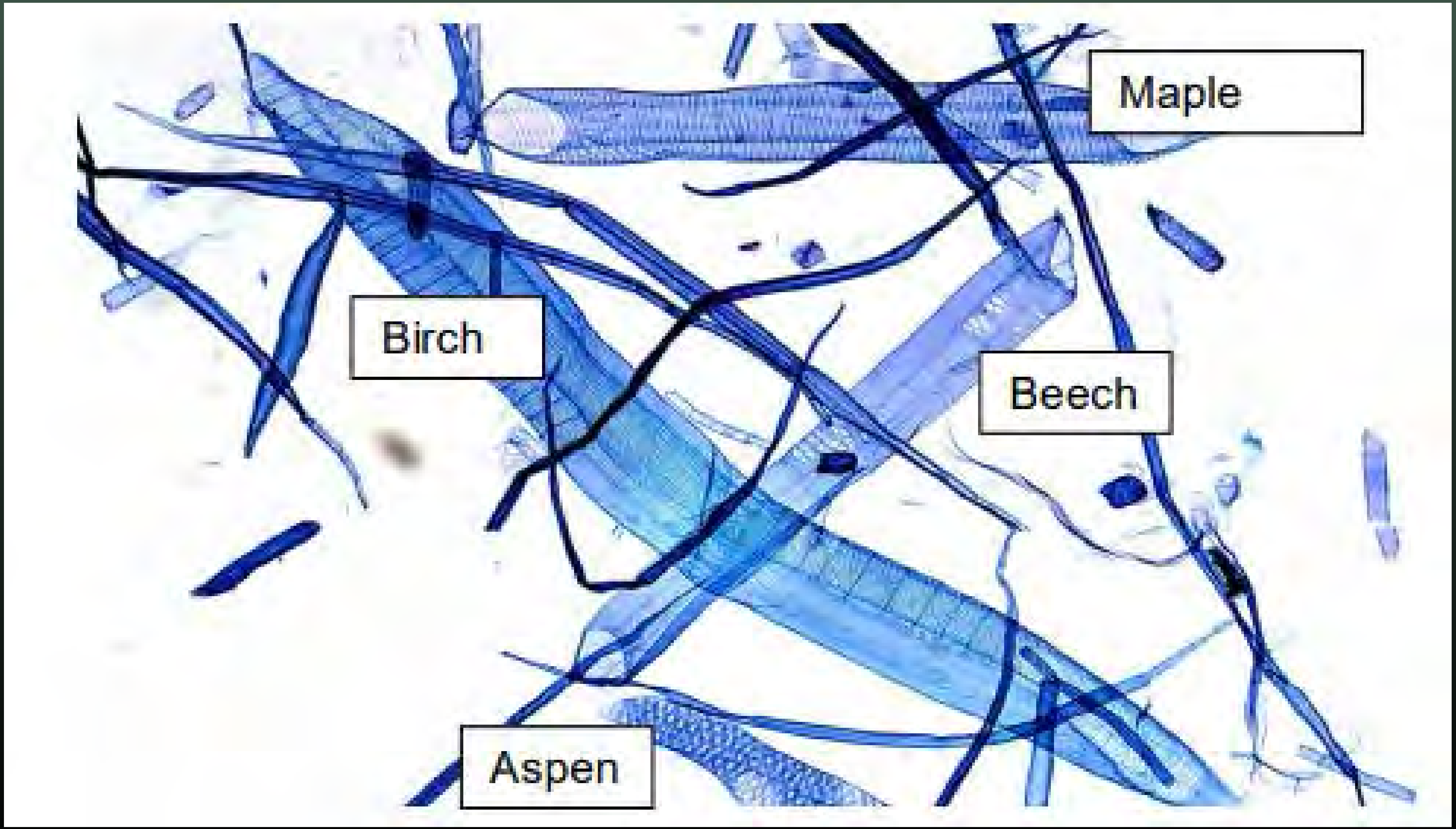
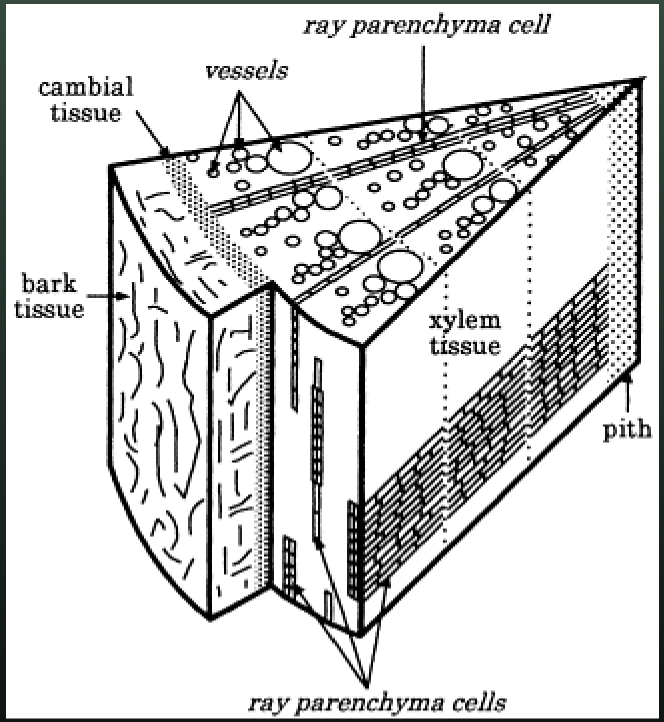


Image: FPInnovations

Hardwood pulp dispersed in water

20x

Wood through a microscope -Parenchyma



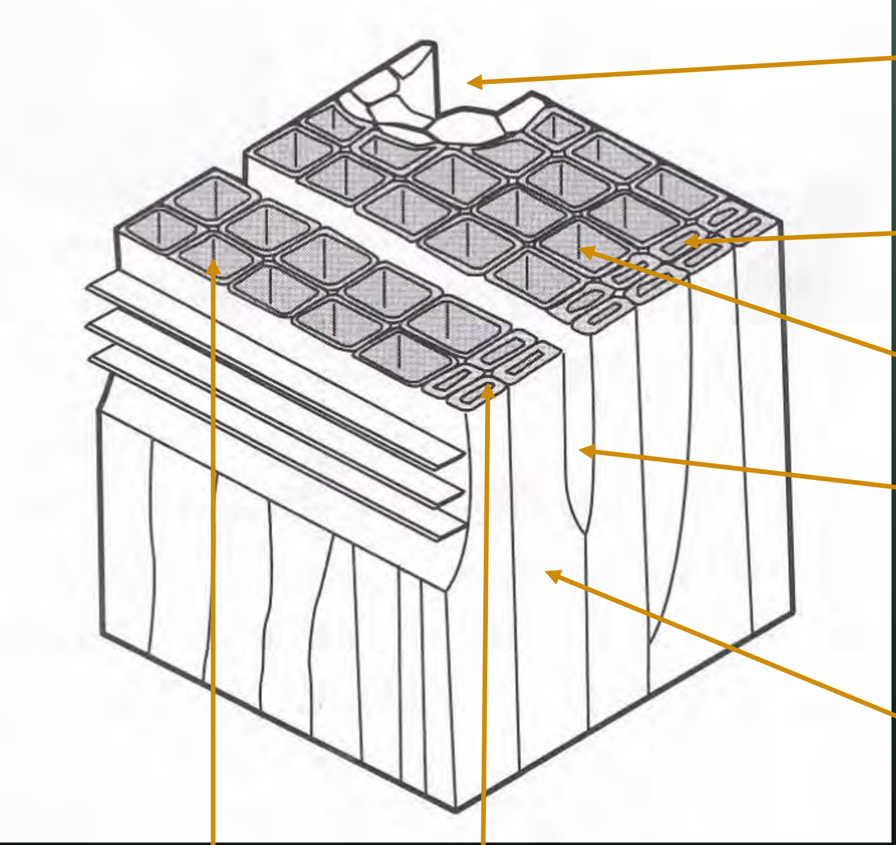
- **Parenchyma** is the name given to the three-dimensional network of living cells within the tree. This network distributes the energy for building and maintaining living tissues by transporting and storing nutrients through the tree. The 2 dimensions are:
  - Ray parenchyma connecting the bark with inner portions of the stem
  - Axial *parenchyma* running parallel with the length of the stem.
- The network also plays a key role in protection against pathogens (bacteria, rusts etc).

Ray parenchyma in Western Red Cedar

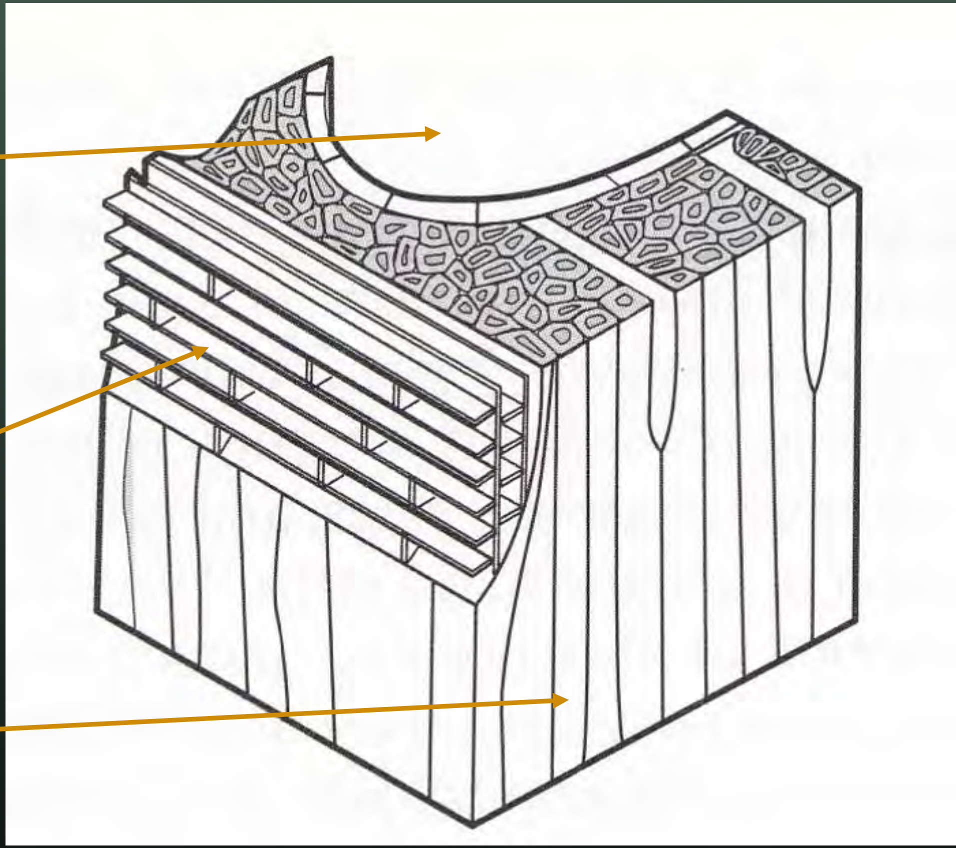
Tangential section
(10x 0.30NA)

Image: Watermark log display, Sechelt seawall, Michael Bradley

Softwood

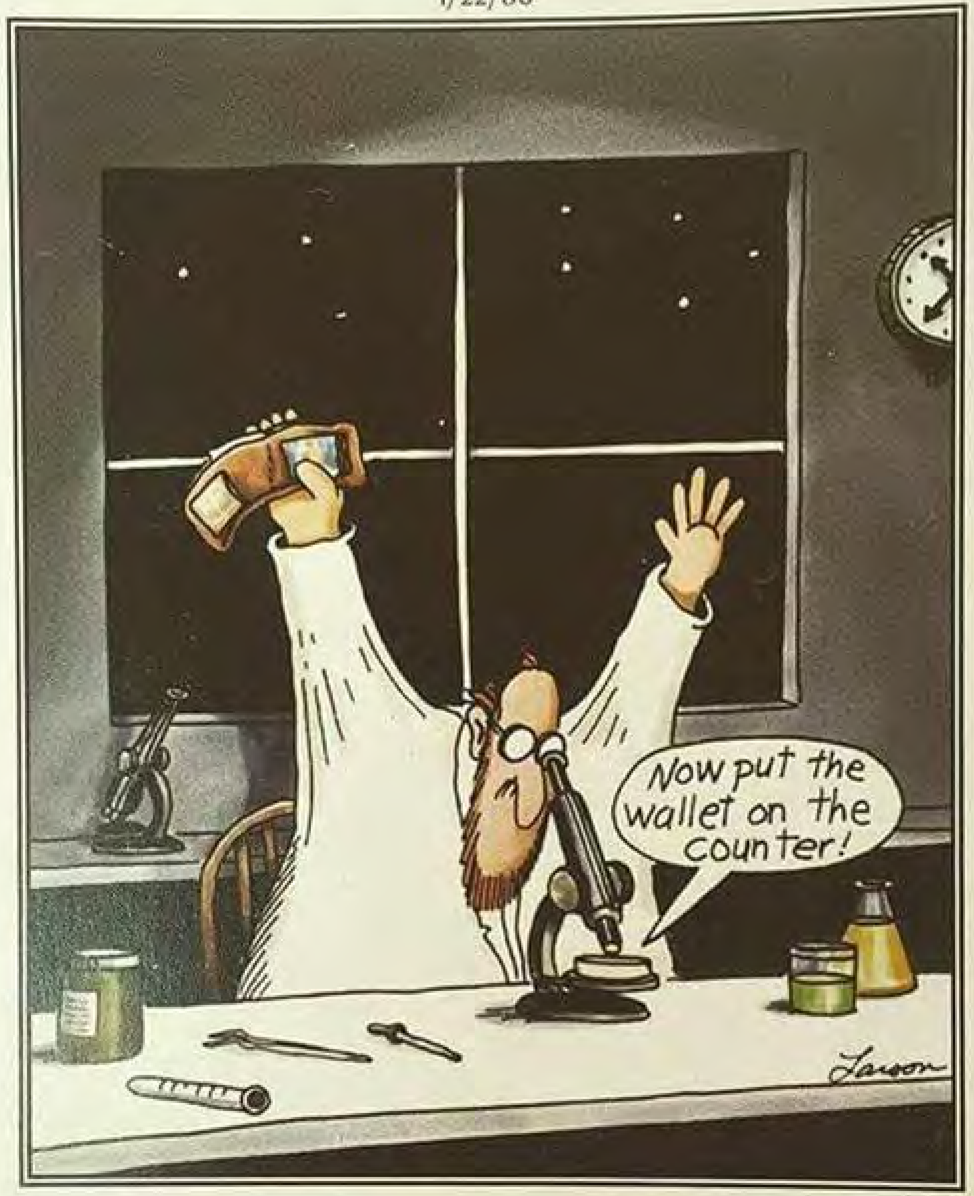


Hardwood



Questions?

1/22/86



Working alone, Professor Dawson stumbles into a bad section of the petri dish.

Jos. G. G. Morgan's slides

Jos. G.G.Morgan and N.L.Wright

- The slide maker was Morgan – each slide was signed.
- UBC records from around early century show a G.G.Morgan making a donation of some sort.
- The name appears in 1915 “American Lumberman” as a Construction Superintendent.

- An N.L.Wright appears frequently around this time in the records of Pacific Northwest forestry. He (she?) seems to have been involved in policy discussions, conferences etc.

Jos. G. G. Morgan

American lumberman, July 10, 1915.— Granite block shows less endurance than wood block paving, p. 19; The double campaign for wood block pavement must start in the west, p. 20; Wood block paving in the Pacific northwest, p. 21; Efficiency of a wood treating process, p. 21; Creosoted blocks in relation to lumber business, by Joseph G. G. Morgan, p. 36; Log delivery costs studied; Forest service shows expense from tree to water in Puget Sound, p. 38.

PAGE 86

Forest; Frederick Hanson, forest ranger, Olympic National Forest; assistant forest rangers Thos. H. Griggs, Paulina National Forest; Oliver C. Klingensmith, Joseph L. Mackechnie, Jos. G. G. Morgan, Edgar J. Murnen, Robt. J. O'Farrell, William Sethe, and Ed Tittle, Rainier National Forest; Revis Costello, Siskiyou National Forest; Clarence Anderson, Wiley E. Escher, M. Donald Knapp, Ernest J. Moore, Leland S. Wellington, Wendell R. Whitney, Snoqualmie National Forest; Amos O.

PAGE 19

Clark, Santiam; Wiley E. Escher, Earl G. Forbes, Lonzo D. Hurt, Walter H. Leve, Jos. G. G. Morgan, Wendell R. Whitney, and Newell L. Wright, Snoqualmie; Lovell E. Tipton, Umatilla; E. E. Harpham, Homer J. Ireland, and U. F. McLaughlin, Umpqua; Charles C. Hon and Oscar Pratt, Wallawa; James Lowden, Washington; Thomas H. Parker and R. E. Kan Smith, Whitman.

Pamphlets on Forestry in Washington - Volume 7 - Page 70
books.google.ca › books
1991 · Snippet view
FOUND INSIDE – PAGE 70
... **Forestry** Though a lack of funds has hampered the College of **Forestry** in its efforts to solve some of the more important ... **G. G. Morgan** '13 , superintendent of construction ,

N. L. Wright

Canadian Cataloguing in Publication Data

Rajala, Richard Allan, 1953-
Clearcutting the Pacific rain forest

Includes bibliographical references and index.
ISBN 0-7748-0590-0

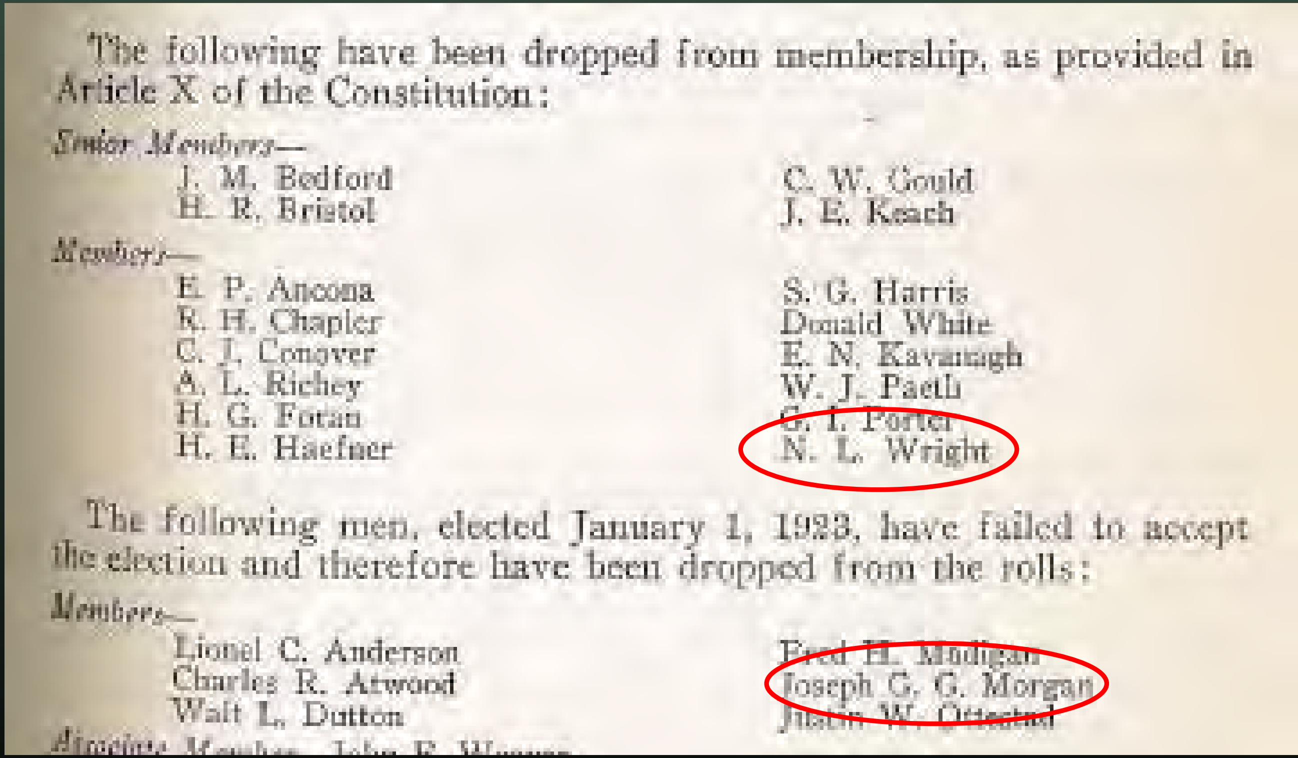
1. Forest management – British Columbia – History. 2. Clearcutting – British Columbia – History. 3. Forest policy – British Columbia – History. 4. Forests and forestry – British Columbia – History. 5. Logging – Technological innovations – British Columbia – History. I. Title.

54 N.L. Wright, 'Memorandum Regarding Progress of Selective Logging in Region Six,' 13 May 1936, Box 17, RG 95, DHF, NARS-PNW; 'Digest Report,' Region 6 Supervisors' Conference, 11-19 Mar. 1937, Box 8, ibid.; E.J. Hanzlik, 'Memorandum for Forest Supervisor,' 21 June 1937, RG 095-54A-0111, Box 59854, NARS-PNW.

WRIGHT, N. L. (11484)
MAKING SHINGLES BETTER. Timberman 17 (11) : 57. 1916.

8 J.J. Donovan to N.L. Wright, 27 May 1913, Box 1, University of Washington College of Forest Resources Records, Acc. 70-1, University of Washington Libraries (hereafter UWCFRR); see also Clarence Ross Garvey, 'Overhead Systems of Logging in the Northwest,' (M.Sc. in Forestry thesis, University of Washington 1914), 1.

1923 Society of American Foresters



The following have been dropped from membership, as provided in Article X of the Constitution:

Senior Members—

J. M. Bedford
H. R. Bristol
C. W. Gould
J. E. Keach

Members—

E. P. Ancona
R. H. Chapler
C. J. Conover
A. L. Richey
H. G. Foran
H. E. Haefner
S. G. Harris
Donald White
E. N. Kavanagh
W. J. Paeth
G. I. Porter
N. L. Wright

The following men, elected January 1, 1923, have failed to accept the election and therefore have been dropped from the rolls:

Members—

Lionel C. Anderson
Charles R. Atwood
Walt L. Dutton
Fred H. Madigan
Joseph G. G. Morgan
Justin W. Ottestad

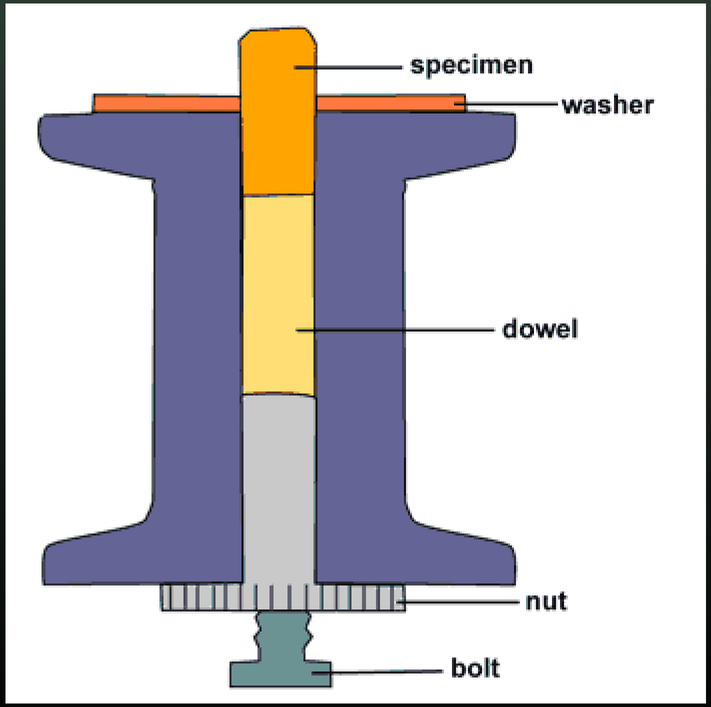
Preparing wood for the microscope

- To be examined and studied on a light microscope the sample must be very thin, 30-50 microns (30-50/1000ths of a mm).
- With fresh wood this can be done with a fresh razor or scalpel blade.
- Dry wood needs reconditioning by boiling, several times for very hard specimens.
- The samples are then placed on a microscope slide and protected with a thin glass cover slip.
- In some cases the sample may be stained to selectively highlight different features before mounting on to the slide.

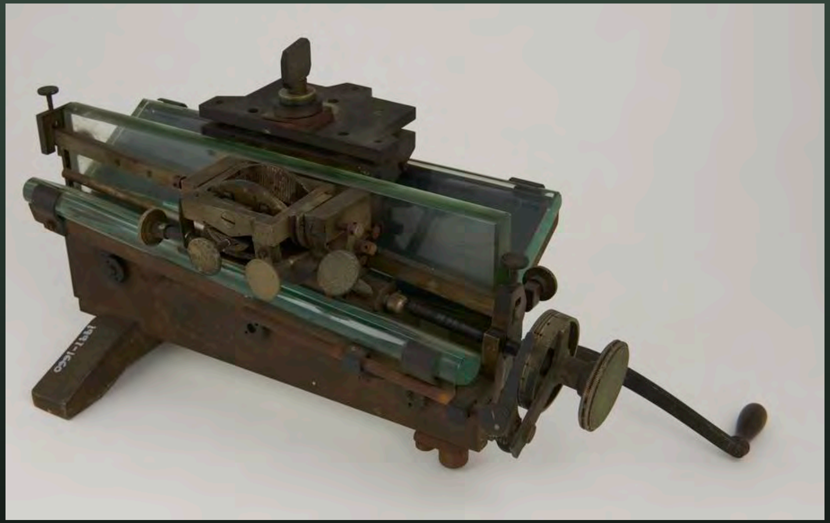
Simple Microtome

These devices are inexpensive and can even be made at home – ask Ken!

Manual cutting of thin sections is possible but use of a simple microtome makes the process much easier and safer.



Cutting a wood section

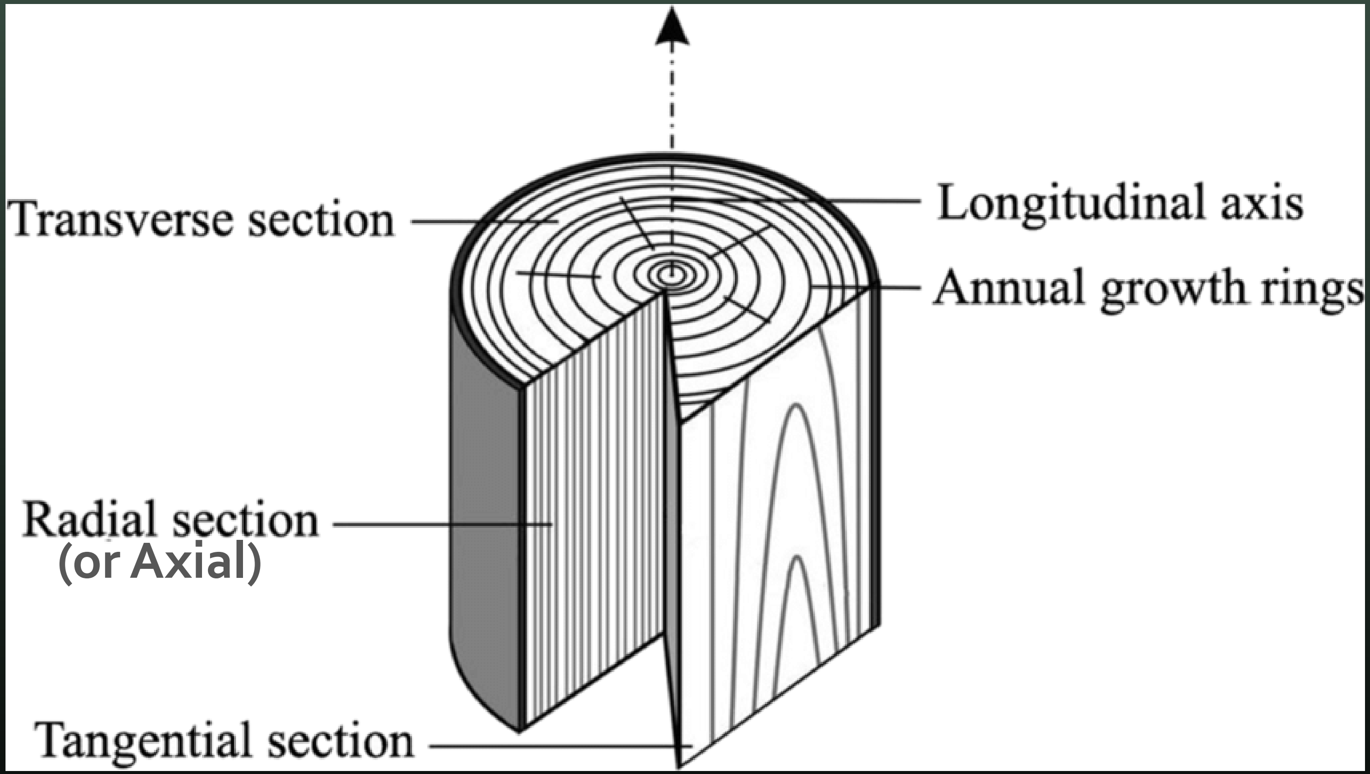


Sledge microtome 1900-1925
Science Museum, London

Hand operated microtome
Science Museum, London

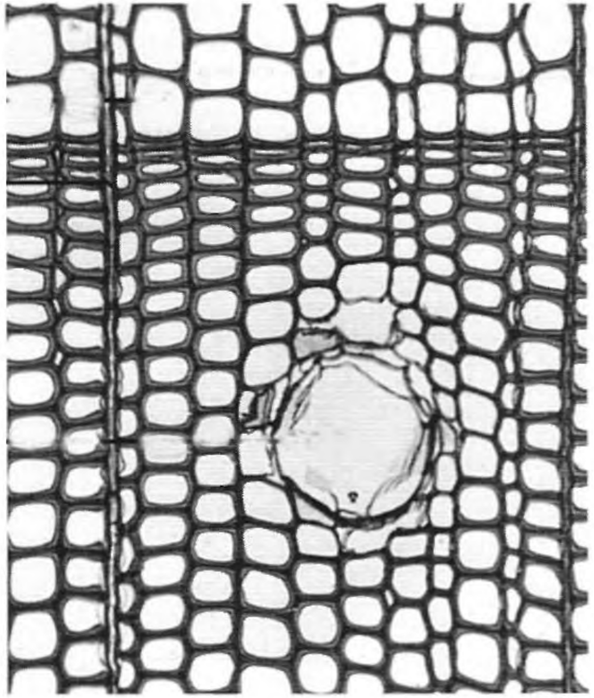
Characterising a wood sample

- Each slide has 3 small slices of wood that have been cut as shown here.
- The sections are cemented in place with “Canada Balsam” and covered with a thin glass cover-slip.
- Canada Balsam is still used today by microscopists – resin from Balsam Fir

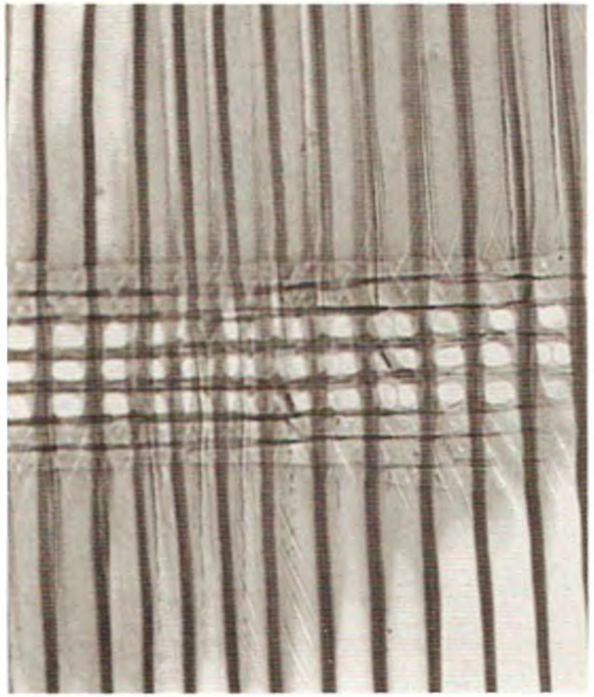


Wood Sections

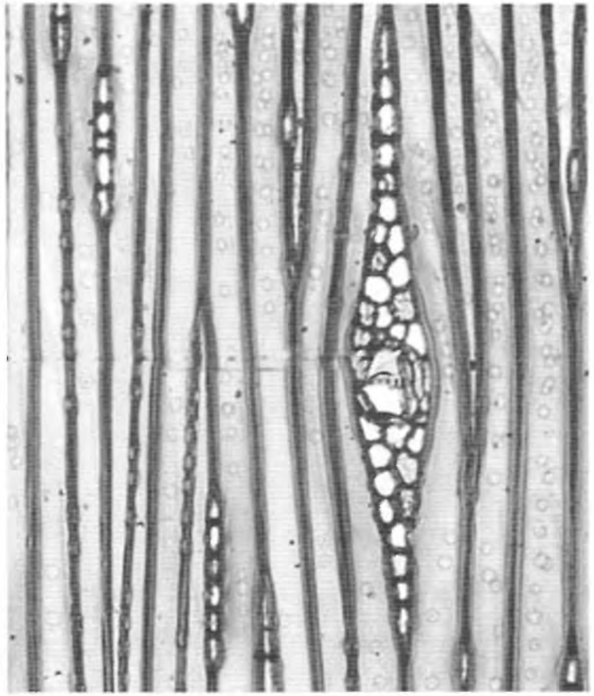
TRANSVERSE

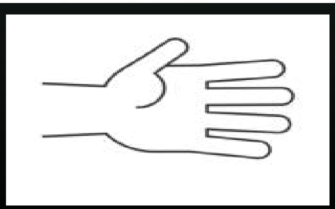


AXIAL (or RADIAL)

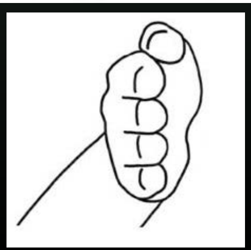


TANGENTIAL





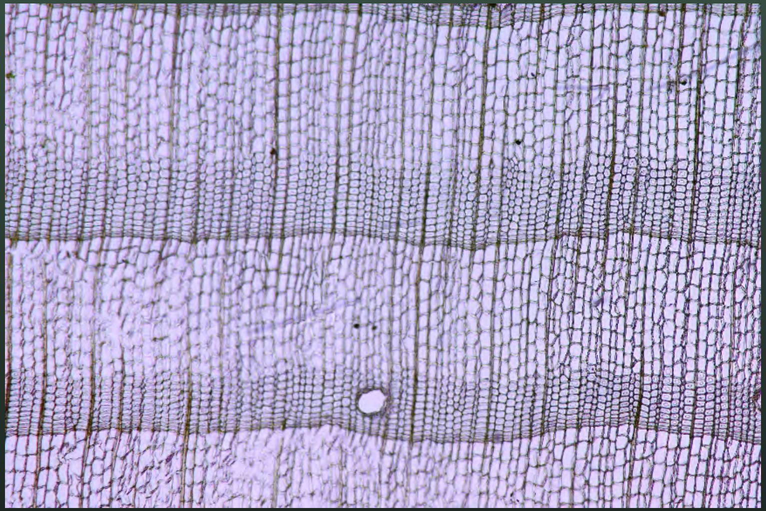
Rays



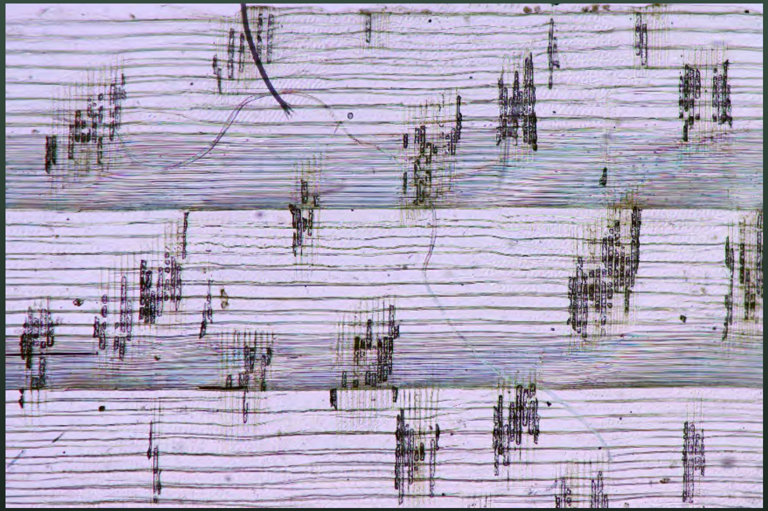
The slides

Western Larch

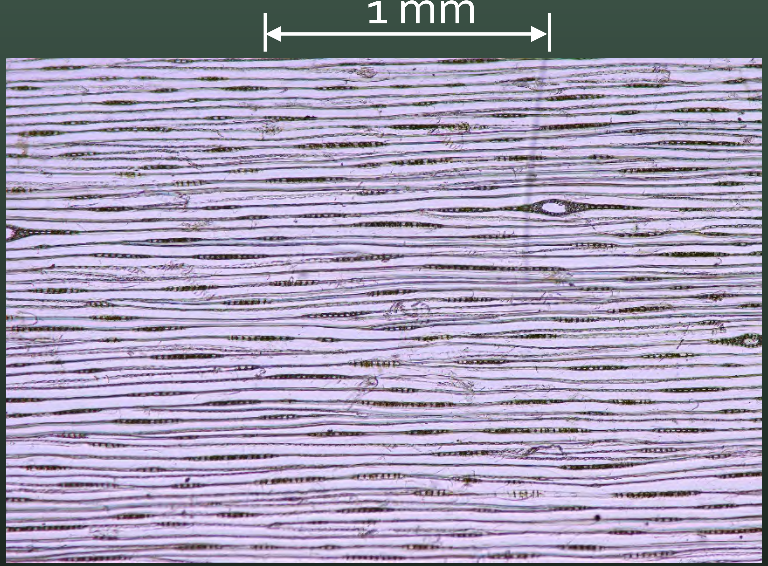
Larix occidentalis



Transverse



Axial



Tangential

Large diameter tracheids

1/18/12

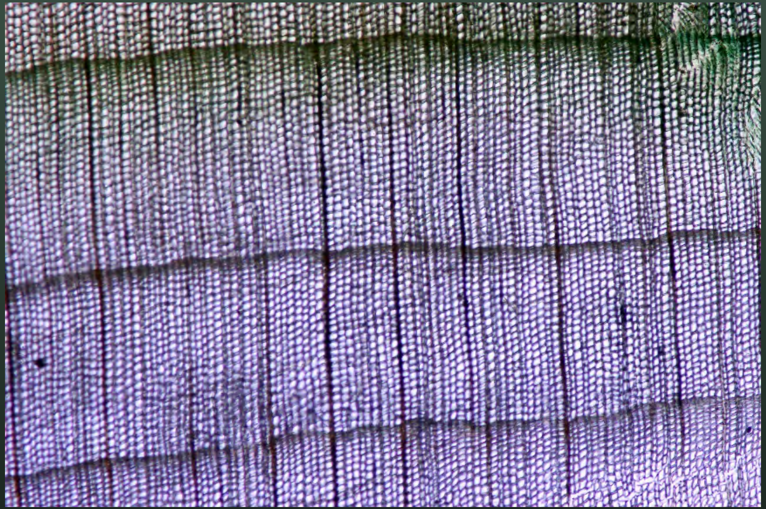
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

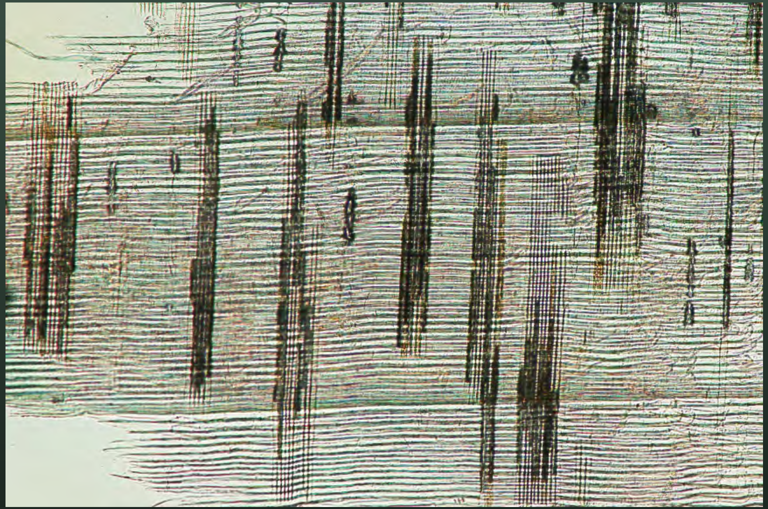
Chaemecyparis nootkatensis

Nootka Cypress

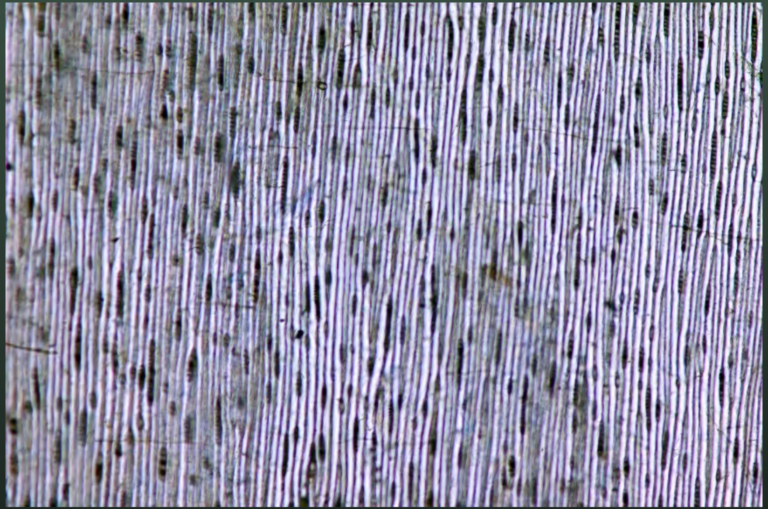
1 mm



Transverse



Axial



Tangential

Small-medium tracheids

12/12/1911

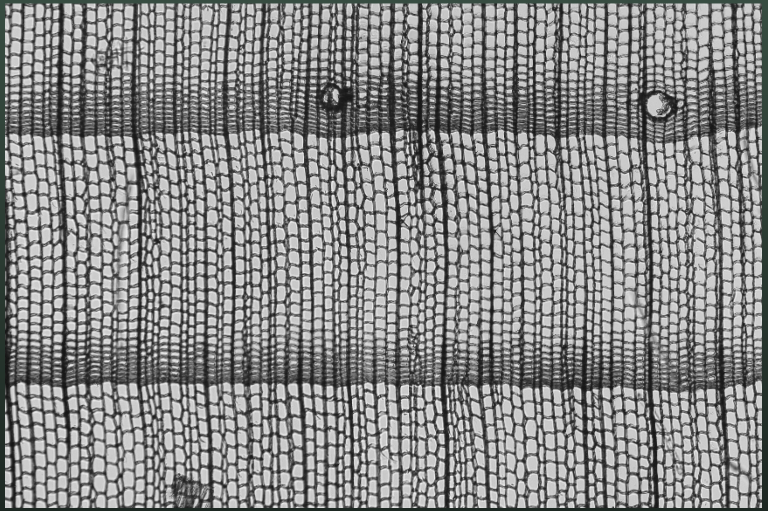
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

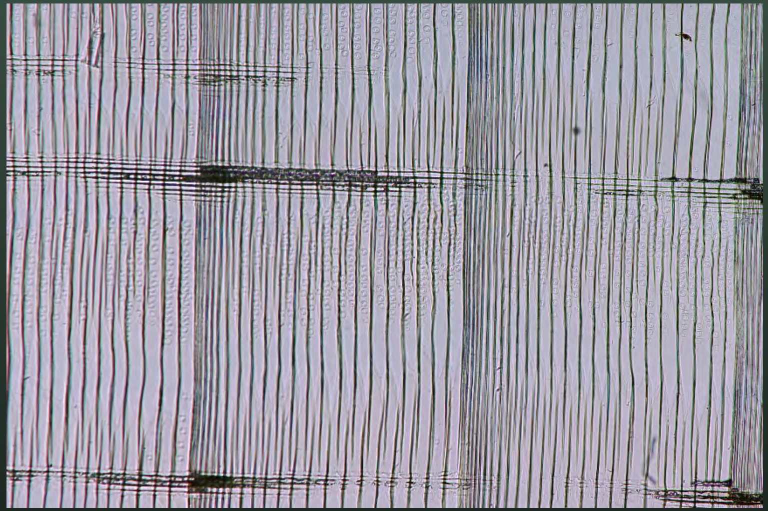
Picea sitchensis

Sitka Spruce

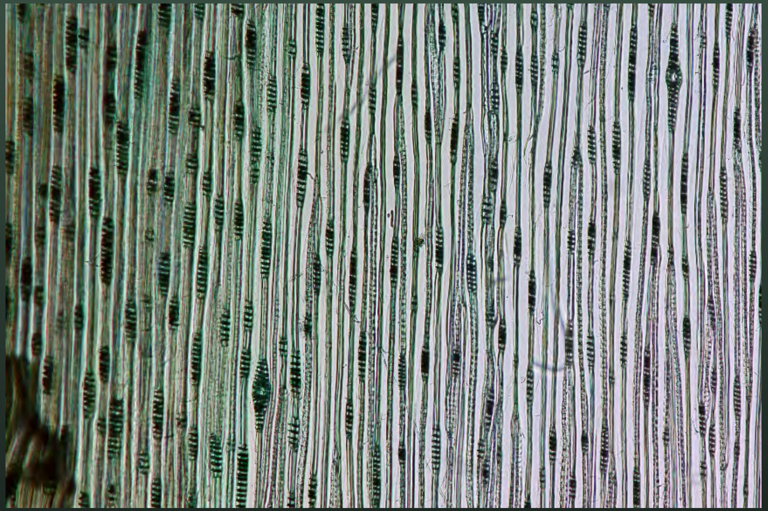
1 mm



Transverse



Axial



Tangential

Medium large tracheids, sharp transitions

Small resin canals

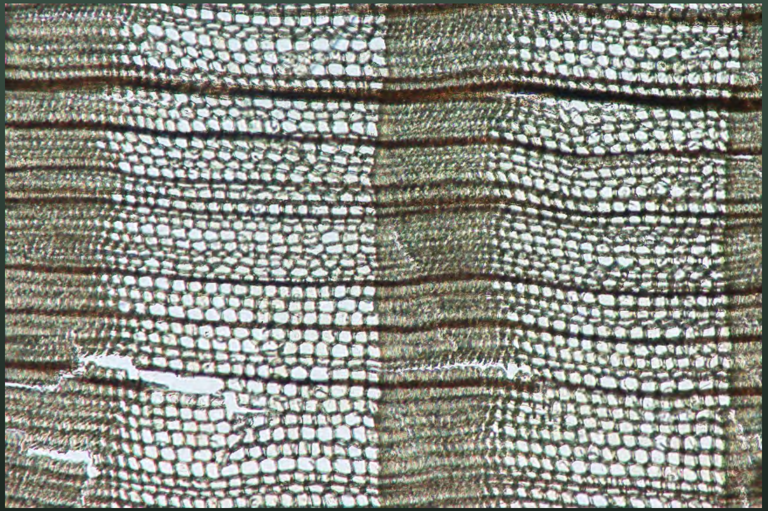
1/18/1912

Jos.G.G. Morgan

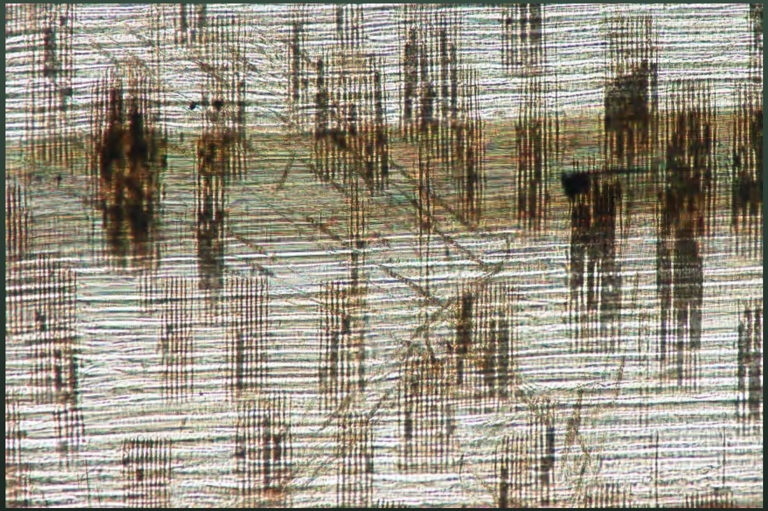
Objective: SPlan 4x 0.13 NA

P. taxifolia

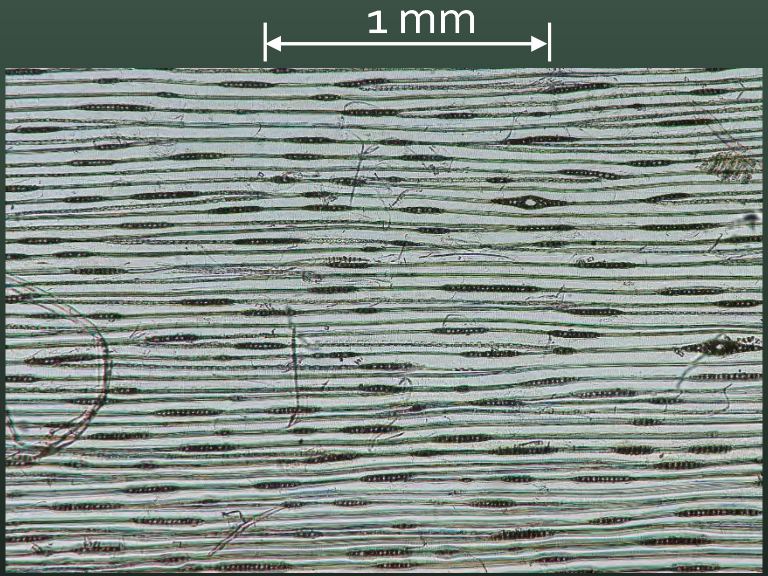
Douglas Fir (P.taxifolia was an old name for DF, now Pseudotsuga menziesii)



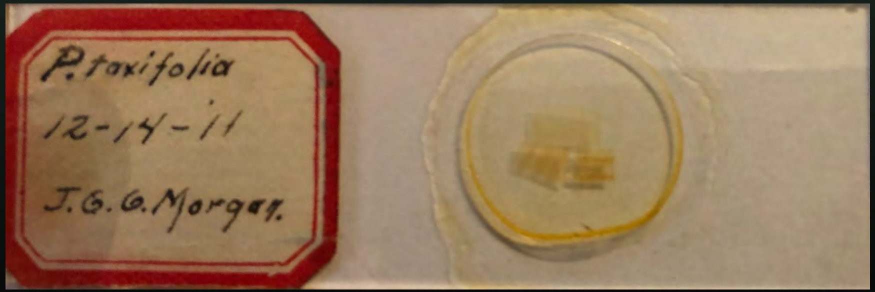
Transverse



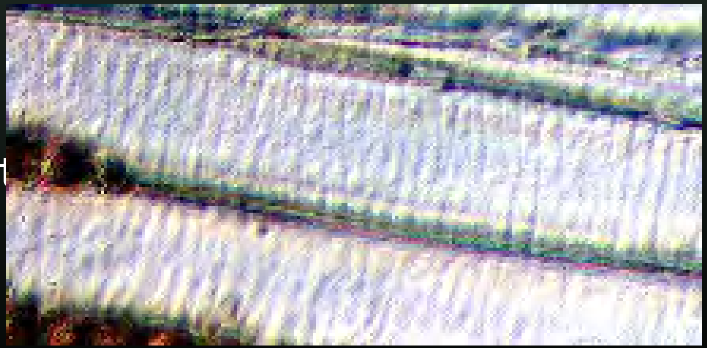
Axial



Tangential



Spiral thickening of tracheid walls was visible in oblique light suggesting that it was probably Douglas fir. (20X 0.46 NA)



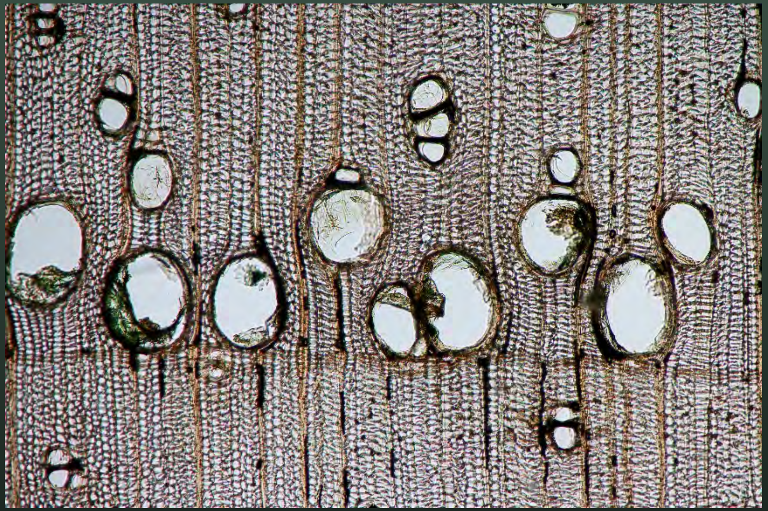
12/11/1911

Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

Fraxinus

American Ash



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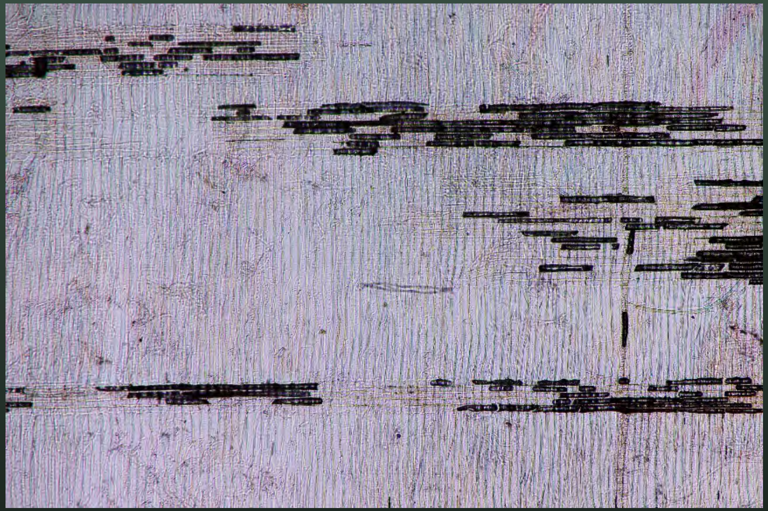

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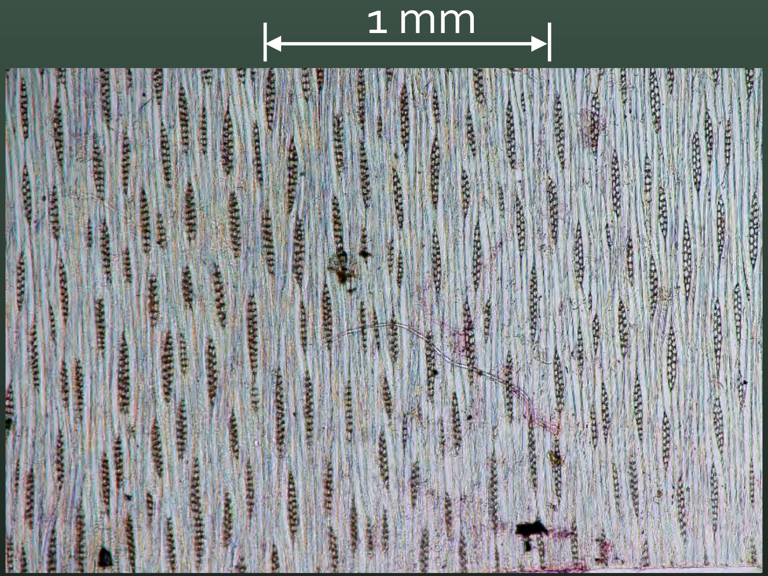


Tangential

Ring porous

Large earlywood pores, 2-4 rows, small, solitary latewood pores with thicker walls

Note Fraxinus spelling

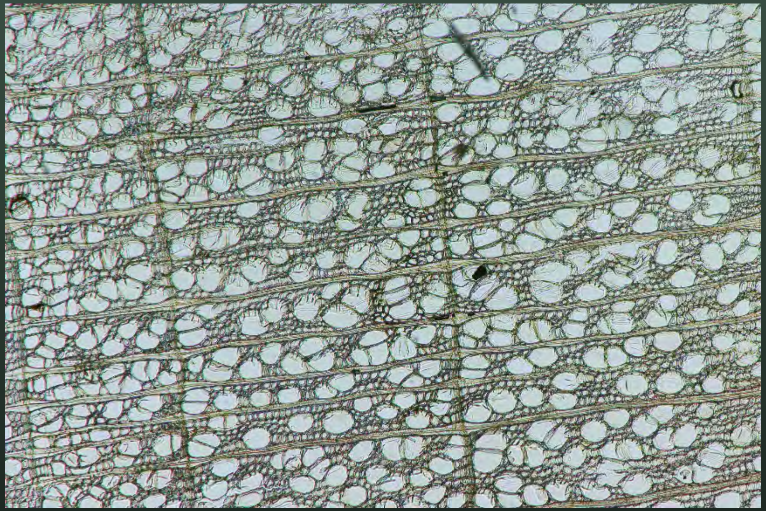
12/1/1911

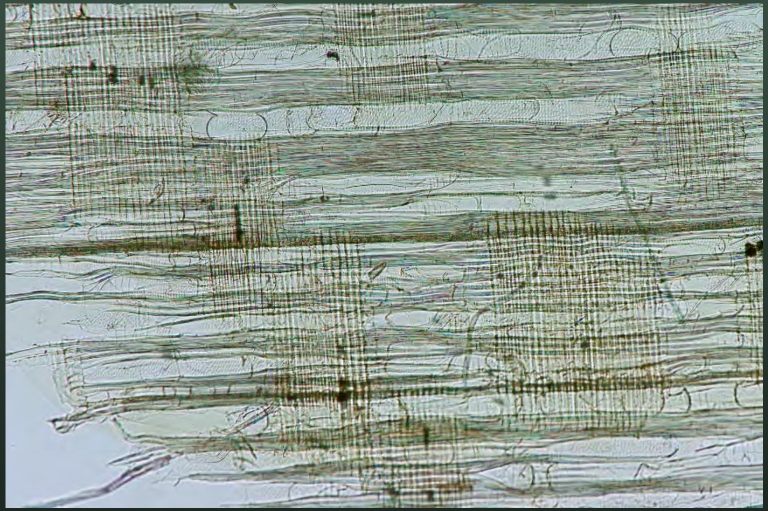
Jos.G.G. Morgan

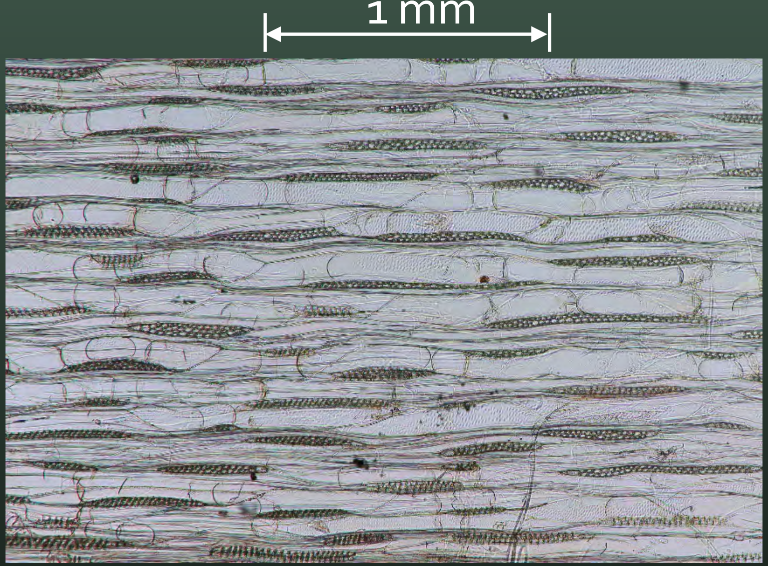
Objective: SPlan 4x 0.13 NA

Yellow poplar

P. tulipifera


Transverse


Axial



Tangential

Diffuse porous

Small pores, uniform size

12/12/1911

Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

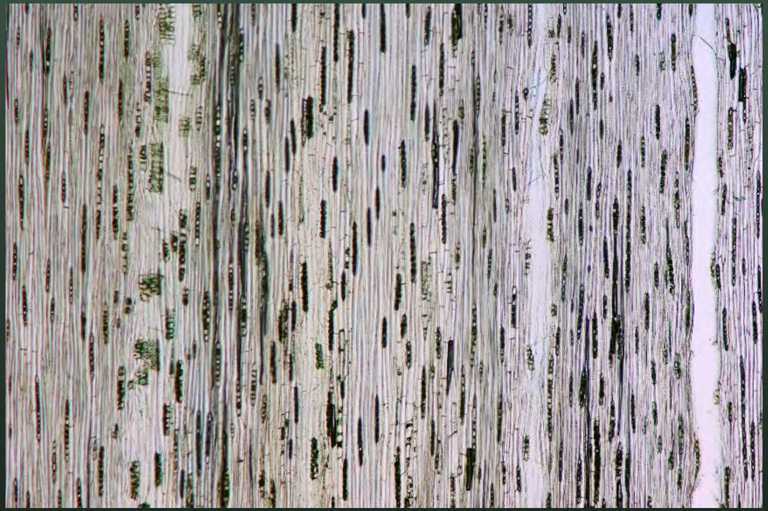
Querkus virginiana

Southern Live Oak

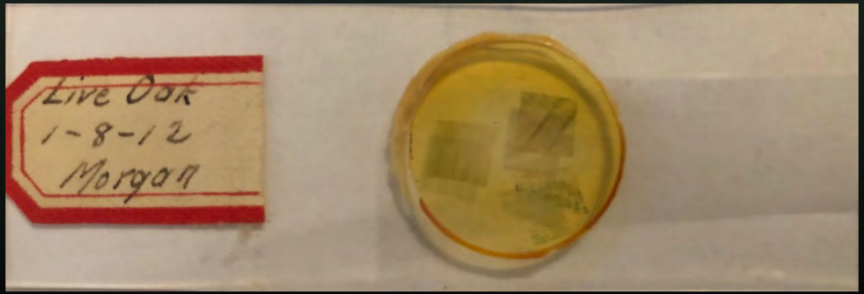
1 mm

Transverse

Axial



Tangential



Ring porous

Large/very large earlywood pores –oval/circular

Very wide and also narrow rays

1/8/1912

Jos.G.G. Morgan

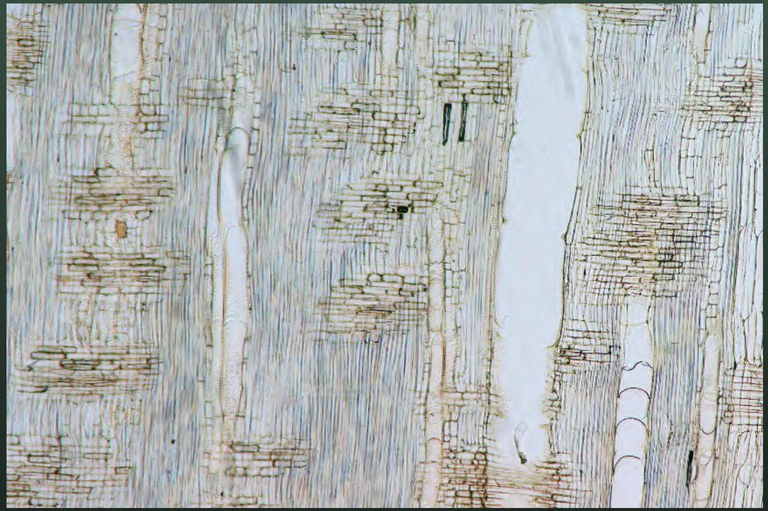
Objective: SPlan 4x 0.13 NA

Sassafras

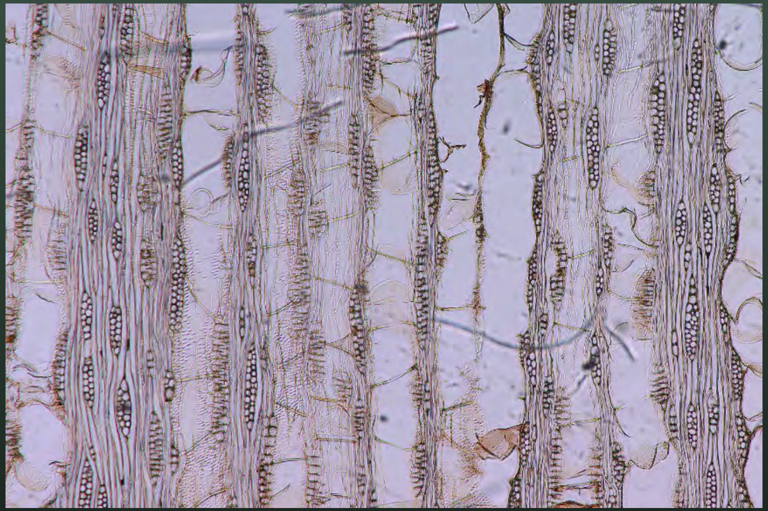
Sassafras albidum

1 mm

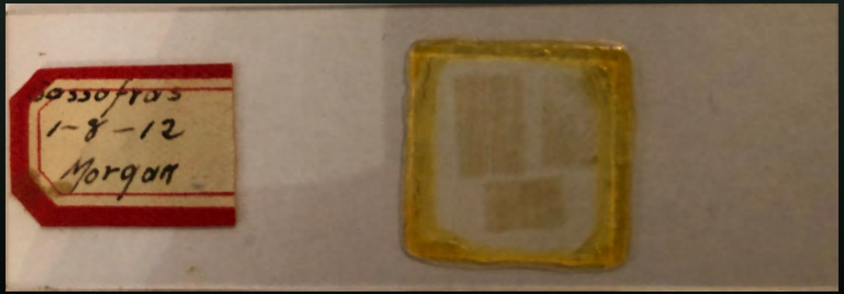
Transverse



Axial



Tangential



Ring porous

Large earlywood pores easily seen

1/8/1912

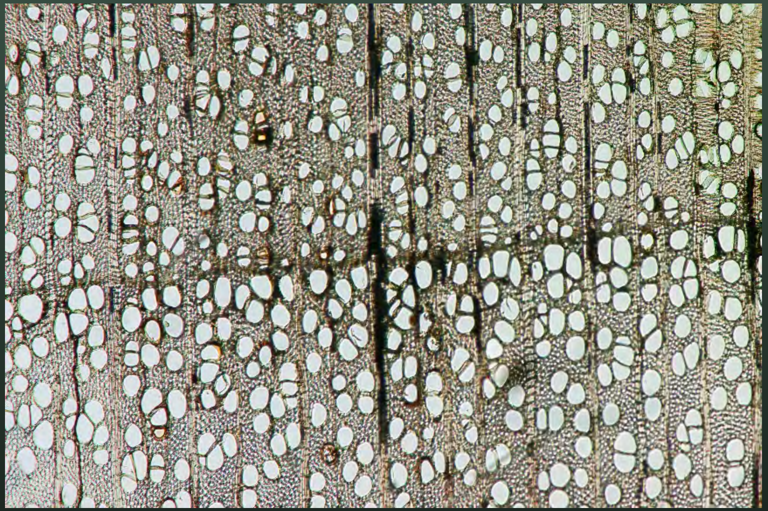
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

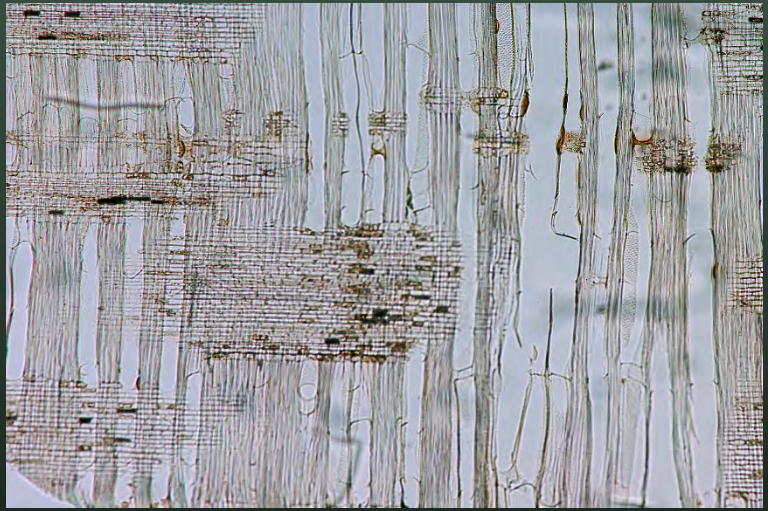
Cherry

Sweet Cherry, European Cherry

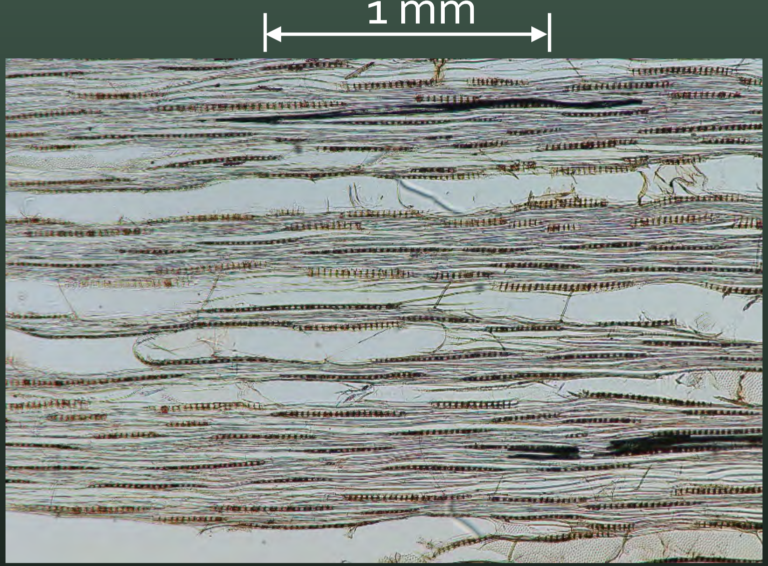
(Prunus avium)



Transverse



Axial



Tangential

Semi-diffuse

Pores in clusters of 2-5

Rays easy to see

1/8/1912

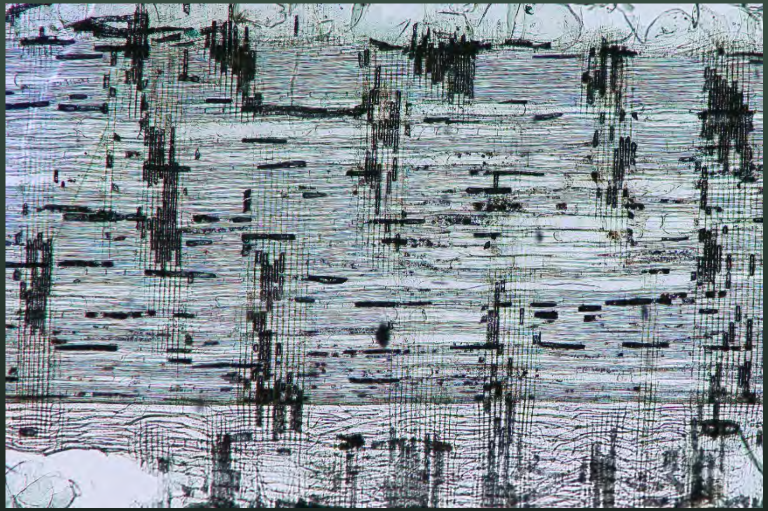
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

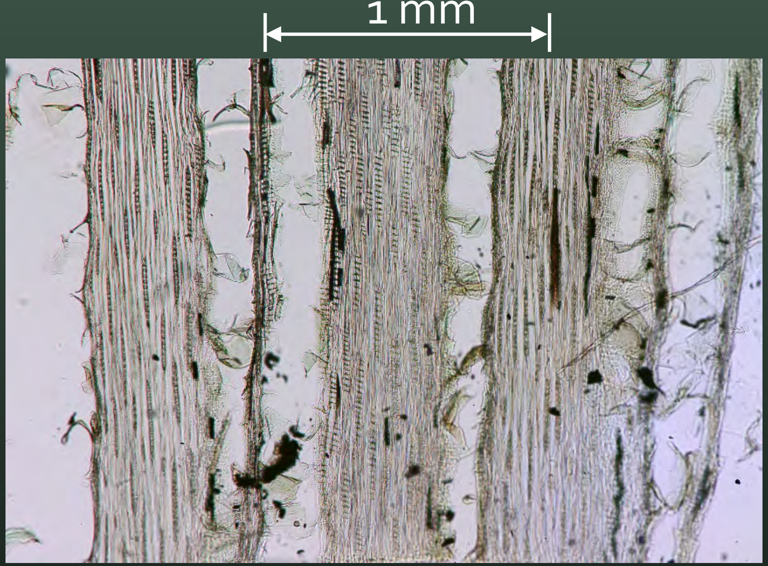
Chestnut

American Chestnut
(Castanea dentata)

Transverse



Axial



Tangential

Ring porous

2-4 rows of large early wood pores, many latewood pores in dendritic pattern (?)

4/1/1912

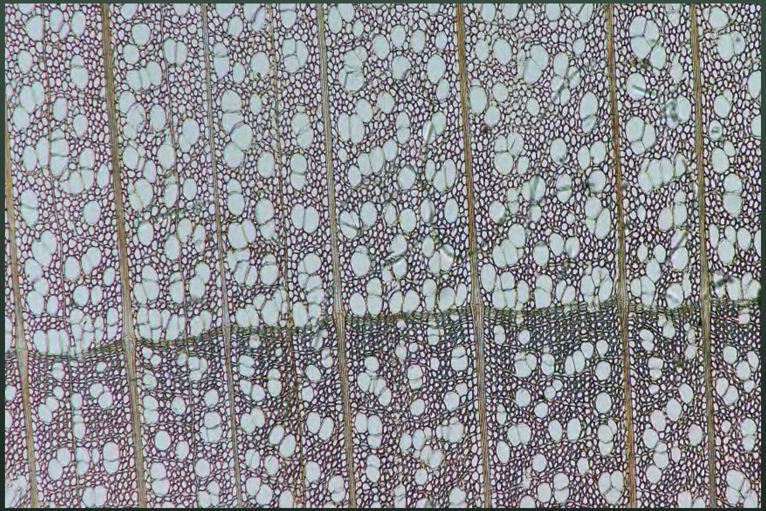
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

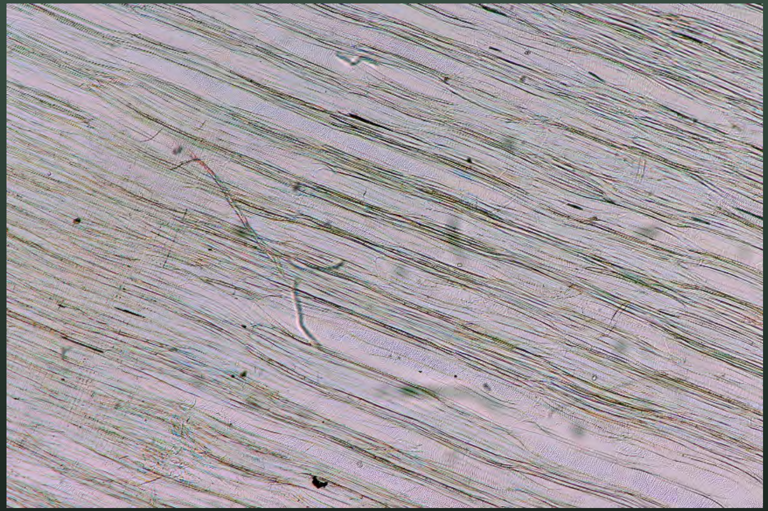
Basswood

Tilia americana

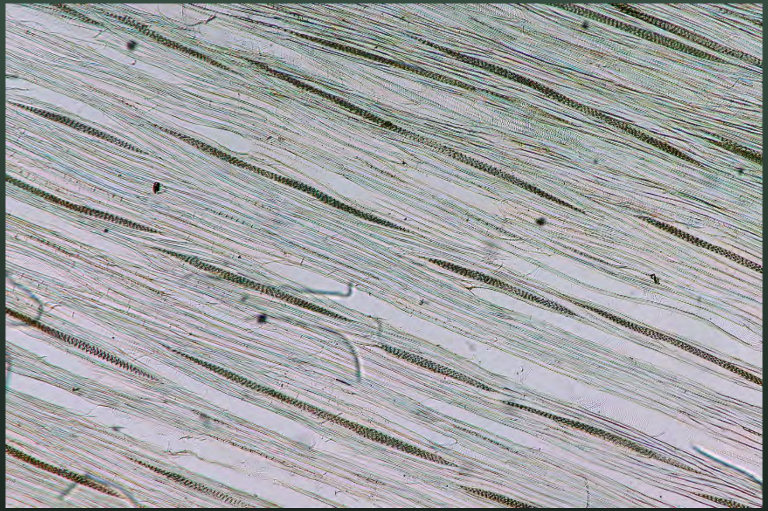
1 mm



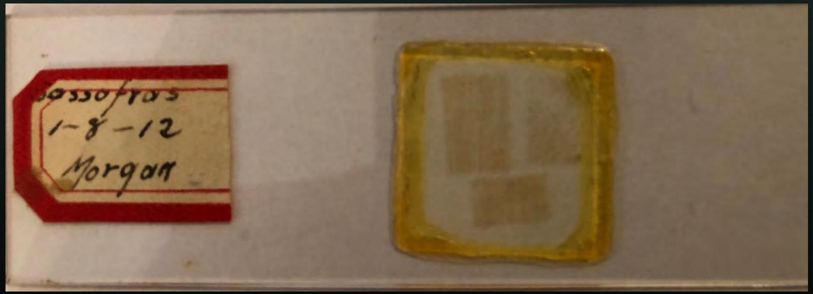
Transverse



Axial



Tangential



Diffuse porous

Pores medium size, evenly distributed, plentiful, in clusters of 2-4

Rays are fine

1/8/1912

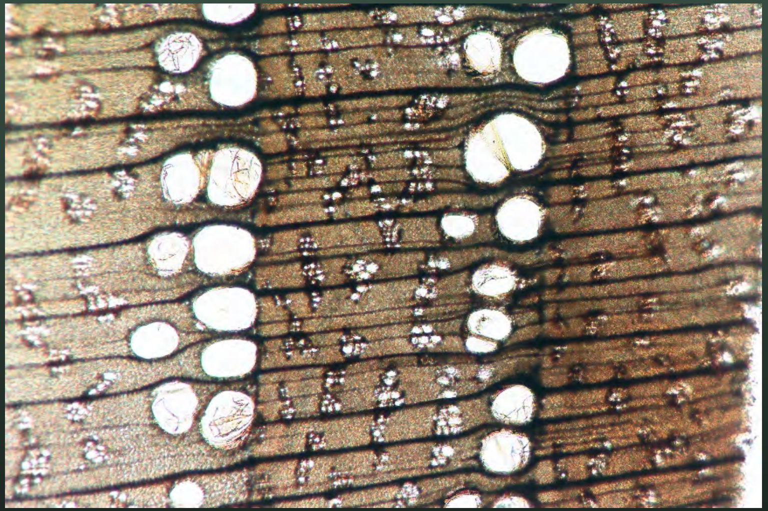
Jos.G.G. Morgan

Objective: SPlan 4x 0.13 NA

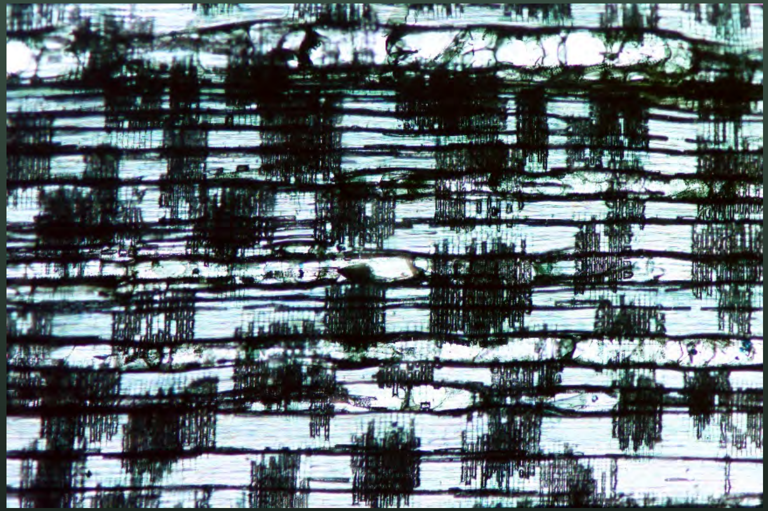
Elm

Ulmus americana

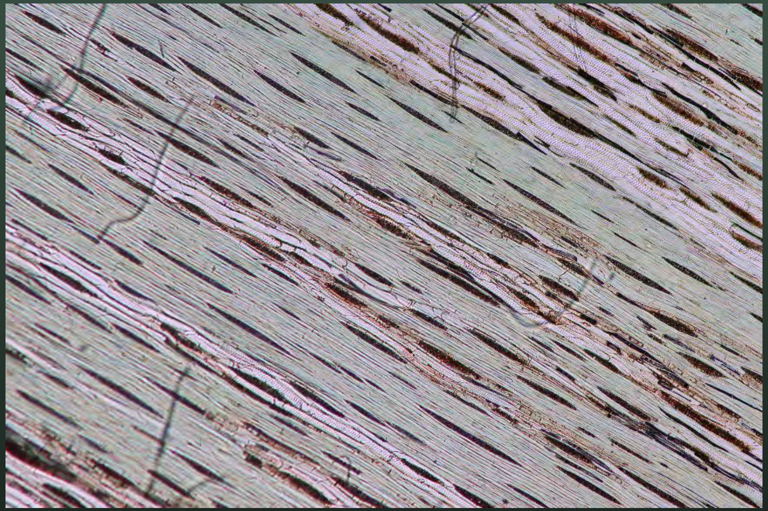
1 mm



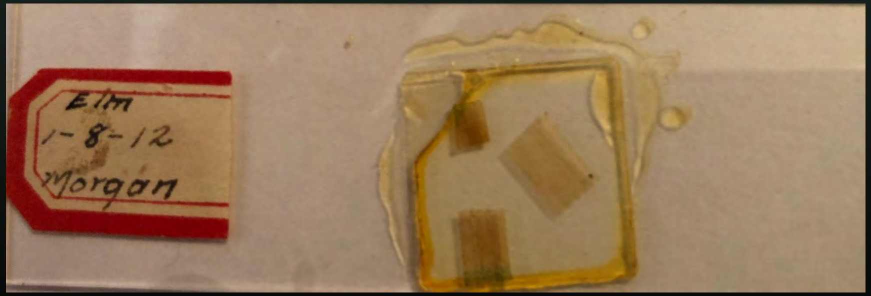
Transverse



Axial



Tangential



Ring porous

Large-very large earlywood pores, small latewood pores in wavy bands. The latewood pores are unique in being connected together by white parenchyma cells.

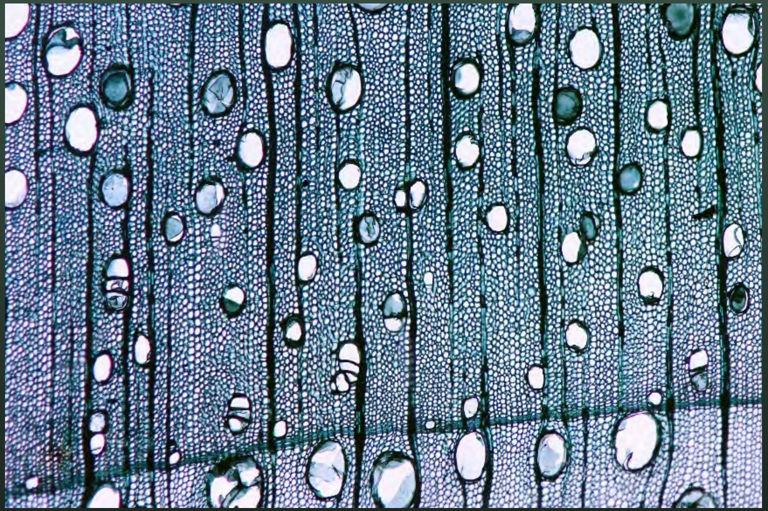
1/8/1912

Jos.G.G. Morgan

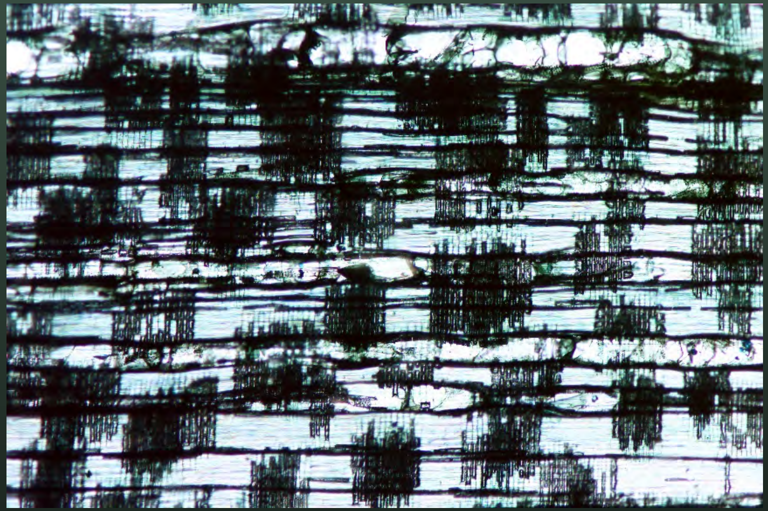
Objective: SPlan 4x 0.13 NA

Juglans nigra

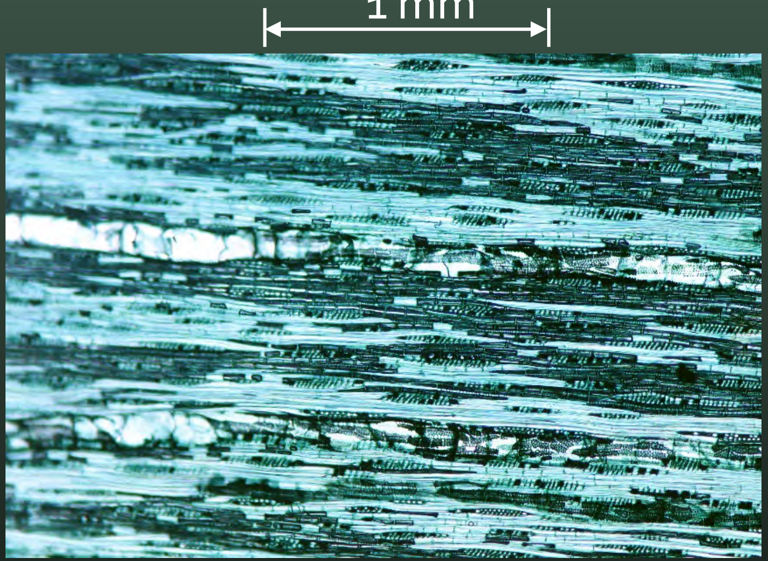
Black Walnut



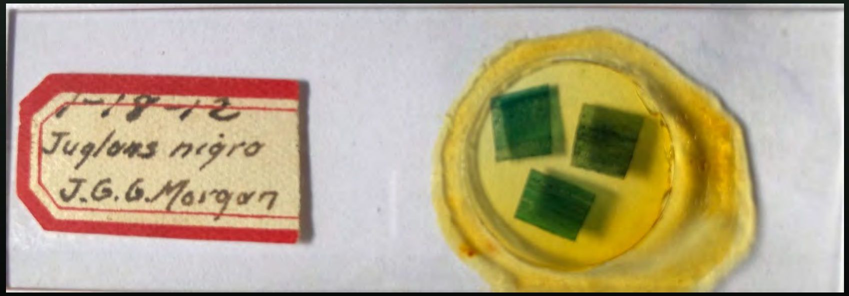
Transverse



Axial



Tangential



Semi-ring porous

Large earlywood pores

1/18/1912

Jos.G.G. Morgan

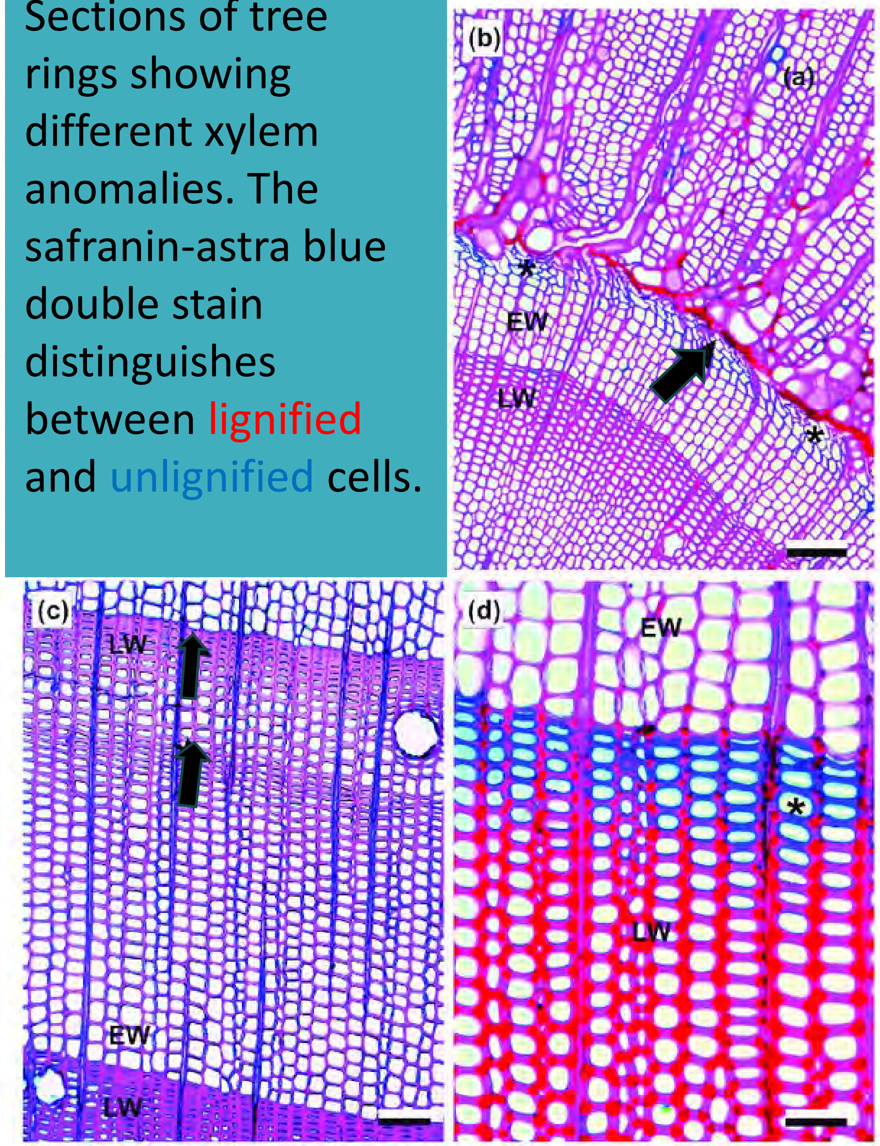
Objective: SPlan 4x 0.13 NA

Questions?

Who's interested in these gory details of wood?

- Apart from wood workers, who is interested in these details about the constituents of wood?
- Foresters are – effects of climate maladaptation etc
- Forensic investigators certainly are:
  - traces of wood and components can identify species, provenance etc.
  - archeologists use provenance together with radiocarbon dating
  - Species determination of wood or fibre can determine legality of sources (CITES, EUTR etc)
  - Antique and art dealers
  - Sewer root detectives
- ?
- ?

Sections of tree rings showing different xylem anomalies. The safranin-astra blue double stain distinguishes between lignified and unlignified cells.



(b) The arrow points to a high intensity frost ring that had occurred during the growing season . (Scale bar 100 µm)

(c) Double ring with two bands of latewood-like tracheids (labeled by arrows) caused by dry conditions in late summer. (Scale bar 100 µm)

(d) Blue ring showing unlignified cells in the latewood of a tree ring due to low temperatures. (Scale bar 50 µm)

EW = early wood, LW = late wood. Species White Spruce.

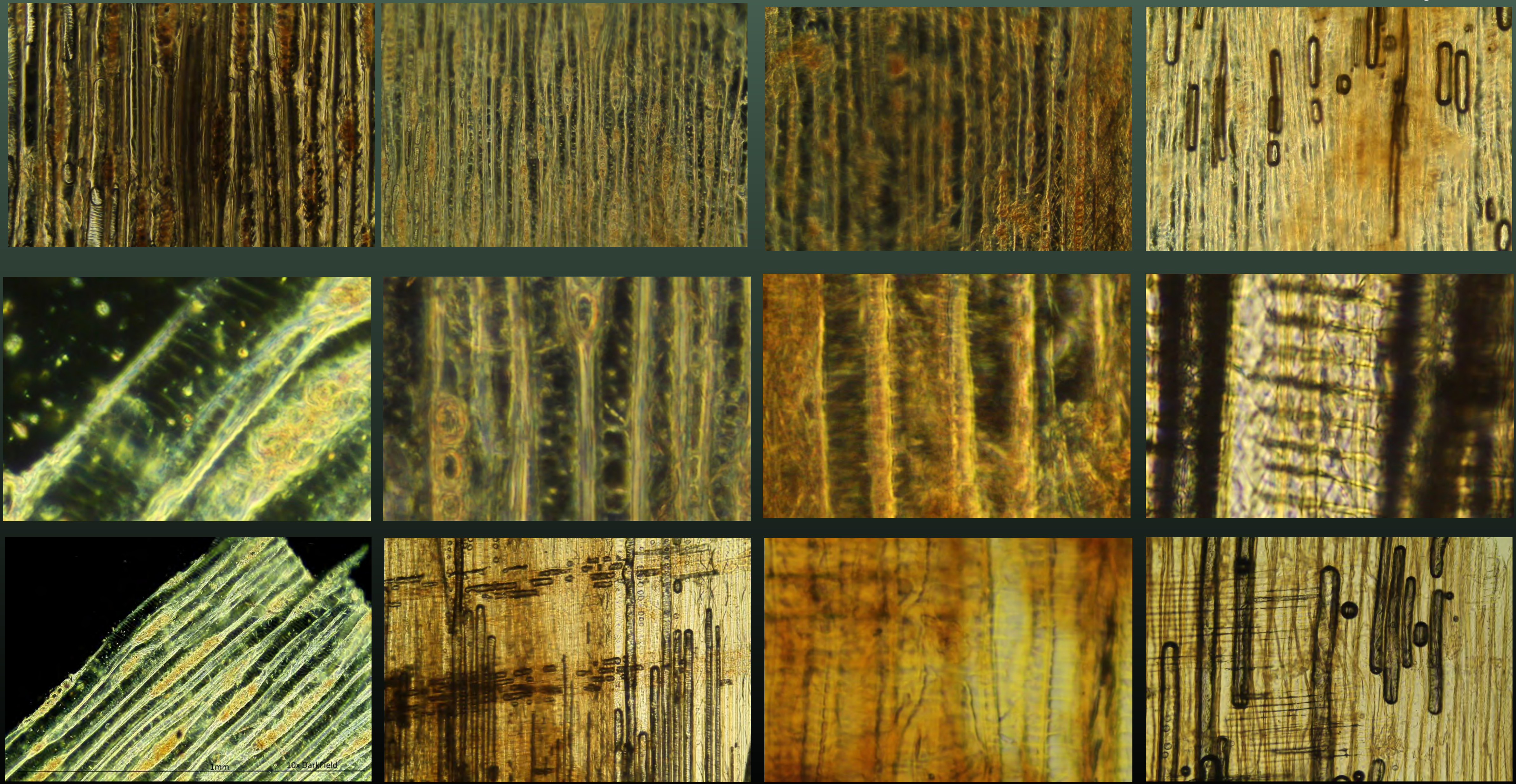
https://www.researchgate.net/publication/339535685_Xylem_Anomalies_as_Indicators_of_Maladaptation_to_Climate_in_Forest_Trees_Implications_for_Assisted_Migration/figures?lo=1

The "Watermark logs"

Sechelt

The “Watermark” logs

- These logs were discovered in 2016 when Wakefield Homes excavated the site for The Watermark development on Sechelt waterfront. The logs were radiocarbon dated as being 4830 years old. They were still in a good condition!
- I examined samples from the logs microscopically and found them to be typical of the Western Red Cedar or Coastal Douglas Fir found in BC today.
- One of the logs and an interpretive sign has been put on display on the Sechelt waterfront in front of the Watermark condominiums. The log on display is identified as Western Red Cedar.
- Thanks to Sunshine Coast Natural History Society and Wakefield Homes for their roles in saving these logs and setting up this display.



Images by Michael Bradley

“The Watermark” logs – ca.5000 yrs

Questions?


How to prepare
wood for microscopy

Questions?

Paramecium humor

What about Papermakers?

- The pulping process breaks down wood or other plant materials into their individual fibres.
- The papermaking process blends together different types of fibres (HW/SW), minerals and chemicals to achieve particular end-use properties like printability or strength.
- The medium in which this mixing is done is water – lots of it.
- A loose network forms as water is drained away on a mesh belt and pressed. Finally water is evaporated on a series of heated cylinders.
- As the last water evaporates, the individual fibres are drawn closer together and hydrogen bonds form between the cellulose molecules in the fibre walls. Without water these bonds would not form and the paper would be very weak.

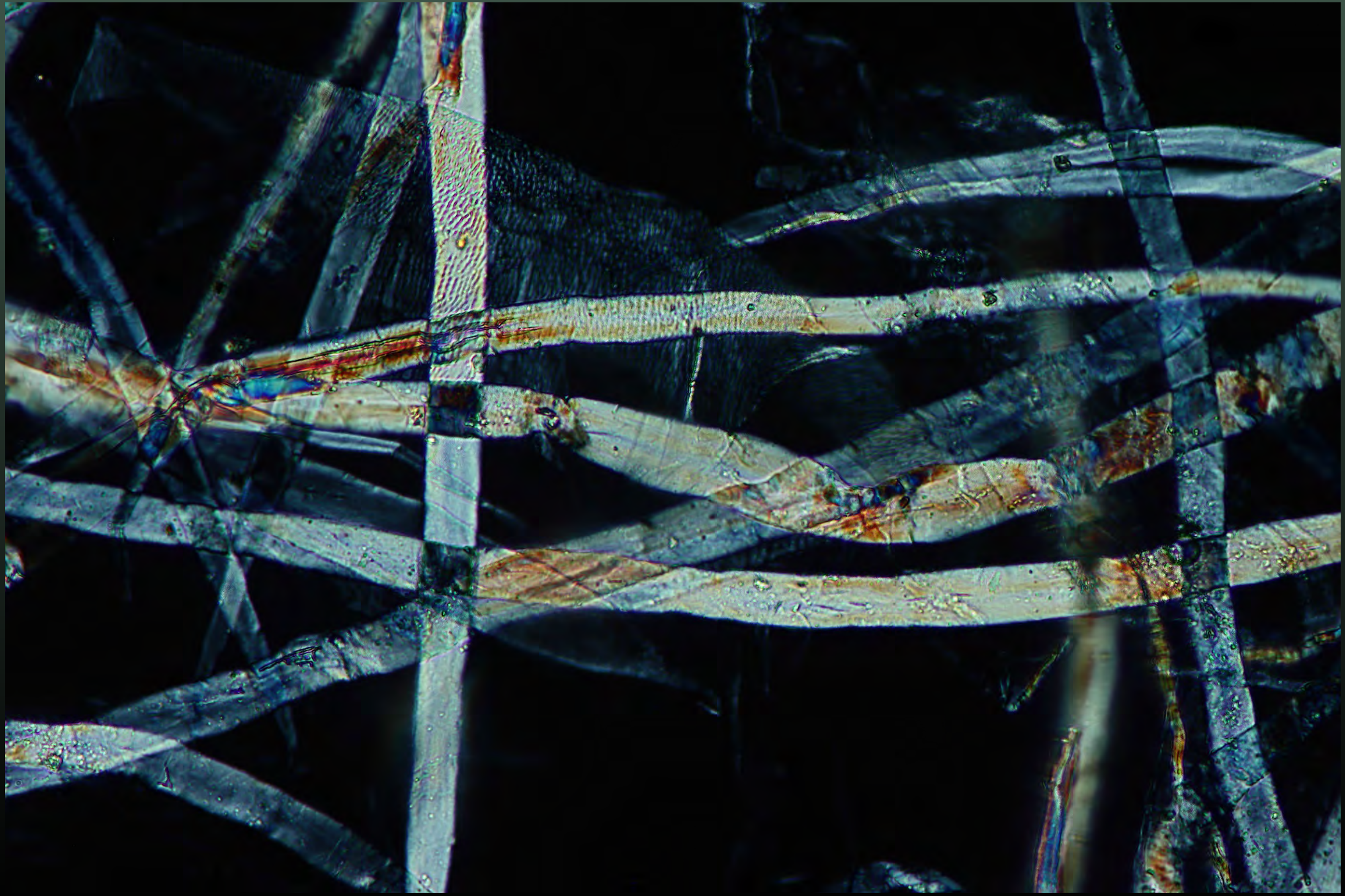
Copy paper (Mix SW/HW, paper disintegrated on slide)

Brightfield Illumination

SPlan 10x 0.30 NA

MJB

Copy paper (Mix SW/HW, paper disintegrated on slide)

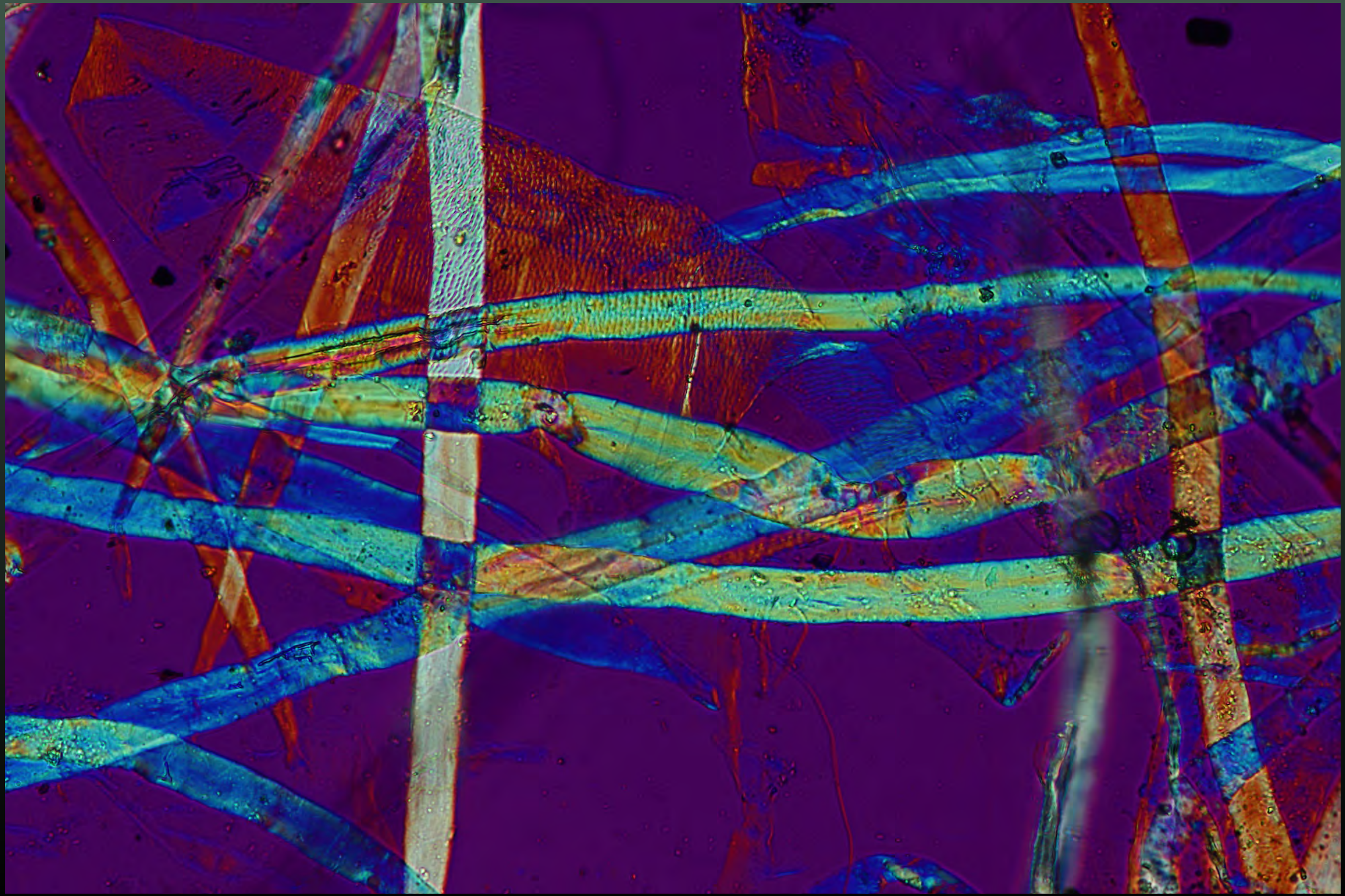


Crossed Polars Illumination

SPlan 10x 0.30 NA

MJB

Copy paper (Mix SW/HW, paper disintegrated on slide)

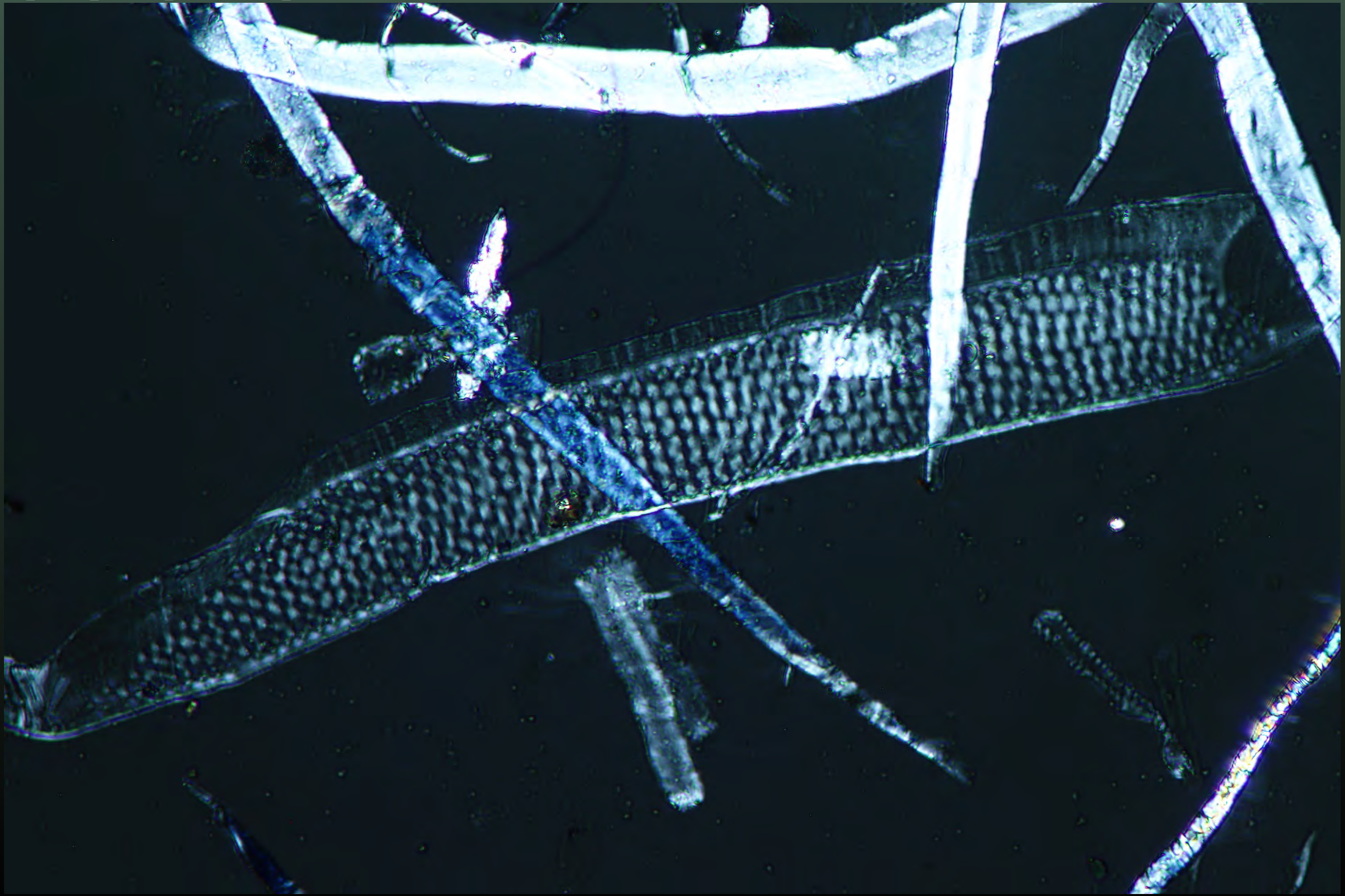


Crossed Polars Illumination
Full λ wave-plate

SPlan 10x 0.30 NA

MJB

Copy paper (Mix SW/HW, part of a HW vessel)

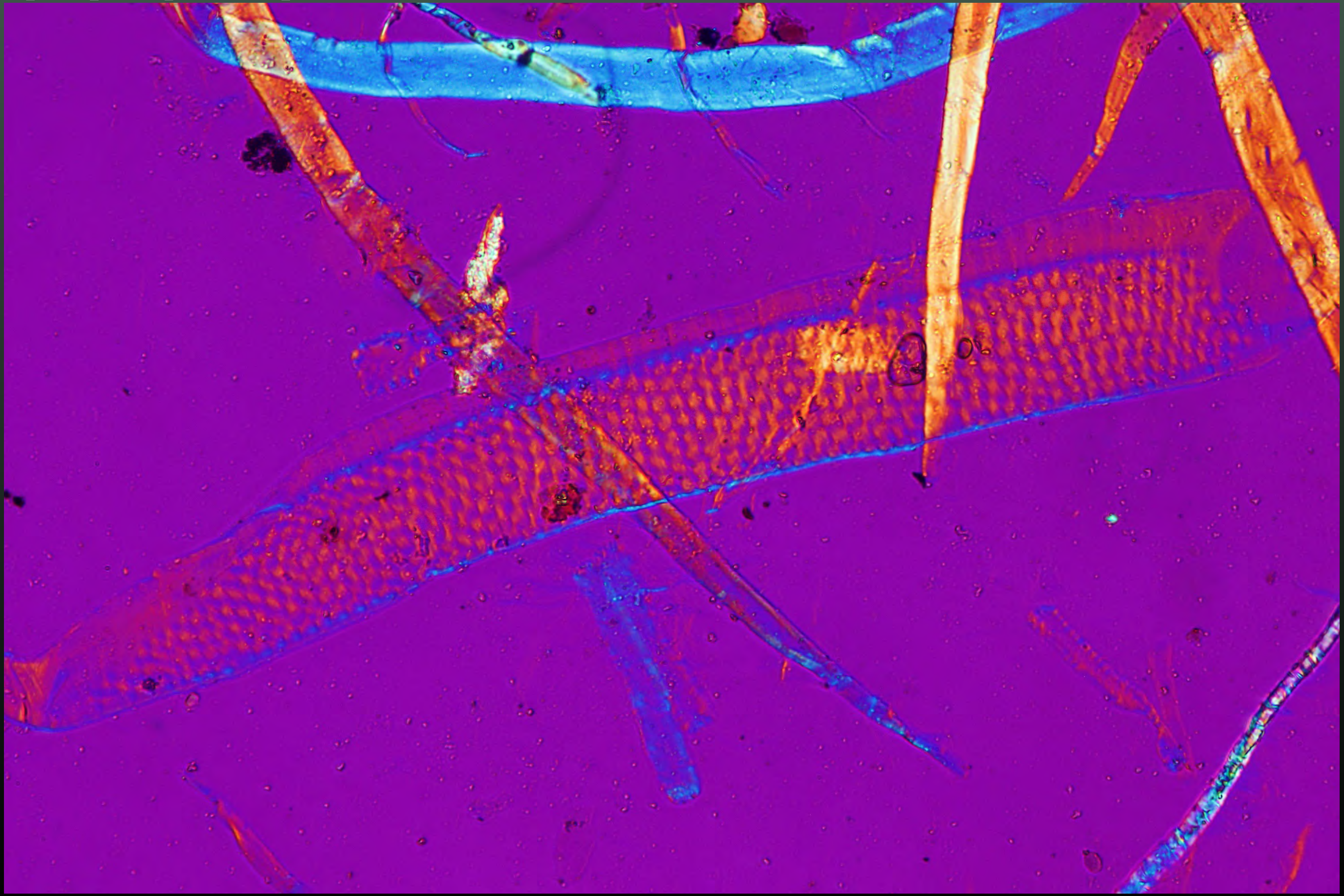


Crossed Polars Illumination

SPlan 20x 0.46 NA

MJB

Copy paper (Mix SW/HW, part of a HW vessel)



Crossed Polars
Illumination
Full λ wave-plate

SPlan 20x 0.46 NA

MJB

Fibre Morphology

Morphology – the science of shape

Fibre Morphology

- Fibre length, cross section area and degree of fibre curl are some of the important properties that determine suitability for different paper types. They vary a lot between species and even within a tree ring.

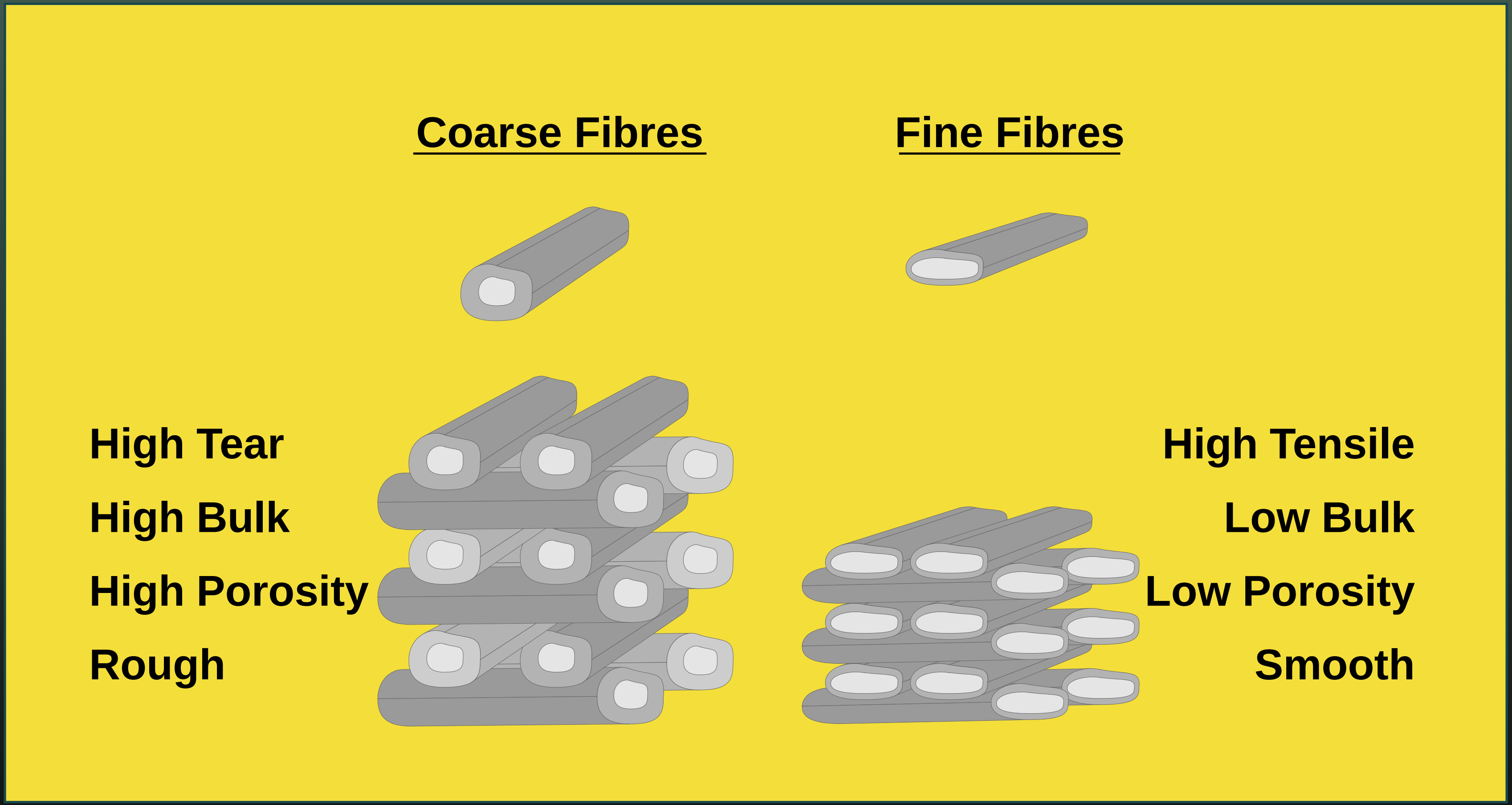
- We saw earlier that tracheids, fibres and vessels are hollow tubes. Whether or not these tubes collapse during the papermaking process turns out to a very important characteristics of a fibre.

Fibre Coarseness

- Describes the weight of a constant length of fibre (100 metres)
- Fibre wall thickness and diameter make the difference

- Fibres are described as “Fine” when the number is low or “Coarse” when it is high.
- BC coniferous forests provide one of the widest range, world wide.

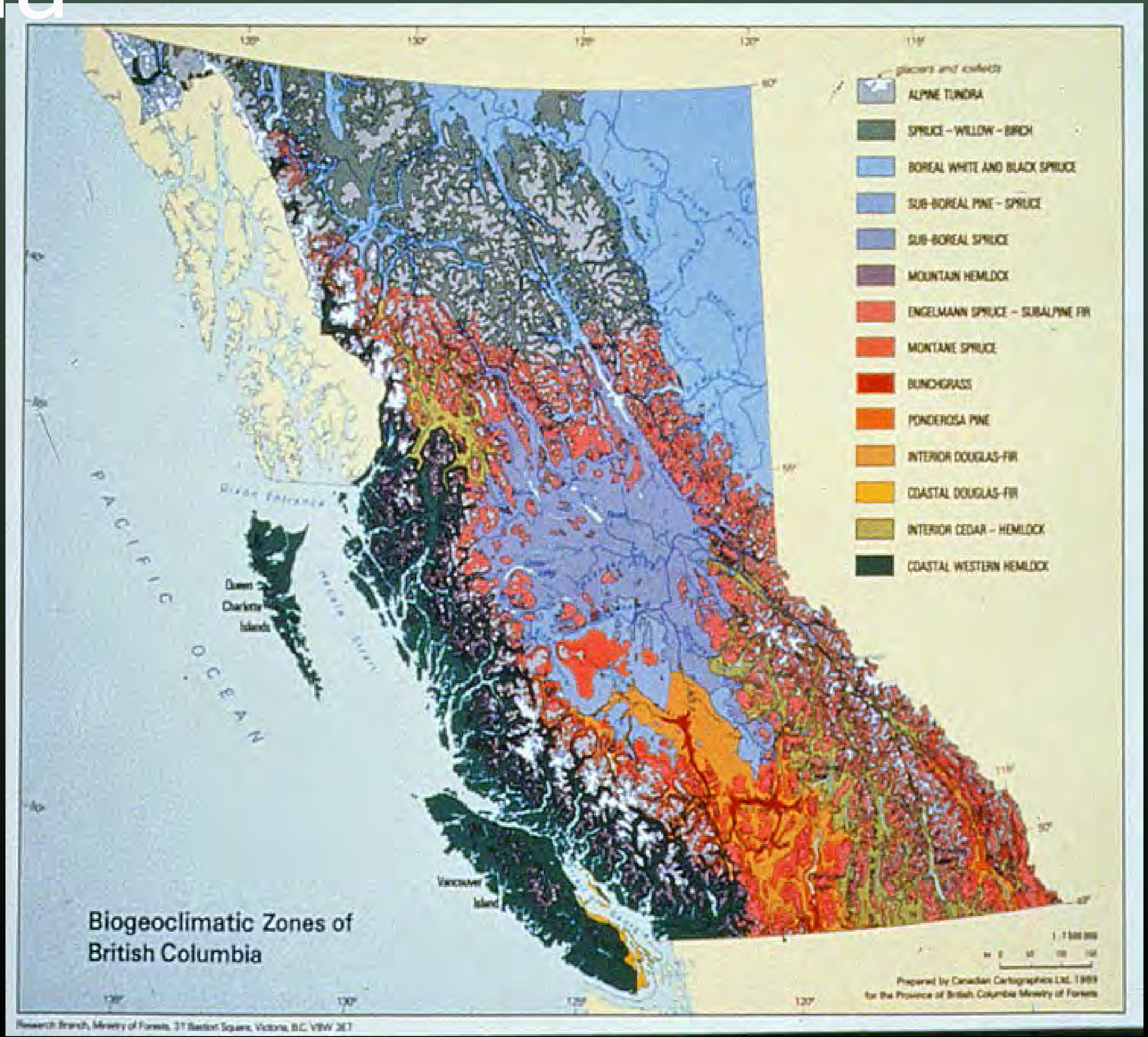
Fibre Coarseness



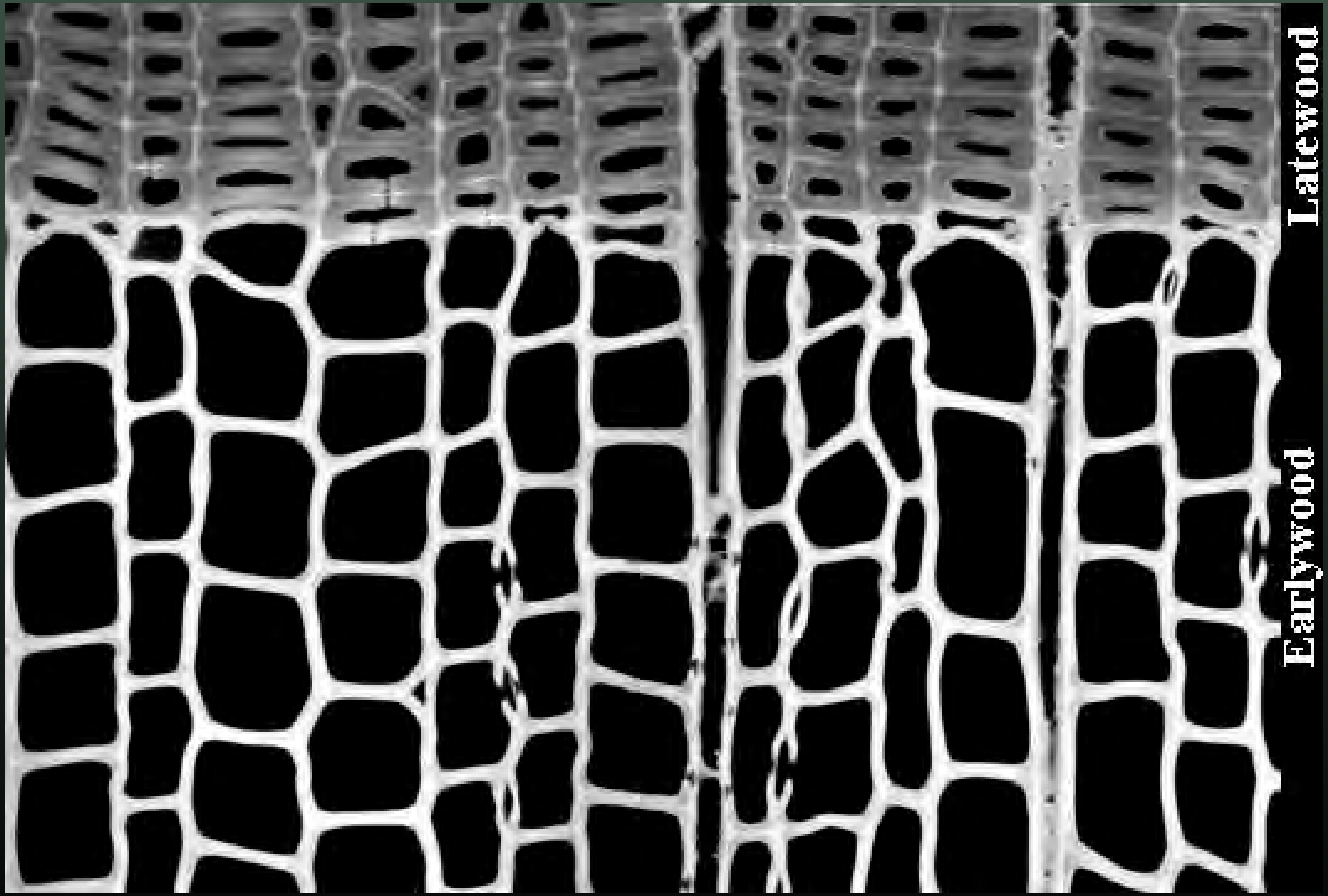
i.e. Douglas fir

i.e. Western Red Cedar

Biogeoclimatic Zones of British Columbia



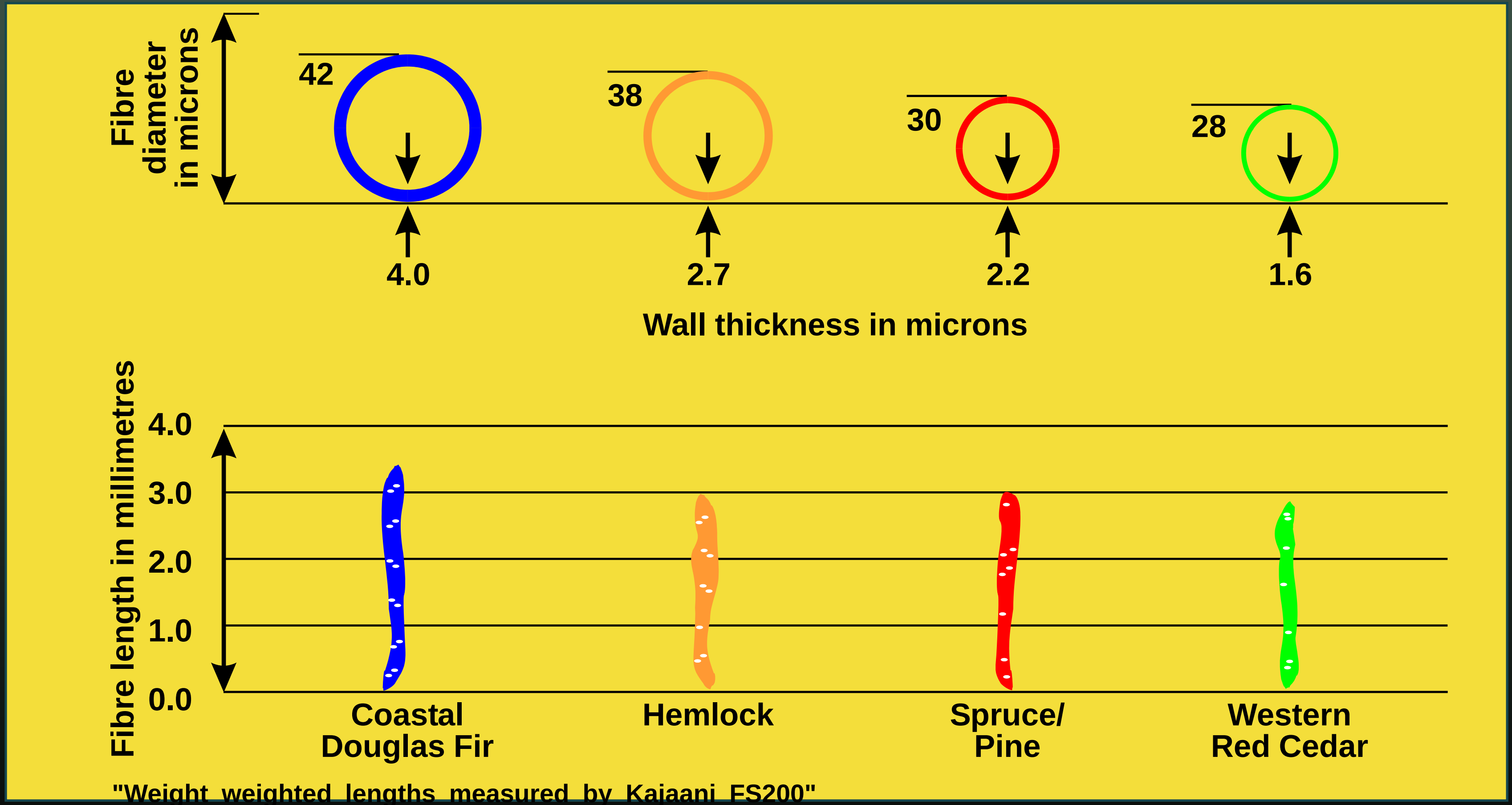
Cross section of one annual ring



Tracheids
(not sure, but S or P or F)

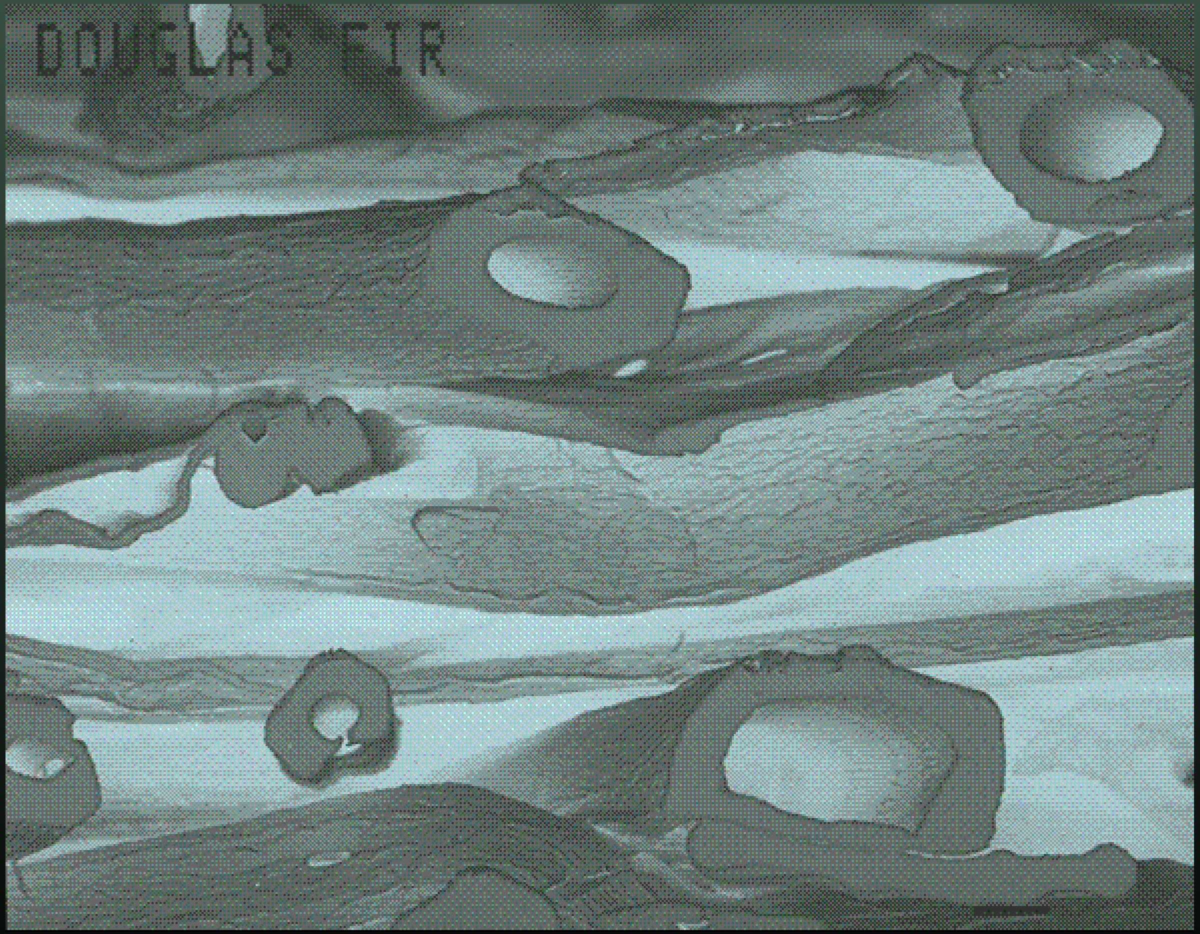
SEM Images: *FPInnovations*

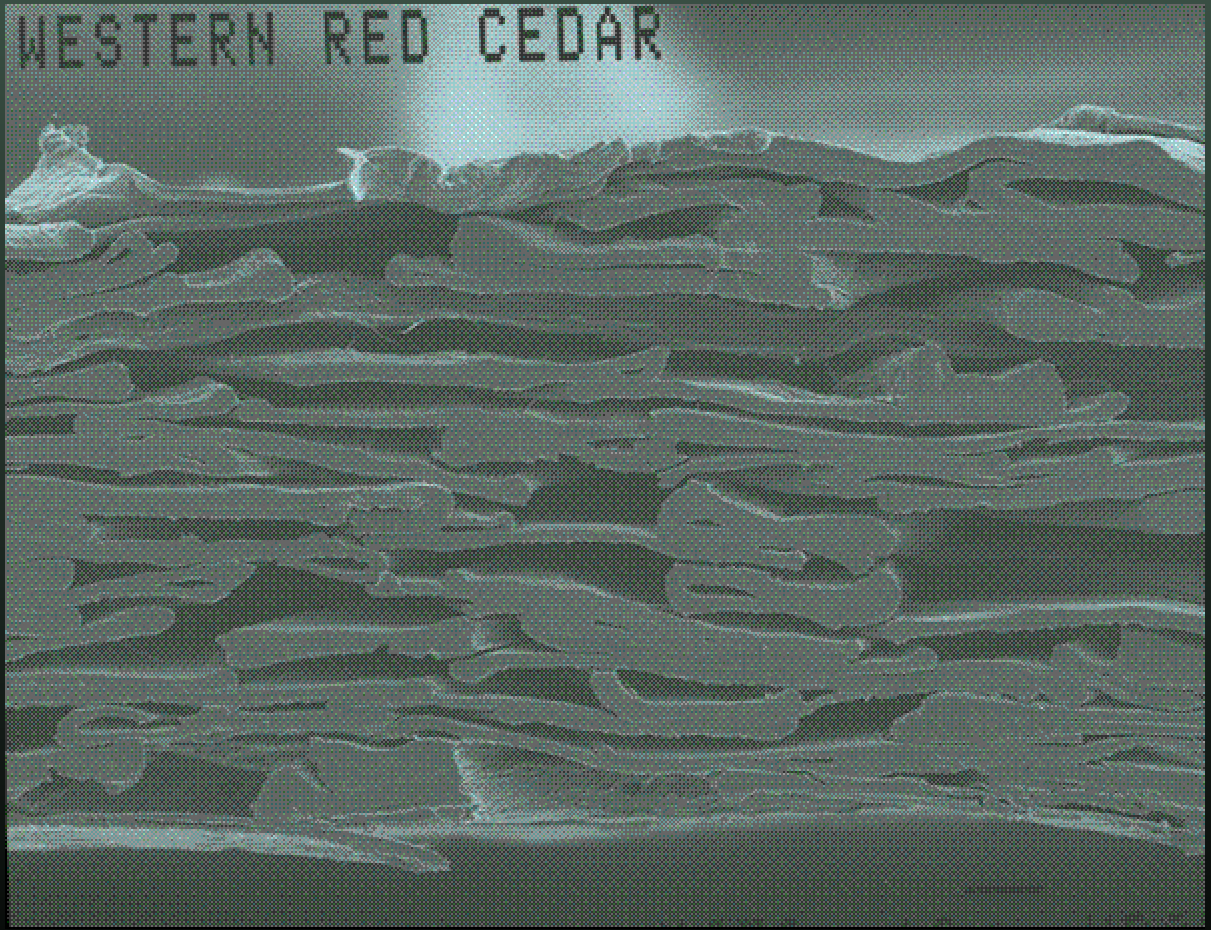
Average Fibre Dimensions



The BC Forest native species possess a very diverse range of morphological properties of value to papermakers.

Handsheet (60 gsm)

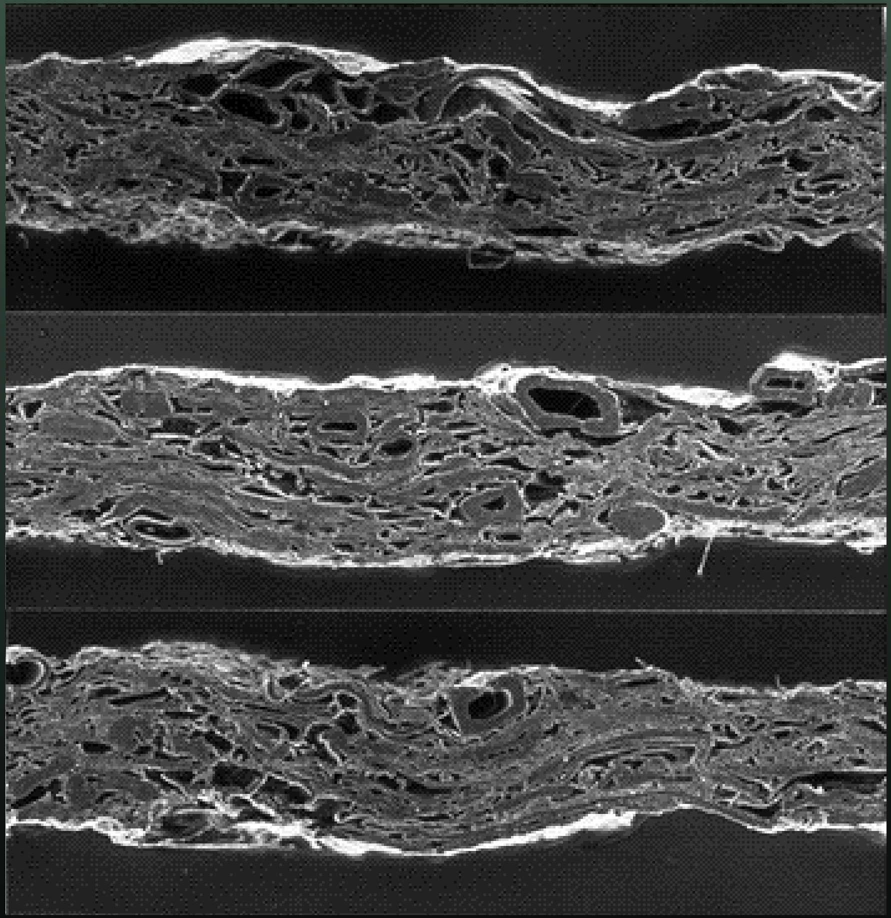




BRD 78 44

SEM Images: *FPInnovations*

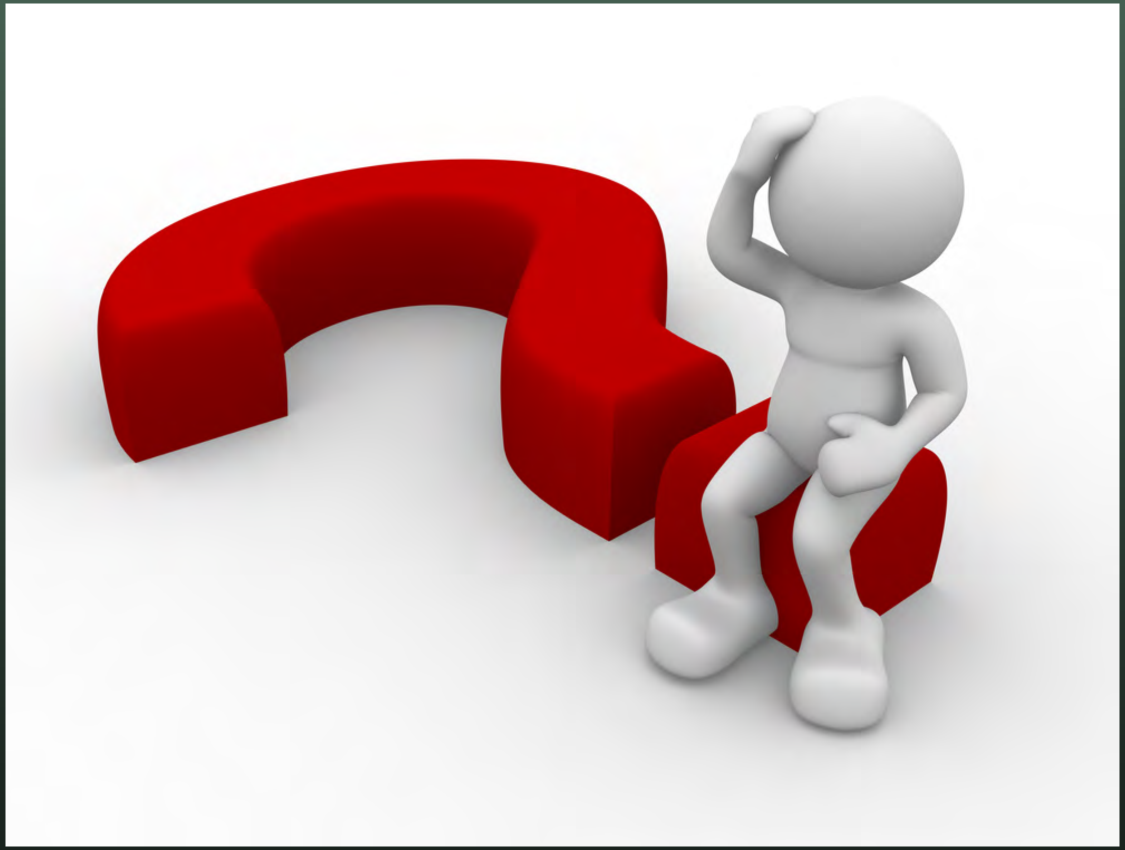
SC Paper (Uncalendered)



BRD 78 48

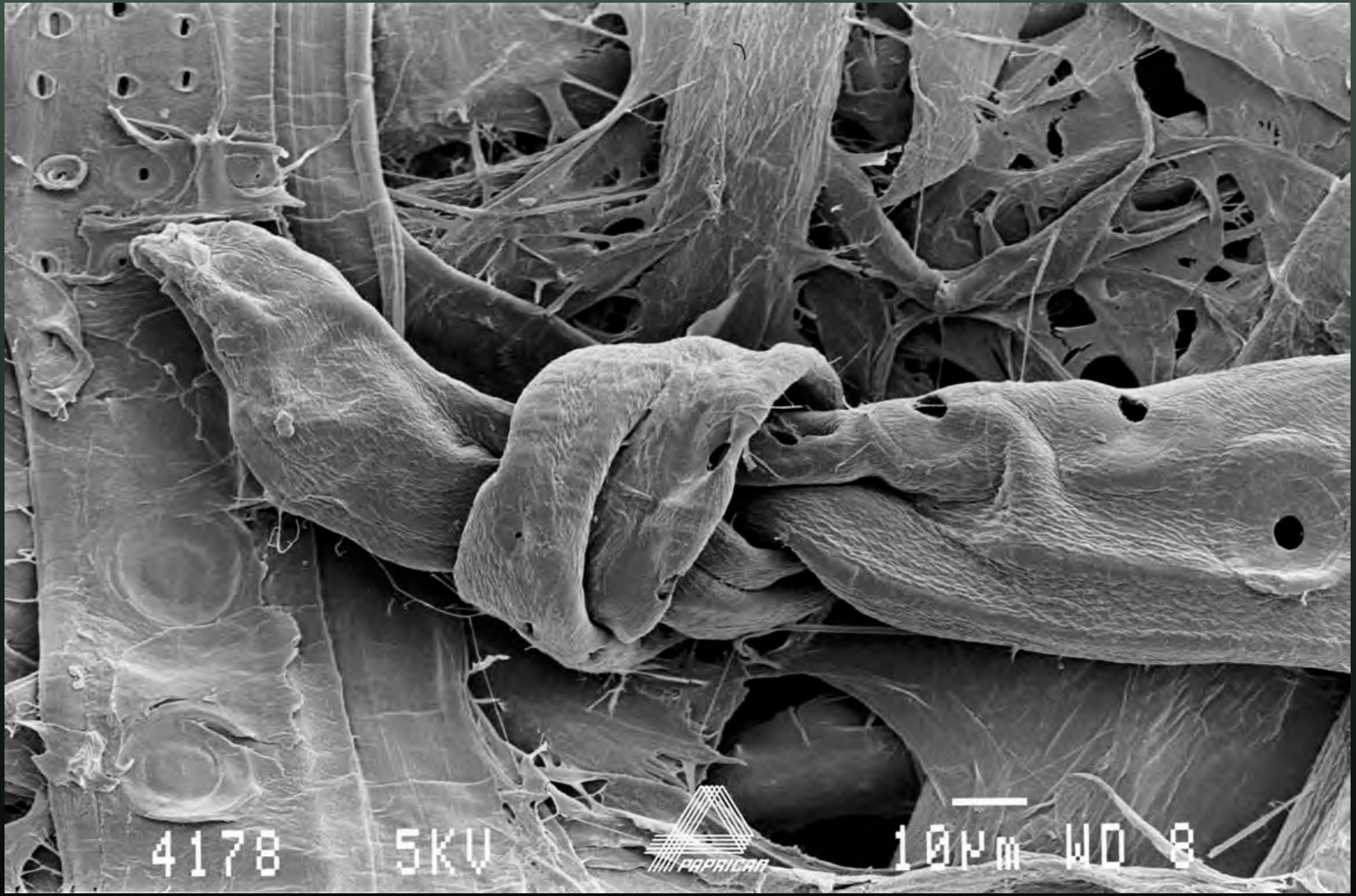
Facial Tissue paper

SEM Images: *FPInnovations*



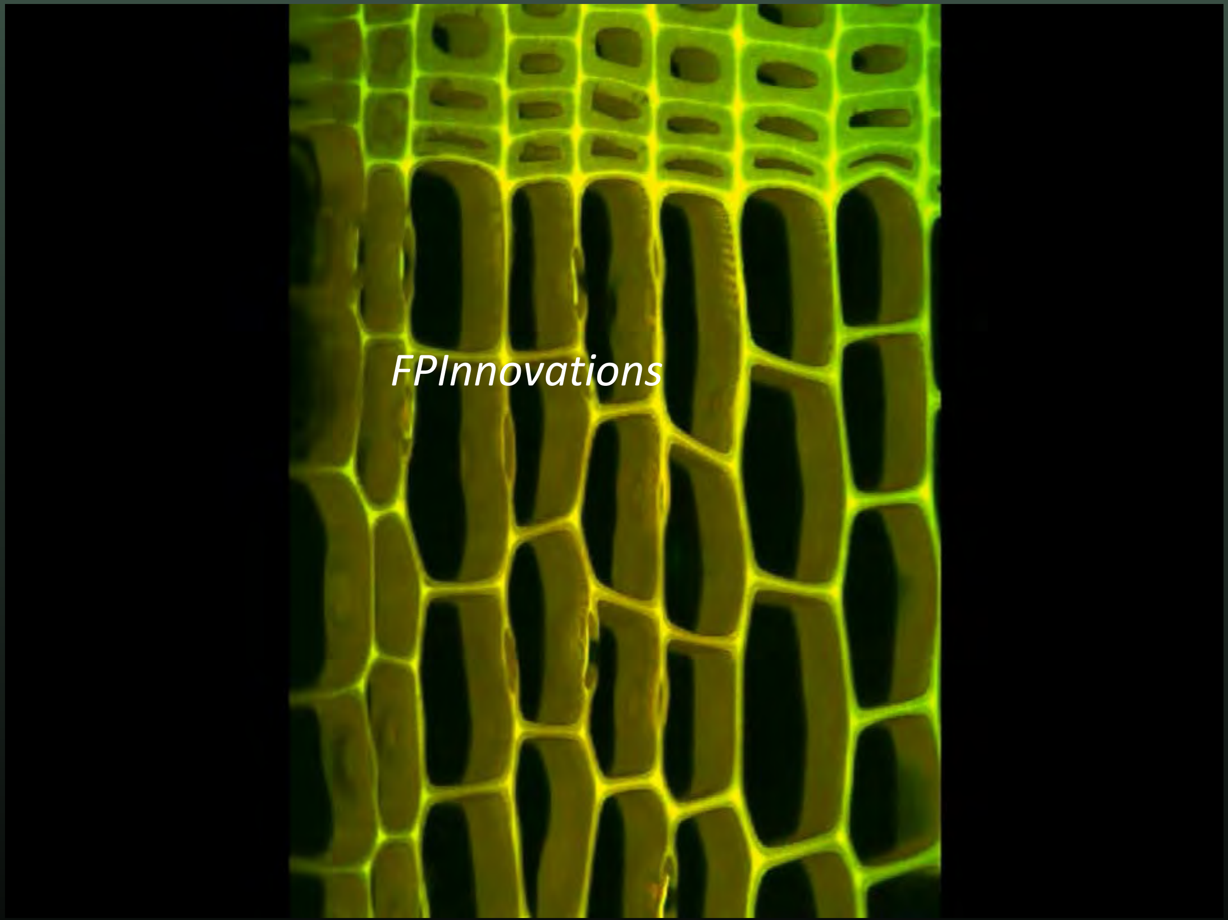
Questions?

Is this how fibre bonding works?



SEM Image: *FPInnovations*

Wood morphology

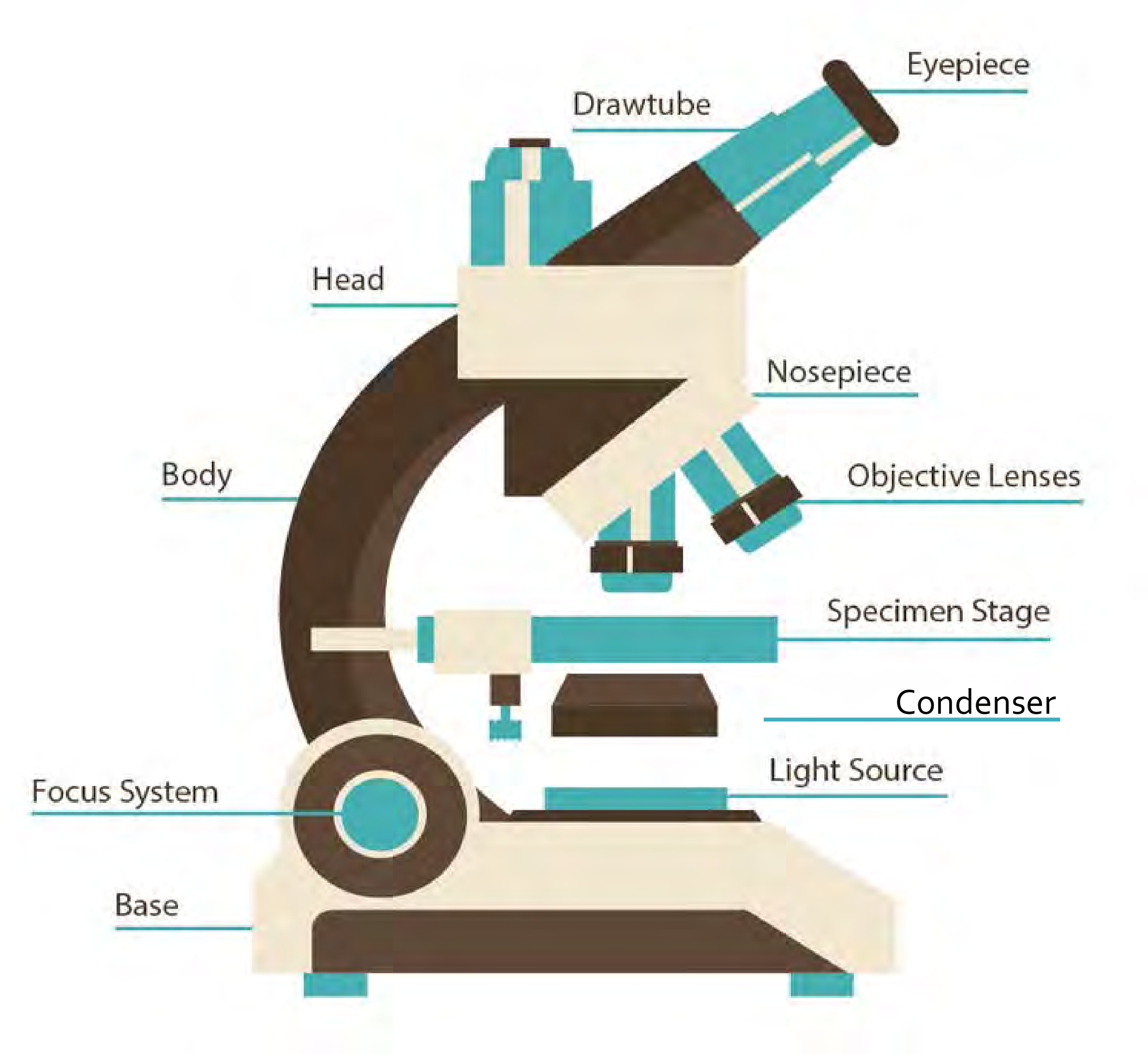


White spruce tracheids
(Picea glauca)

One annual ring

Confocal Image: *FPInnovations*

Compound Microscopes



Available new and used –
great deals on EBAY

Wide range of prices – CN$ 150's - 1000's

Used laboratory instruments are occasionally available from local and online dealers and even "Craigs List".

The only local souce that I'm aware of is Makarian Fine Optics, 1481 Kingsway. They sell new and used instruments.

Useful information sources and links

- Wood Under the Microscope
- https://arboretum.harvard.edu/stories/wood-under-the-microscope/

- Preparation of wood for microscopic examination https://www.wsl.ch/land/products/dendro/preparation.html

- Tree Rings under low power microscope
- http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/libindex.html

- How to prepare wood for microscopy – MicrobeHunter channel, YouTube https://www.youtube.com/watch?v=GrVRX1ZQ4vA

Thank You!