

Hardwood Anatomy

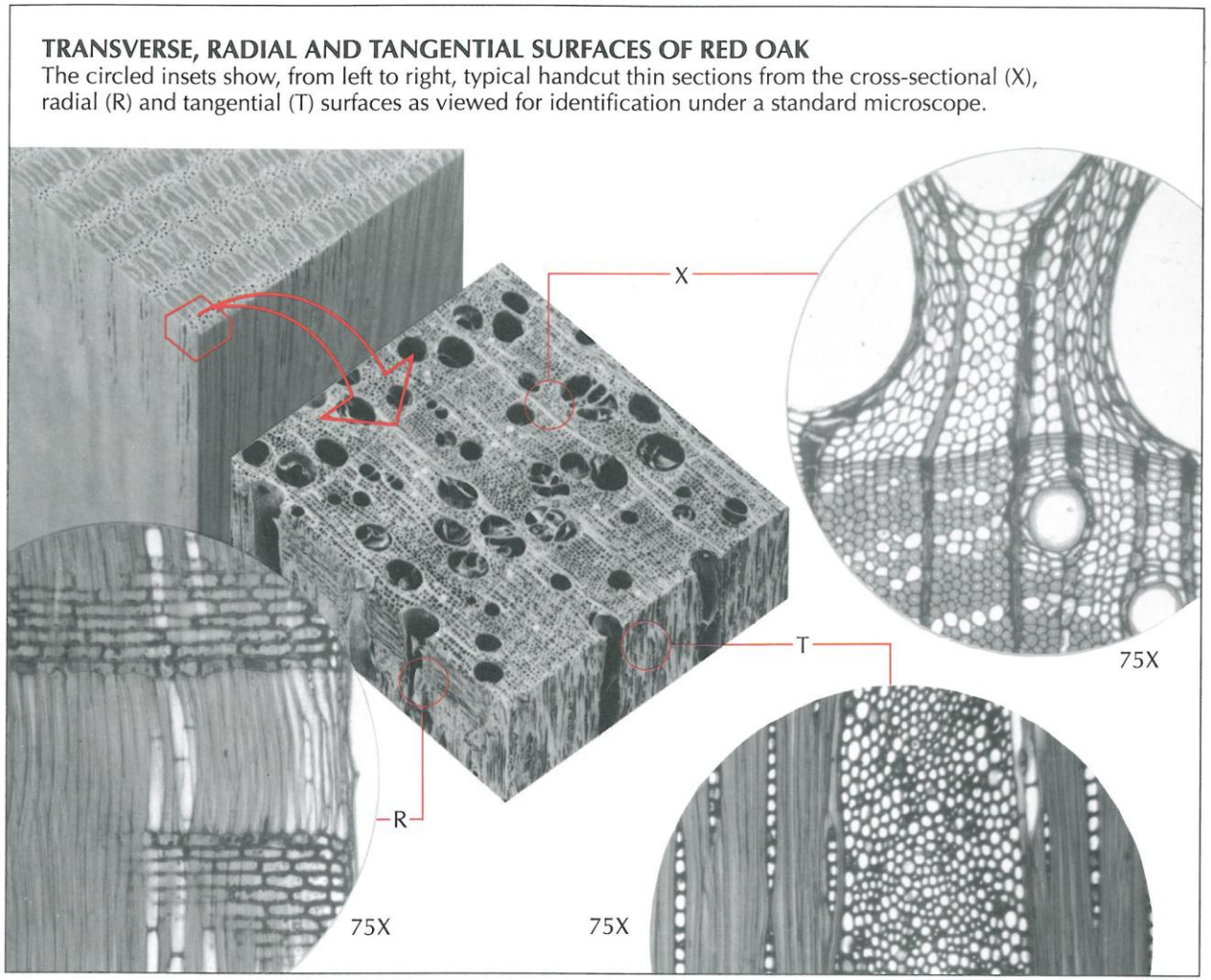
Wood Technology

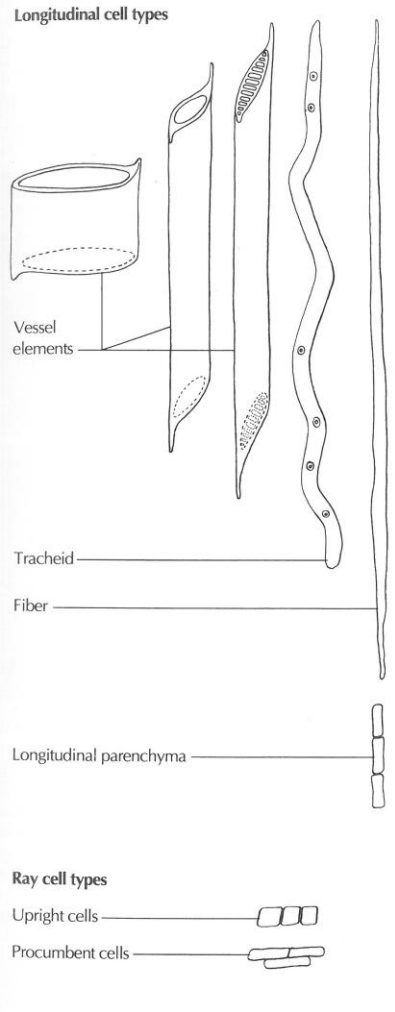
Matthew Schwarzkopf

Hardwood anatomy

- Learning objectives
  - Identify the macro- and microscopic features of hardwood xylem
  - Visually identify and be able to explain the function of the types of cells in hardwoods
  - Recognize the features of hardwoods useful in wood identification

Hardwood structure

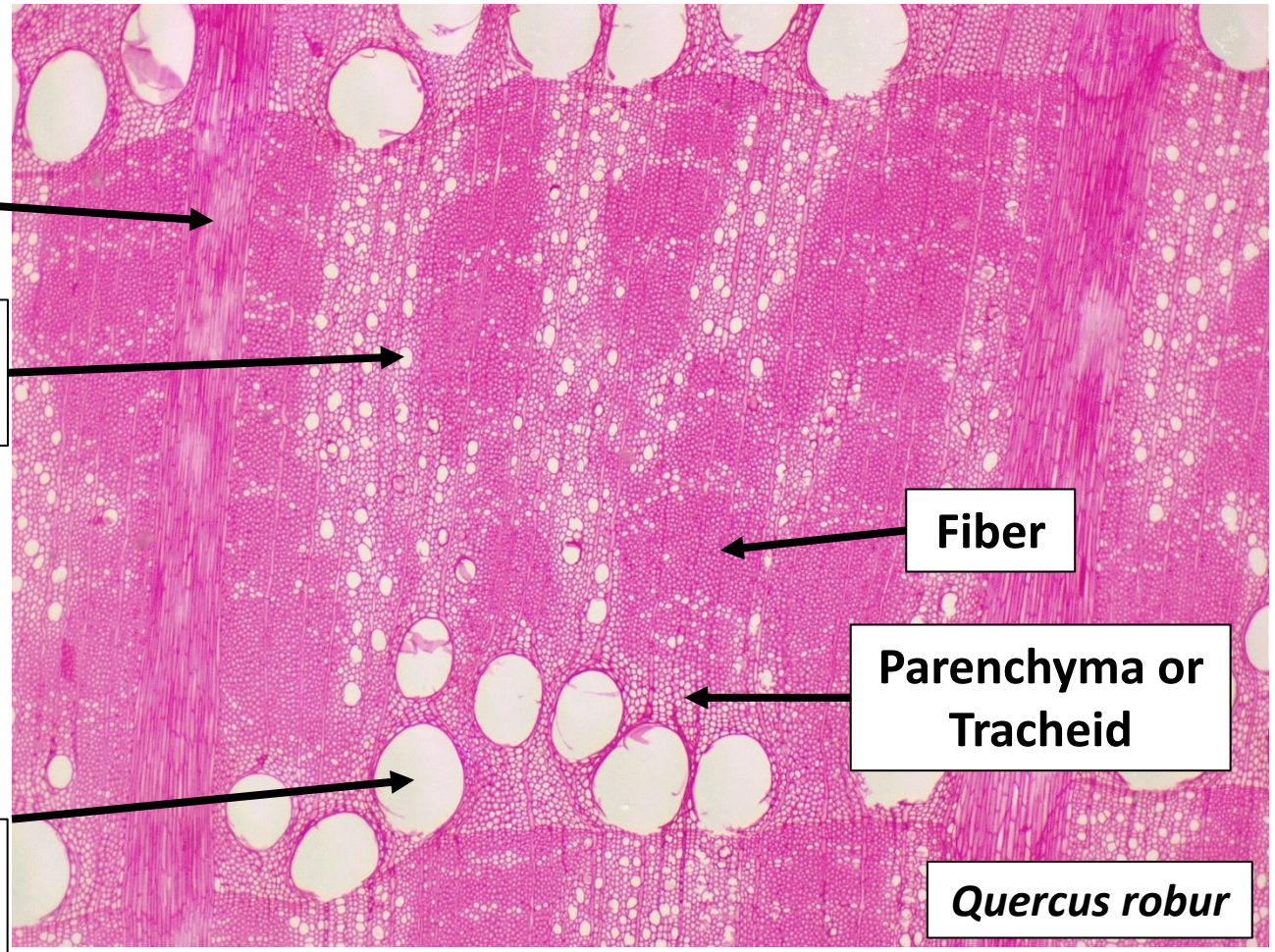




Source: Hoadley

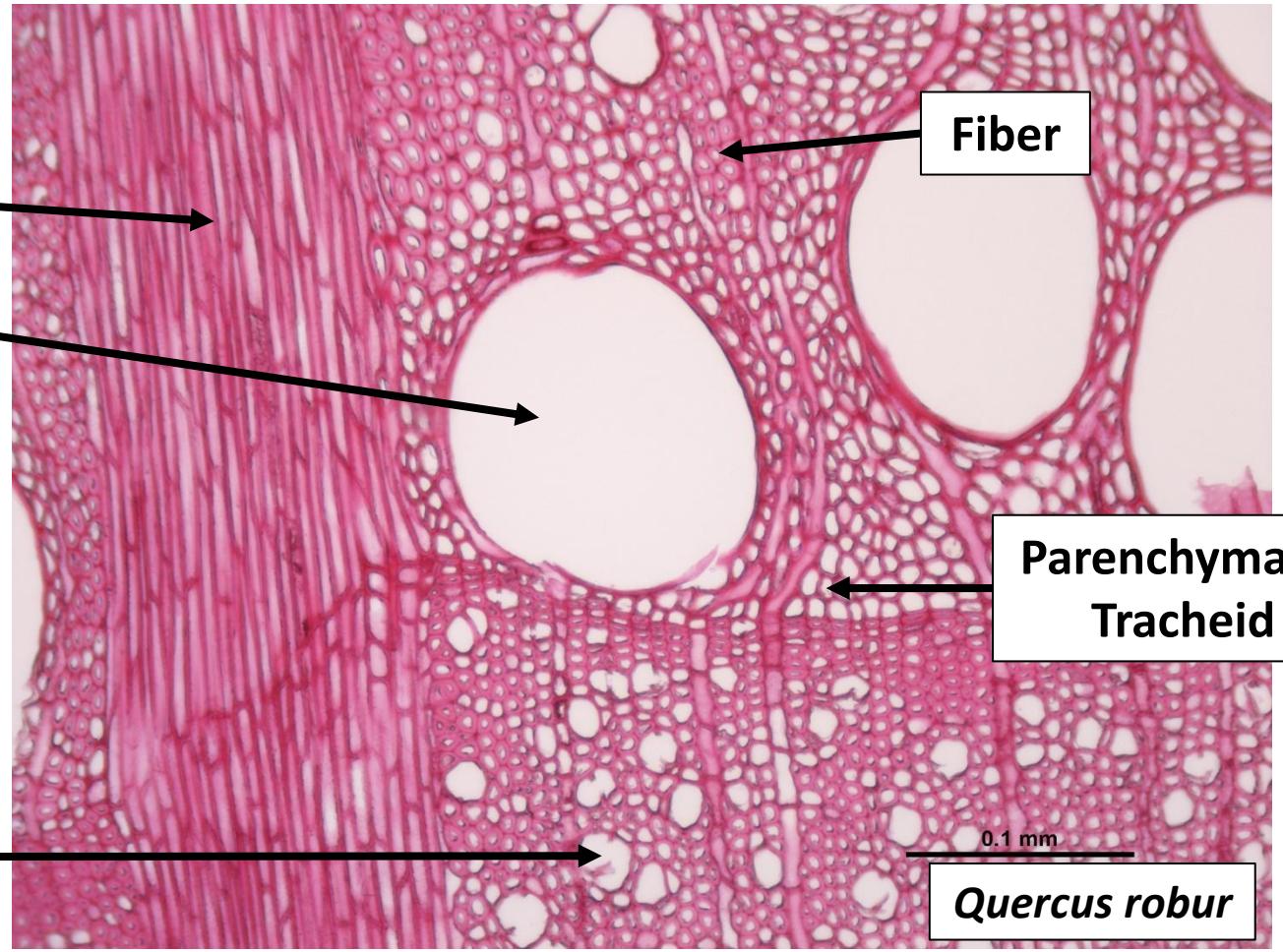
Hardwood cell types - transverse

- Vessels (pores)
- Fibers
- Parenchyma
- Tracheids
  - Less common in hardwoods and hard to differentiate from parenchyma, both thin walled
- Ray cells



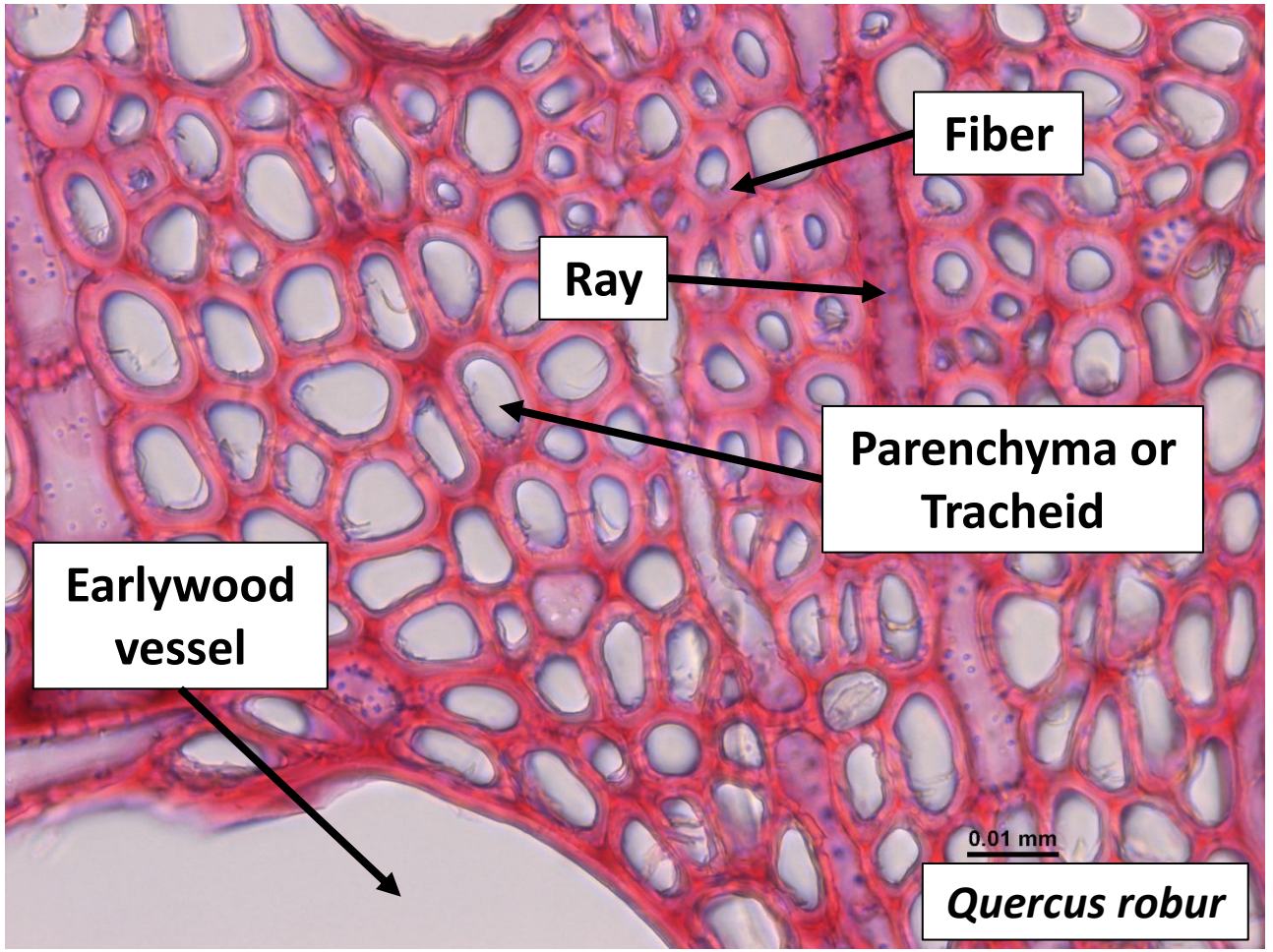
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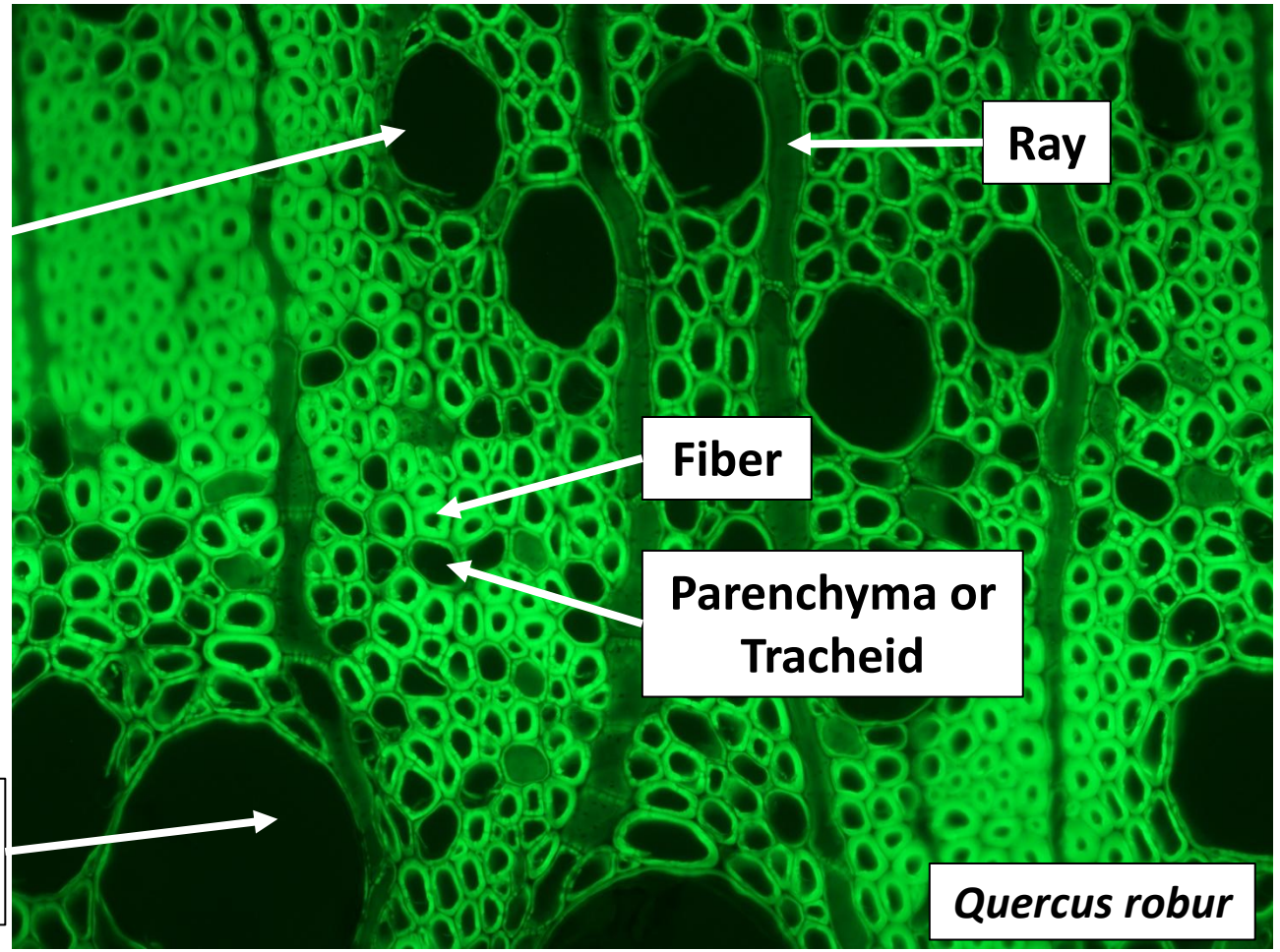
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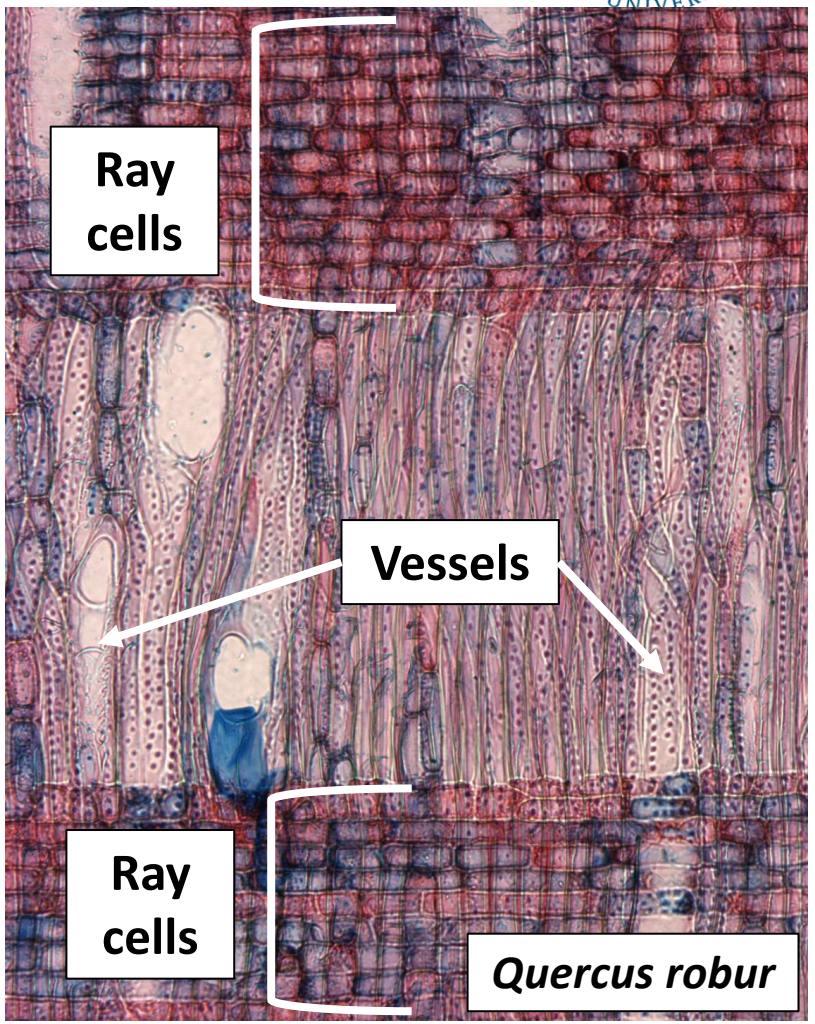
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- Vessels (pores)
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Hardwood cell types - radial

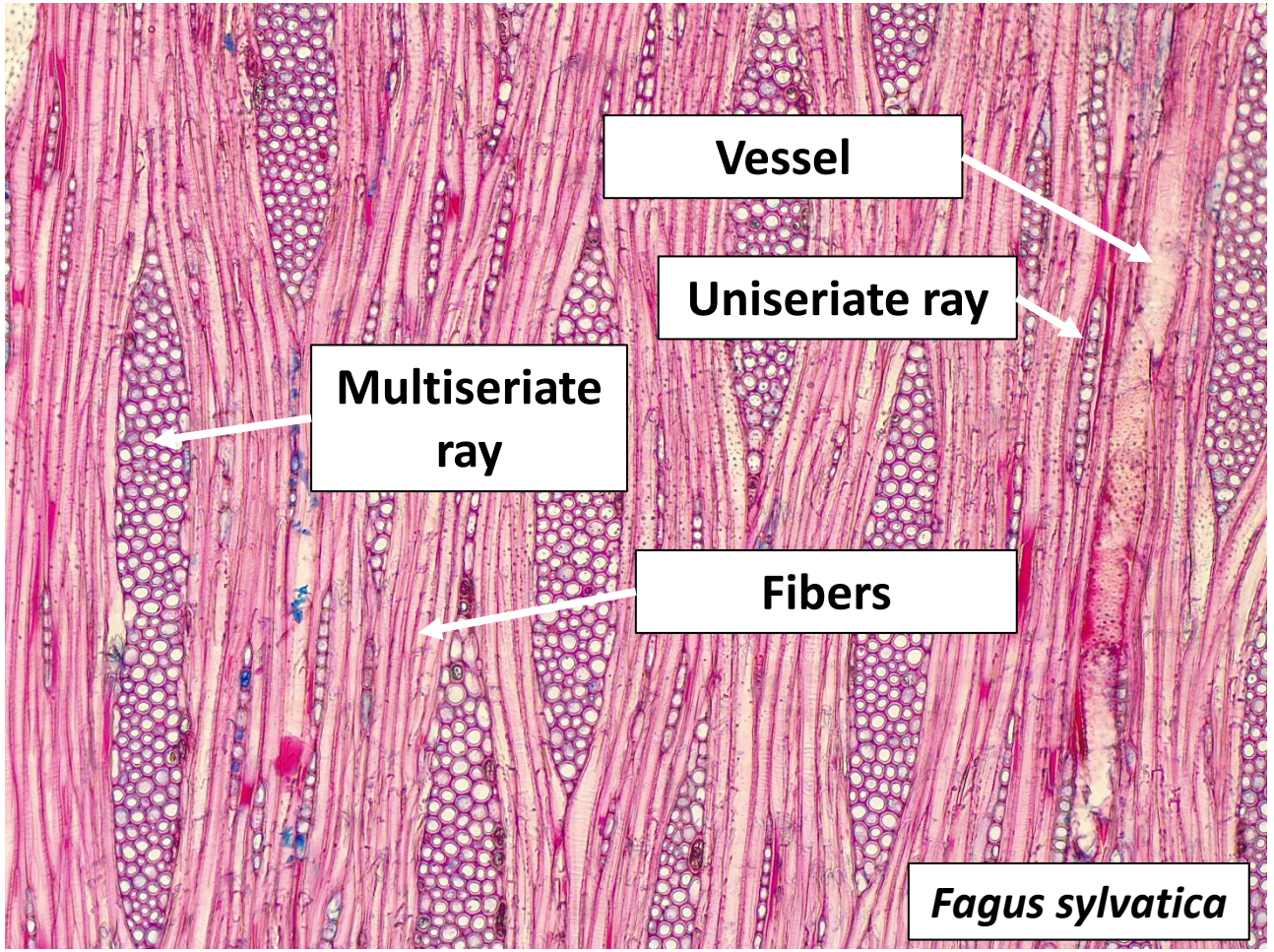
- Vessels (pores)
- Fibers
- Parenchyma
- Tracheids
  - Less common in hardwoods and hard to differentiate from parenchyma, both thin walled
- Ray cells



Source: Inside Wood

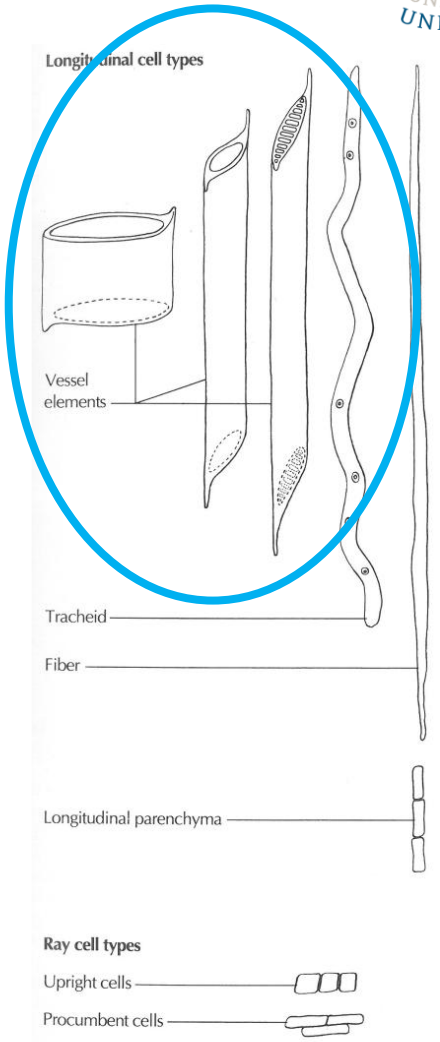
Hardwood cell types - tangential

- Vessels (pores)
- Fibers
- Ray cells
  - Uniseriate – one cell wide
  - Multiseriate – multiple cells wide

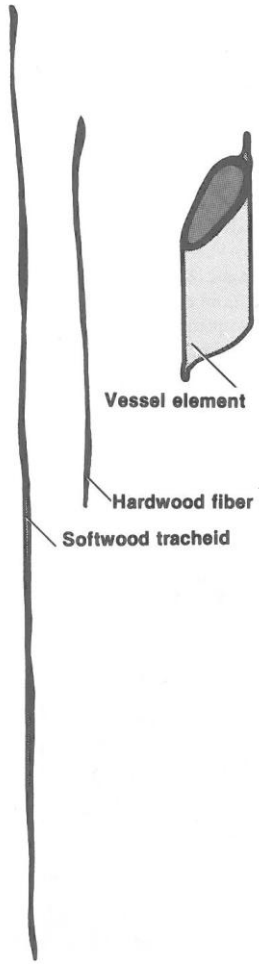


Hardwood cell types - vessels

- Large variation in size
  - Diameter 40 µm to 400 µm
  - Length 0.2 mm to 1.3 mm (for element)
    - Elements joined end to end
- Elements have open ends with perforation plates
- Bordered pits
- Some species form tyloses in vessels when transitioning from sapwood to heartwood
- **Function: conduction, primary pathway for fluid flow**



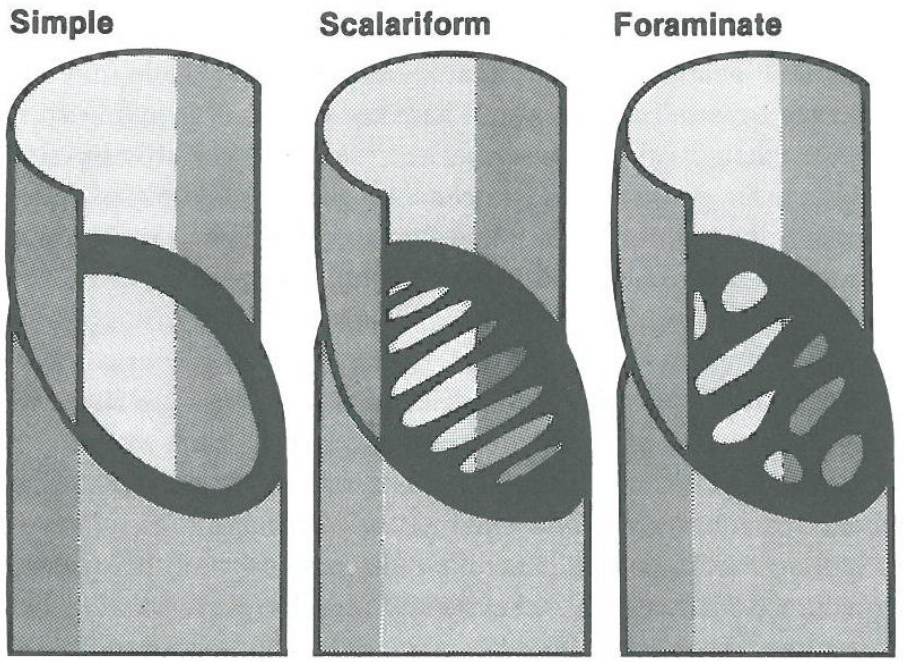
Source: Hoadley



Source: Bowyer

Hardwood cell types - vessels

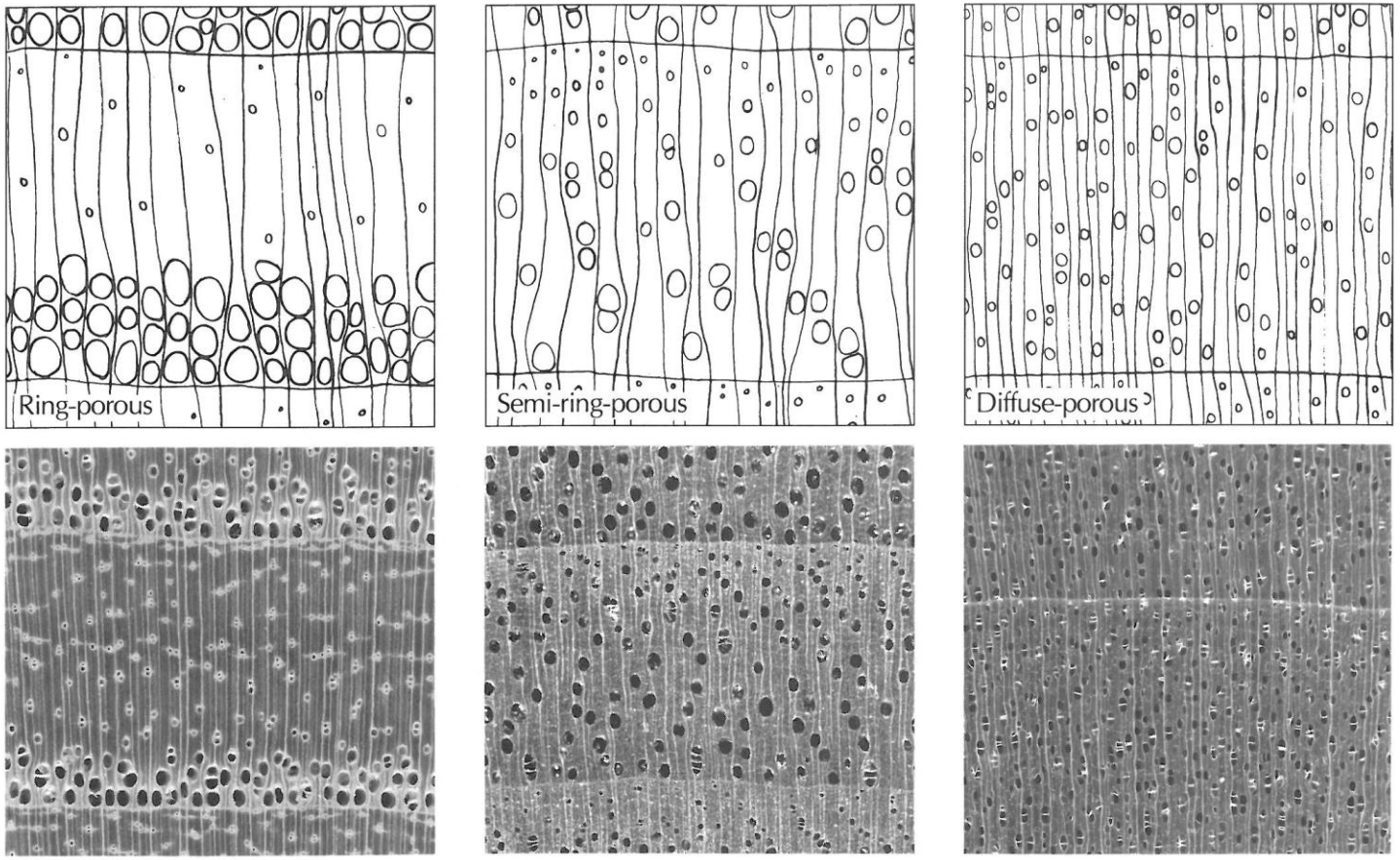
- Types of perforation plates
  - Simple
  - Scalariform
  - Foraminate
- Tyloses



Source: Bowyer

Vessel arrangement

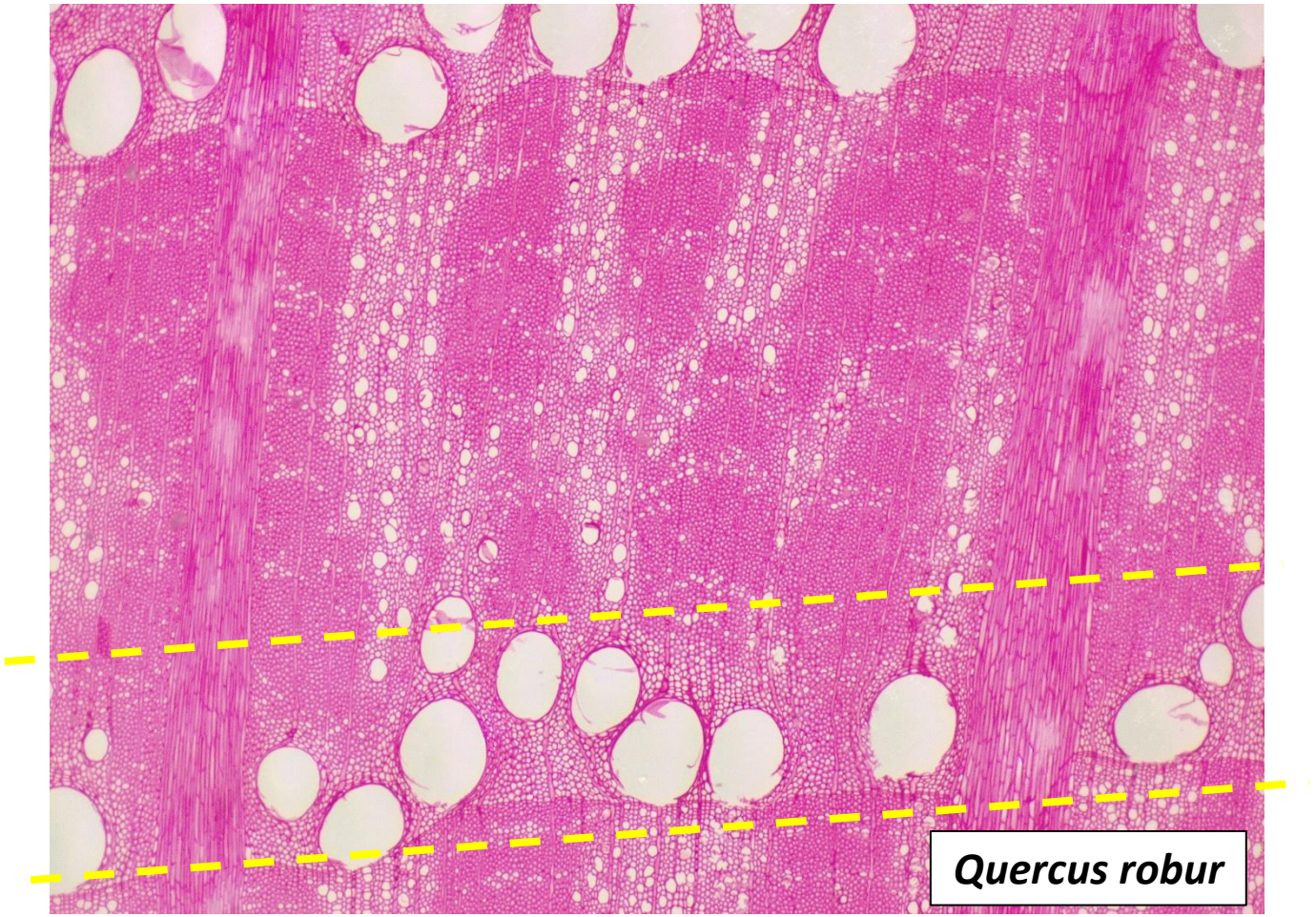
- Ring-porous
  - *Quercus*
  - *Ulmus*
  - *Fraxinus*
- Semi-ring-porous
  - *Juglans*
  - *Diospyros virginiana* (Persimmon)
- Diffuse-porous
  - *Acer*
  - *Fagus*



Source: Hoadley

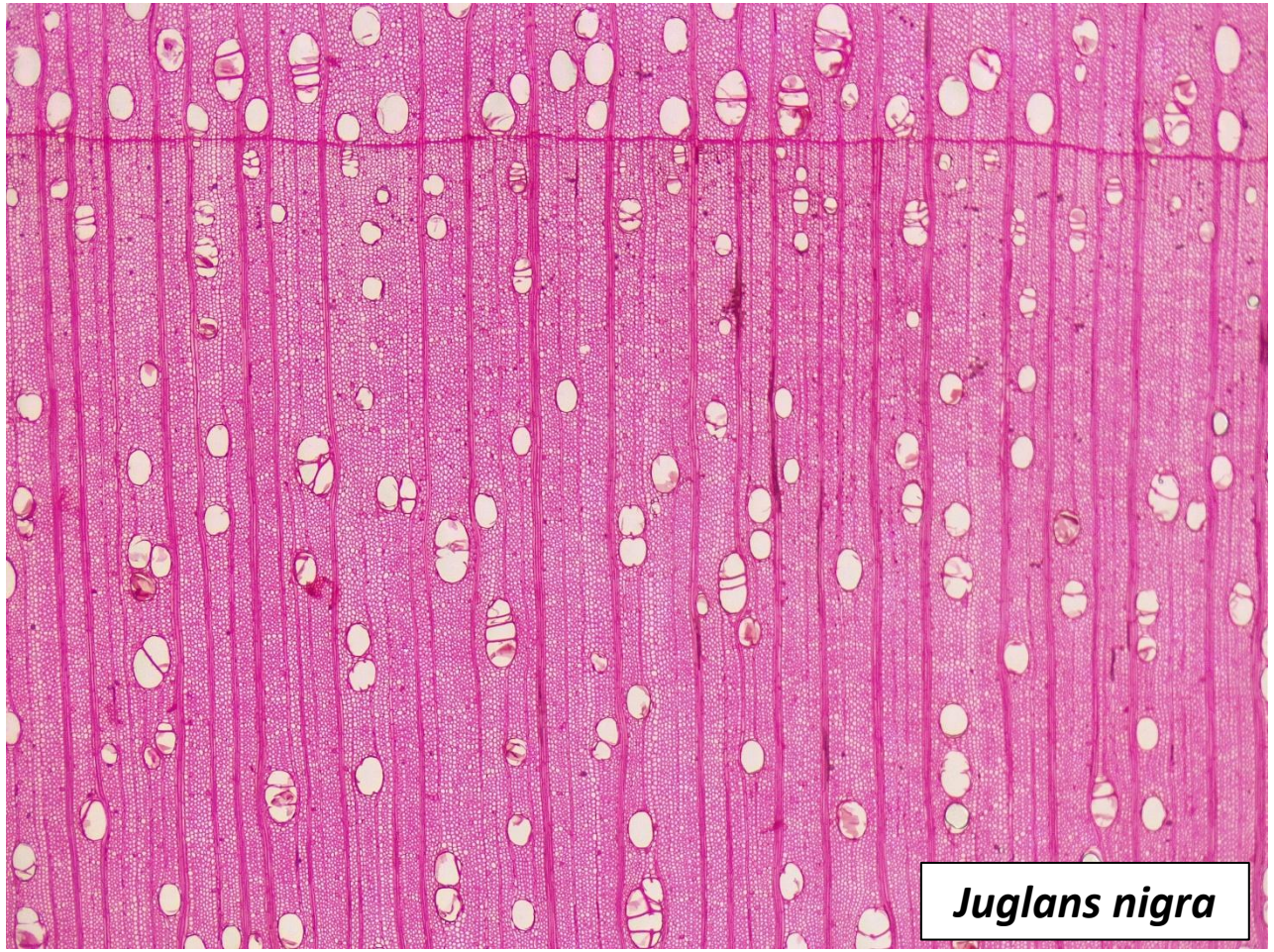
Vessel arrangement

Ring-porous



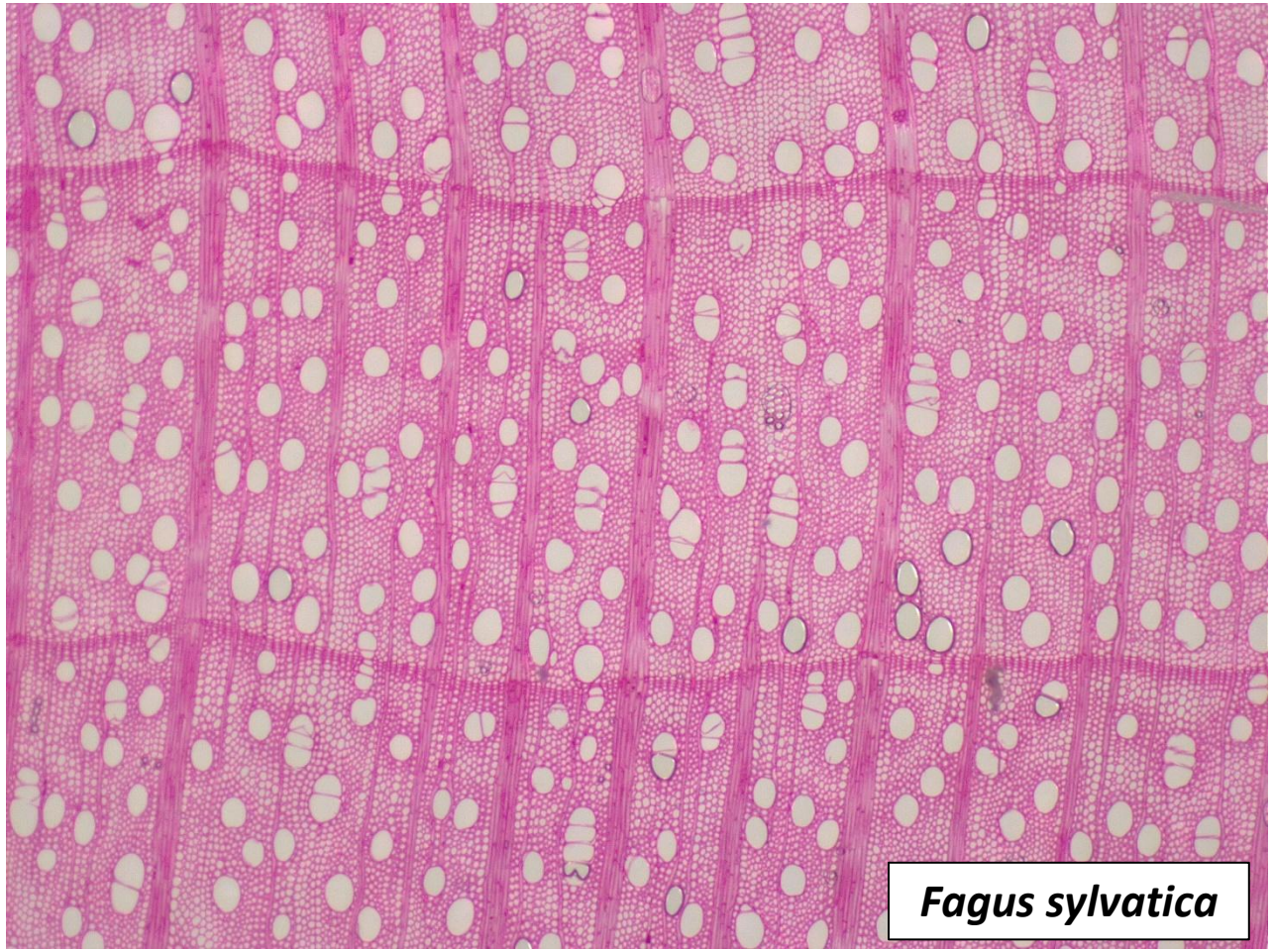
Vessel arrangement

Semi-ring-porous



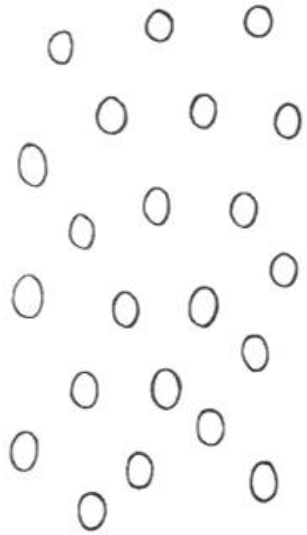
Vessel arrangement

Diffuse-ring-porous



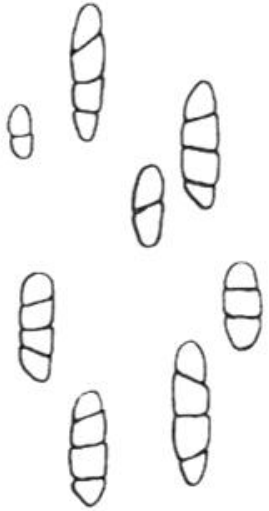
Vessel arrangement

Solitary pores



Acer saccharum

Pore multiples



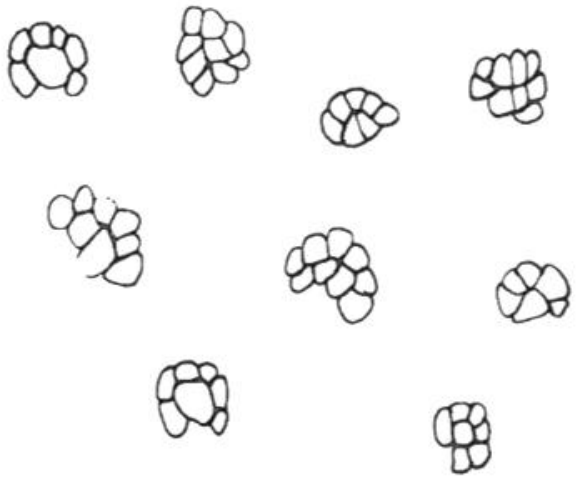
Populus deltoides

Pore chains



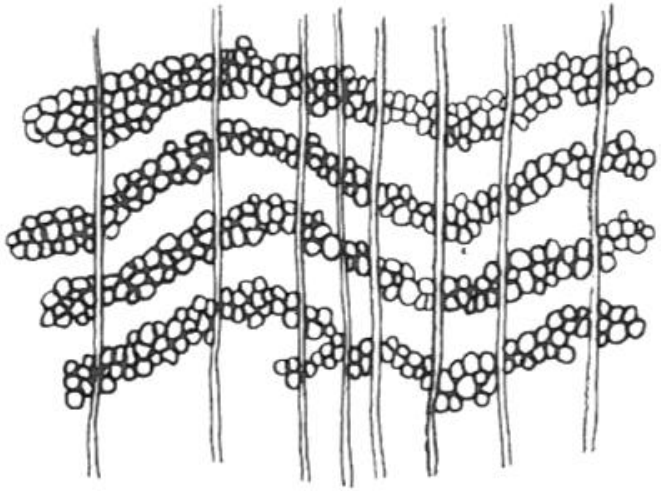
Ilex opaca

Nested pores (clusters)



Gymnocladus dioicus

Wavy bands (ulmiform)

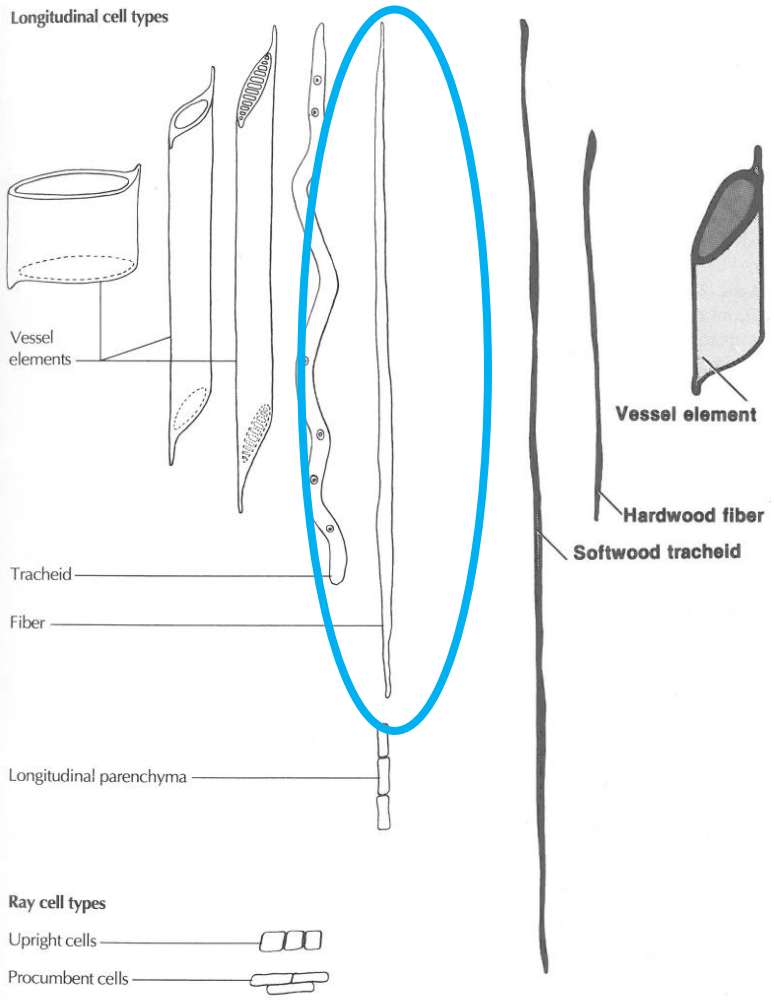


Ulmus americana

Source: Hoadley

Hardwood cell types - fibers

- Small diameter (~30 µm)
- Length 1 mm to 2 mm
- Thickwalled
- Closed, tapered ends
- Two types
  - Fiber tracheids – bordered pits, thick walls, pointy ends
  - Libriform fibers – simple pits
- Make up about 50 % of the wood volume
- Essentially the only cells left after pulping
- **Function: primary structural support for hardwoods**



Source: Hoadley

Source: Bowyer

Hardwood cell types - fibers

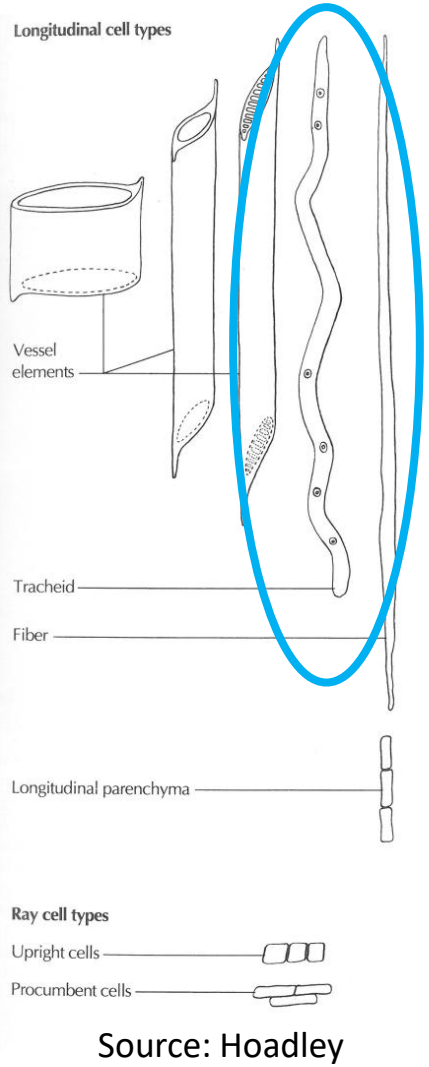
Quercus fibers



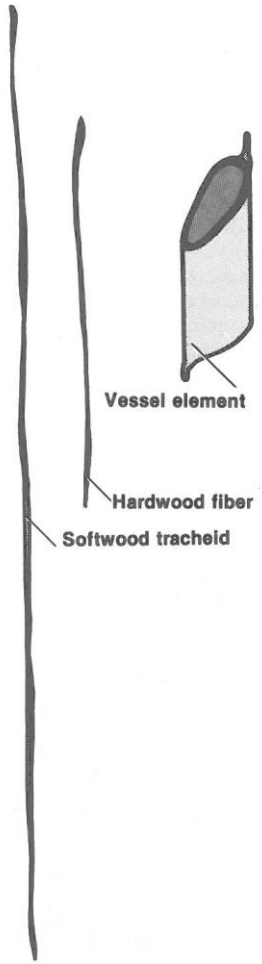
Source: OSU, Mike Milota, WSE 521 lecture

Hardwood cell types - tracheids

- Longitudnal
- Small diameter (~30 µm)
- Length ~1 mm
- Thin walls
- Vascular
  - Similar to small pores
  - Often in latewood
  - Closed at ends
  - Vertically aligned
- Vasicentric
  - Near vessels
  - Tapered, closed ends
- **Function: support of tree and conduction of fluids**



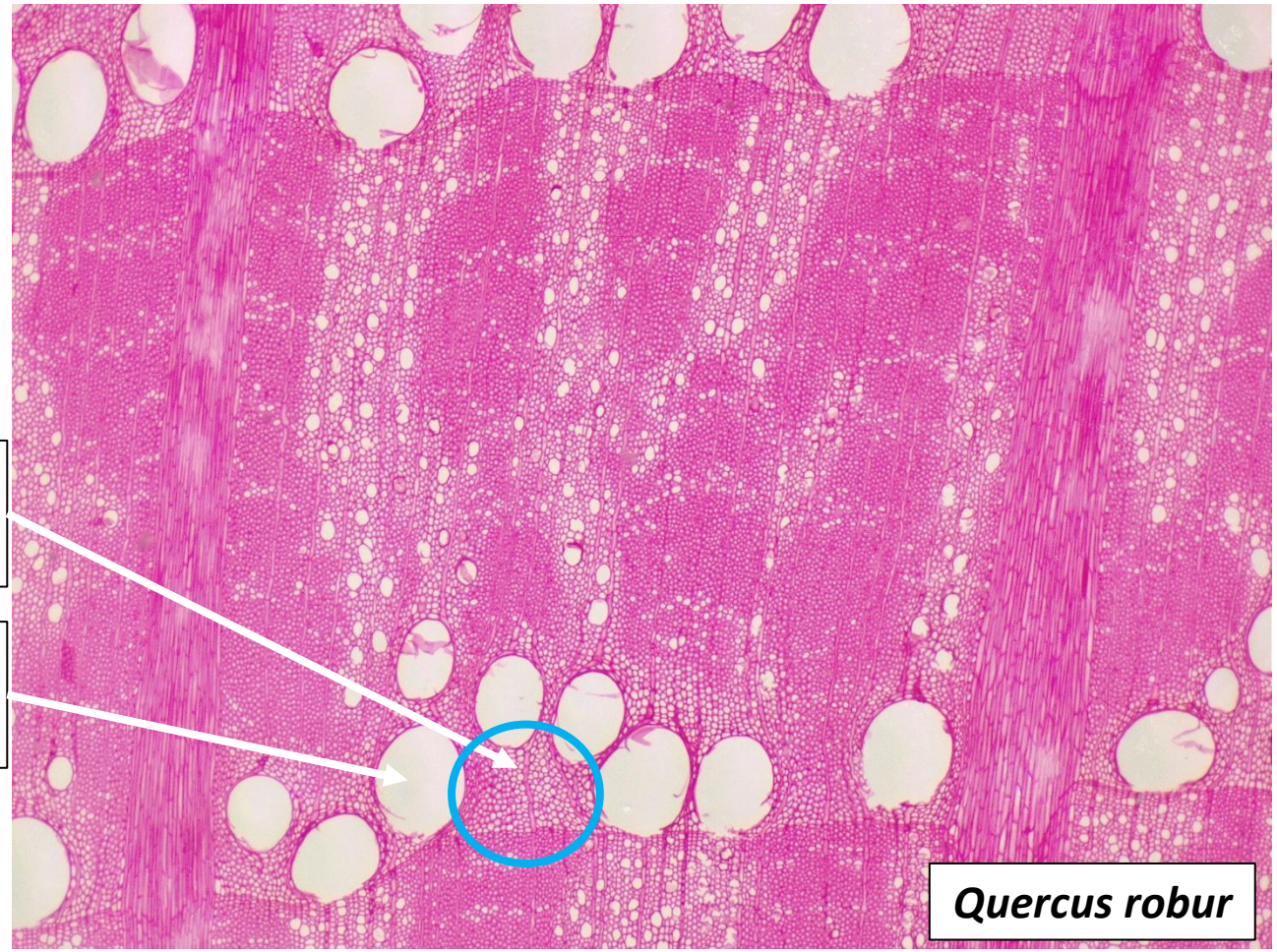
Source: Hoadley



Source: Bowyer

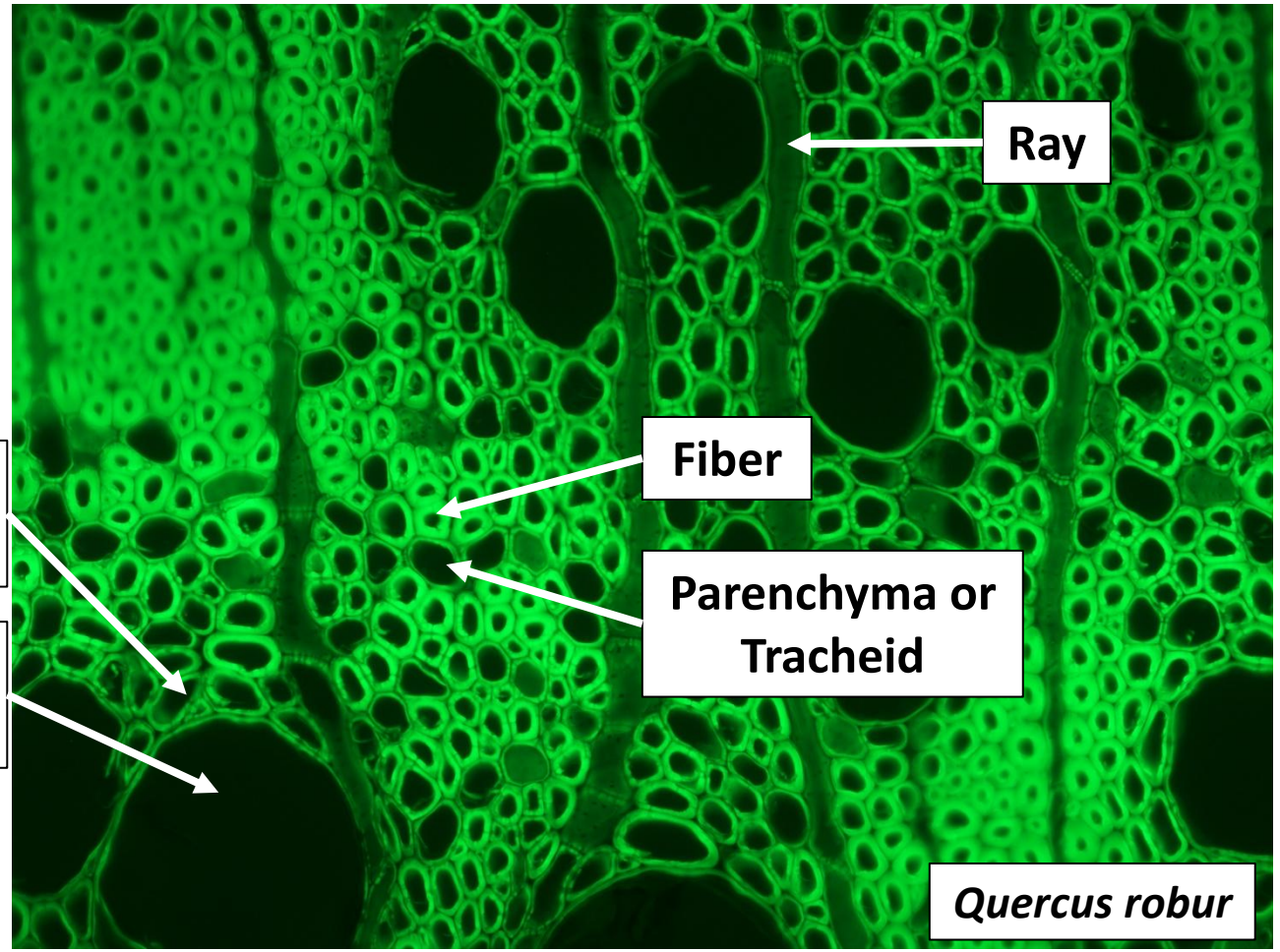
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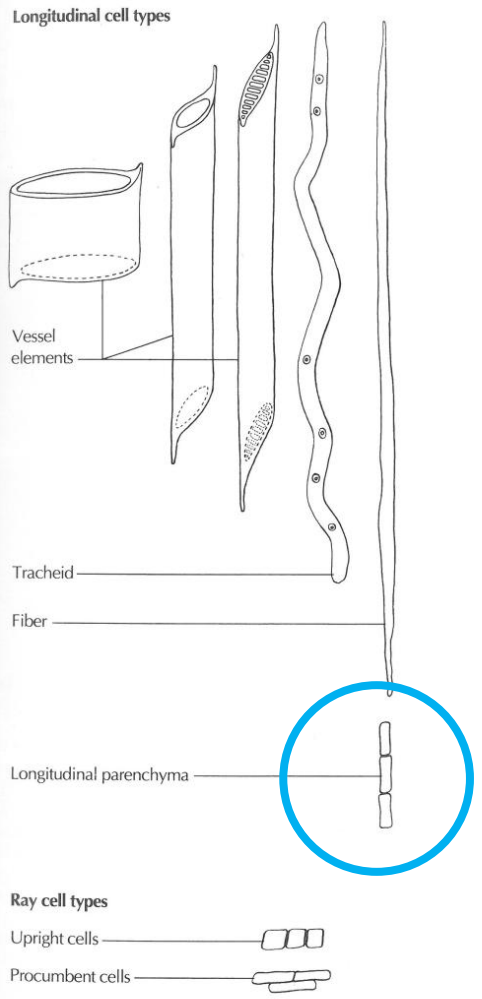
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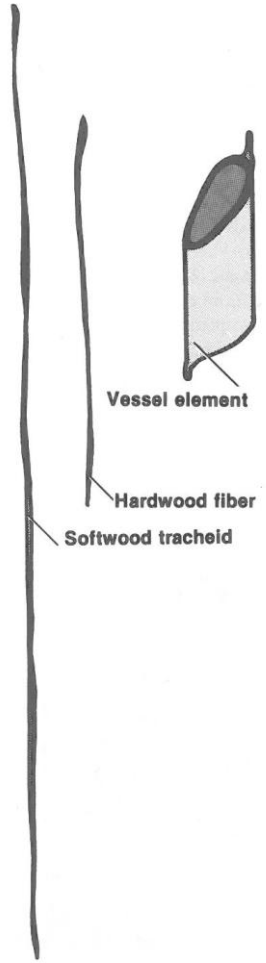


Hardwood cell types - parenchyma

- Longitudinal parenchyma
- Small diameter (~30 µm)
- Length ~0.1 mm
- Thin walls
- Truncated ends
- Arrangement
  - Apotracheal diffuse
  - Apotracheal diffuse in aggregates
- **Function: storage**



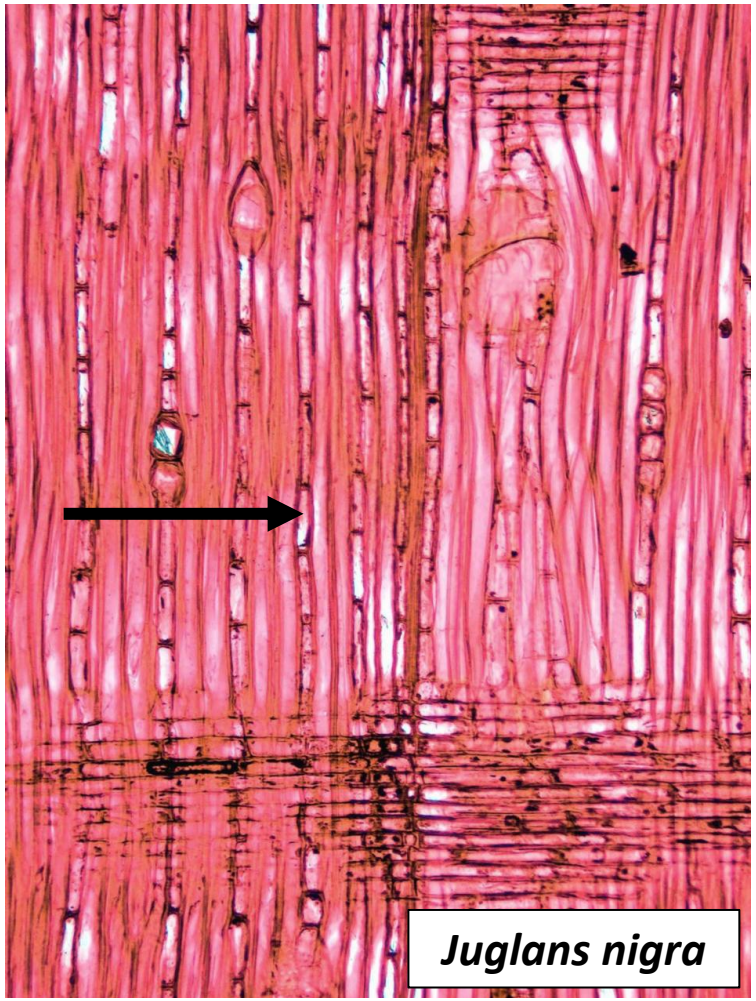
Source: Hoadley



Source: Bowyer

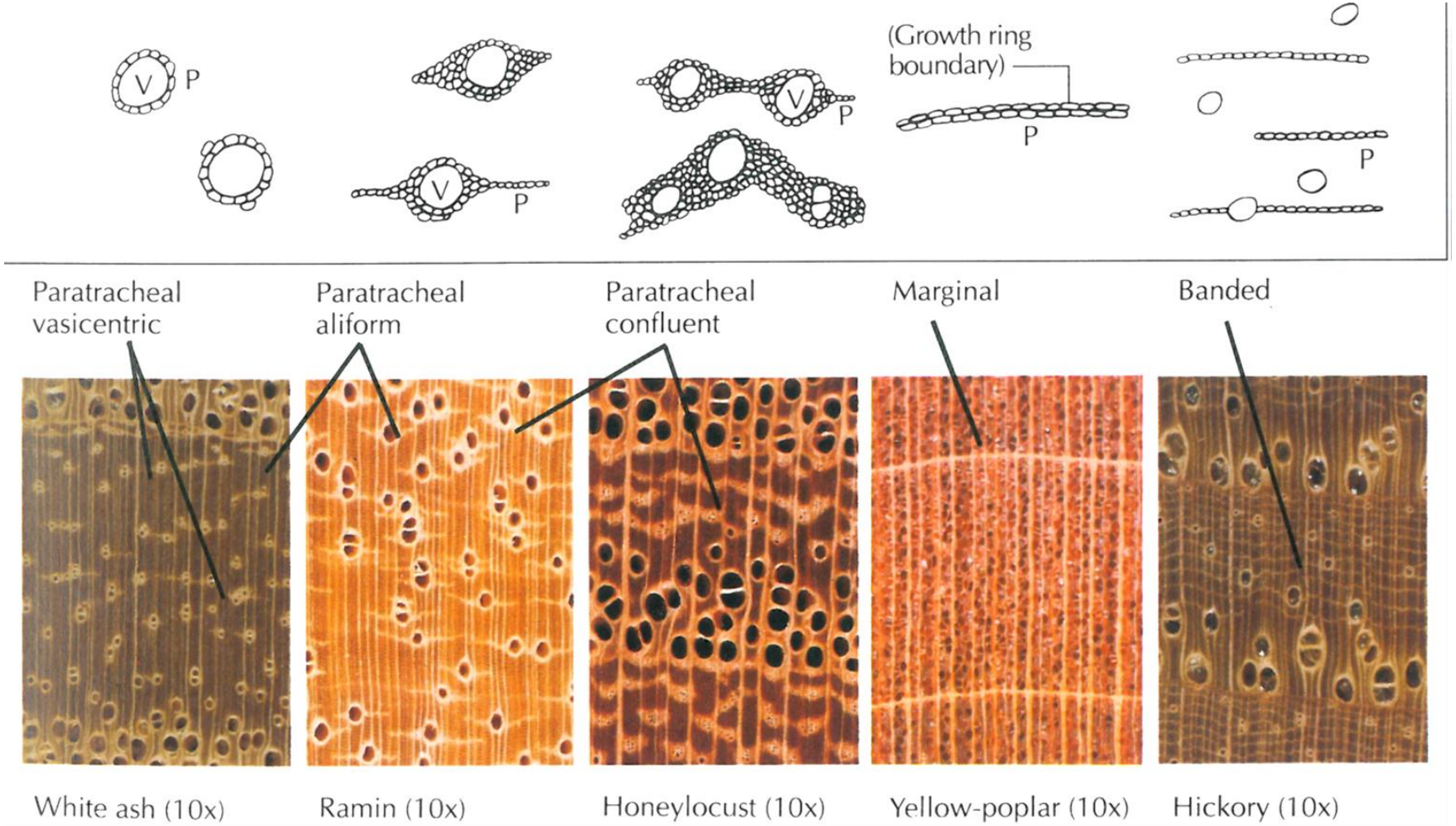
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- Arrangement
  - Apotracheal diffuse
  - Apotracheal diffuse in aggregates
  - Apotracheal = not in direct contact with vessels
- **Function: storage**



Source: InsideWood

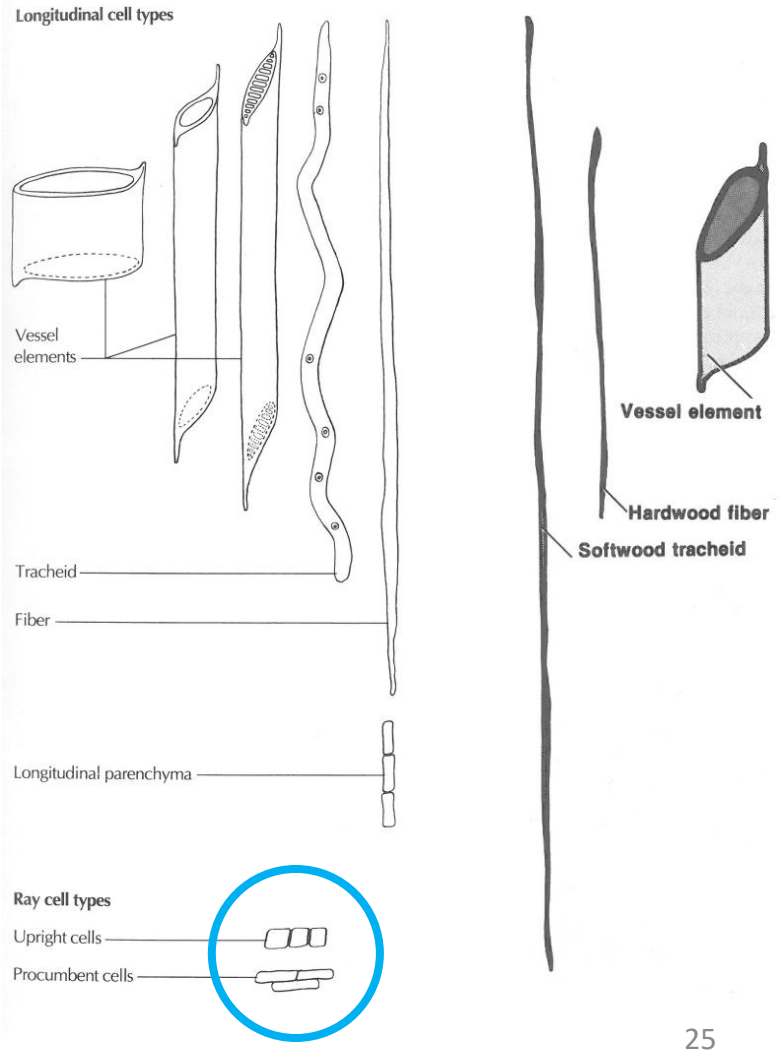
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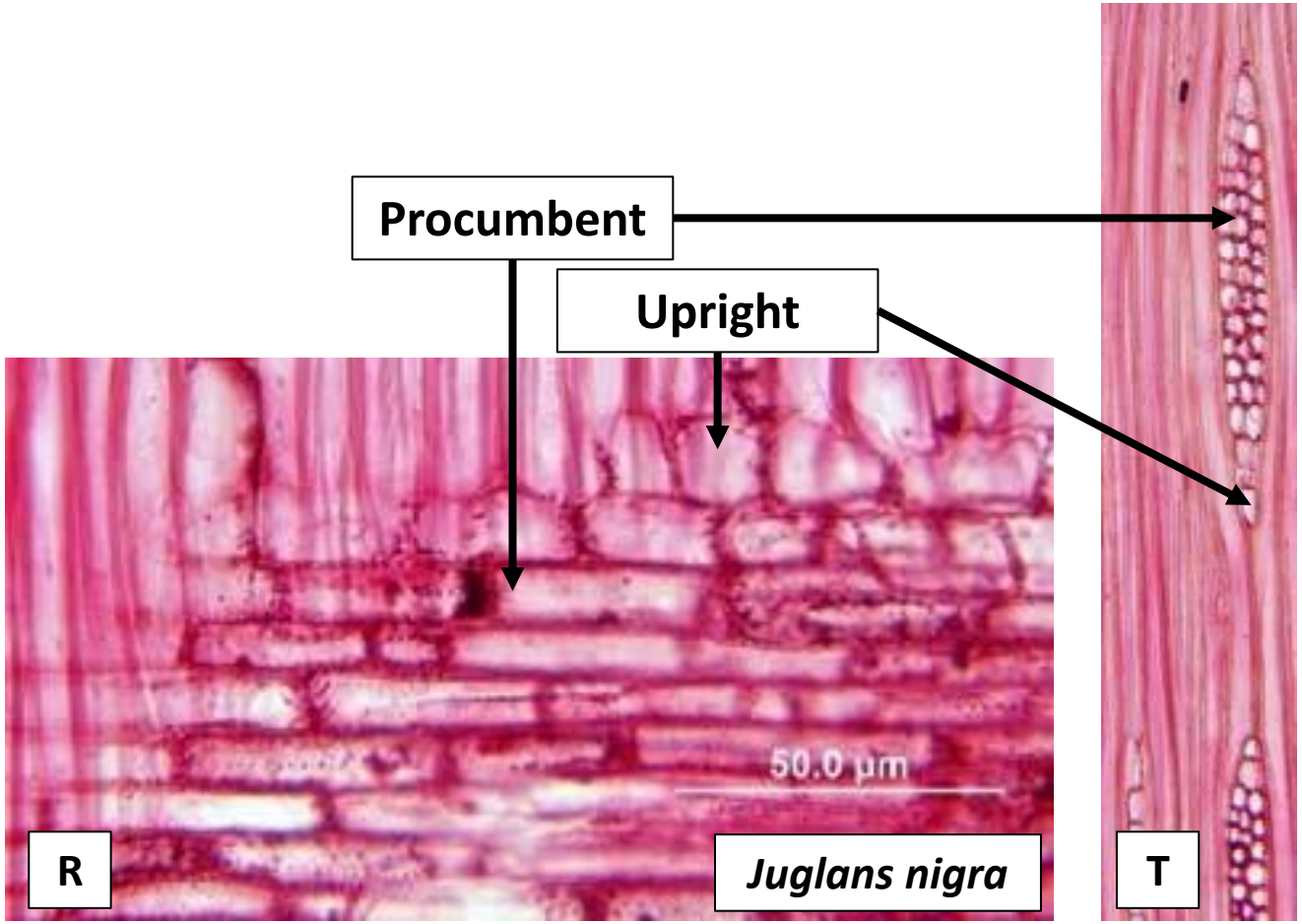
Source: Hoadley

Hardwood cell types – Ray cells

- Radial orientation
- Small diameter (10 µm to 15 µm
- Thin walls
- Truncated ends
- All ray cells are parenchyma
- Types
  - Upright – as tall as they are long
  - Procumbent – elongated radially (laying down)
- **Function: storage and radial transport**



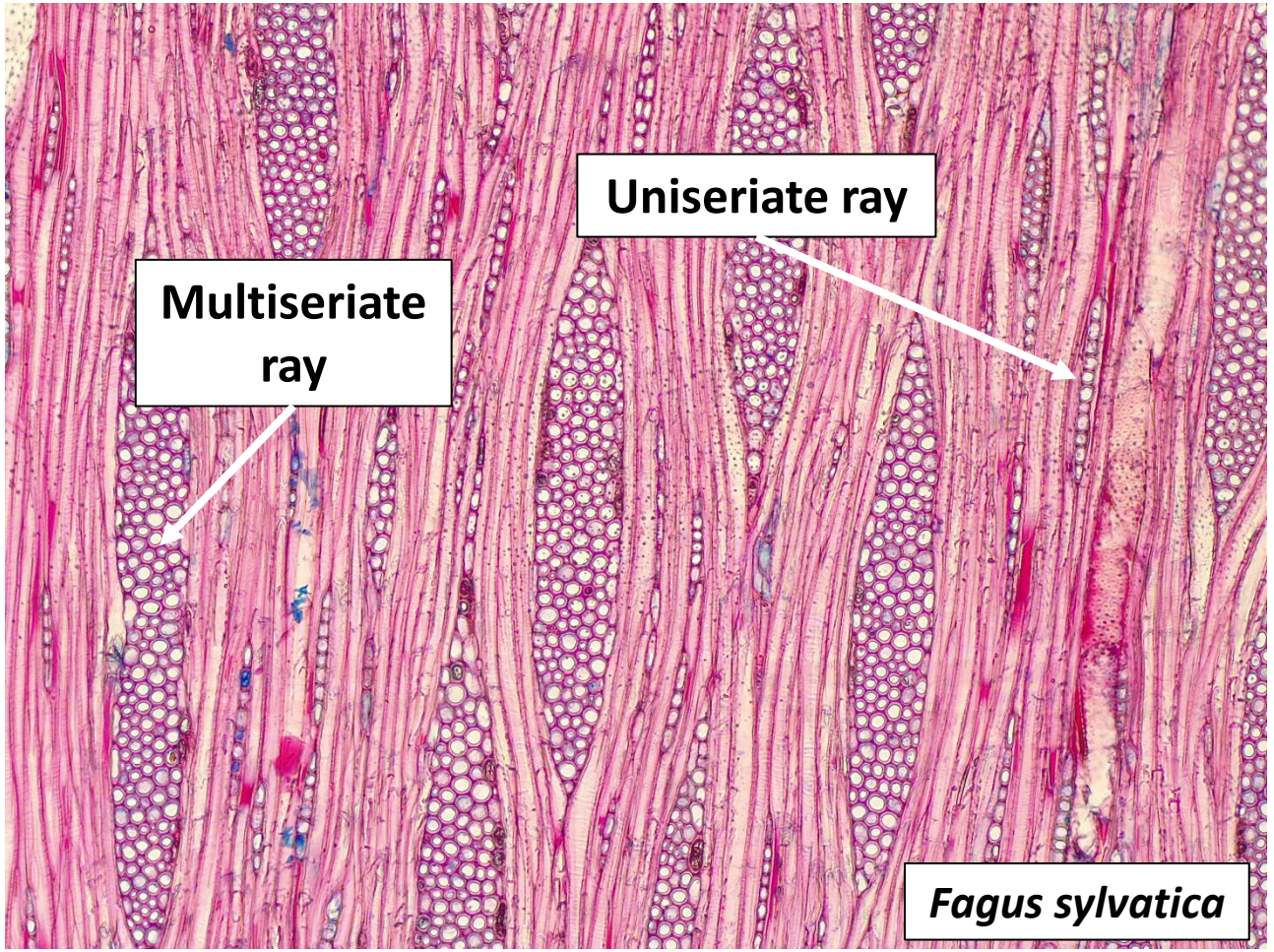
Ray Cells



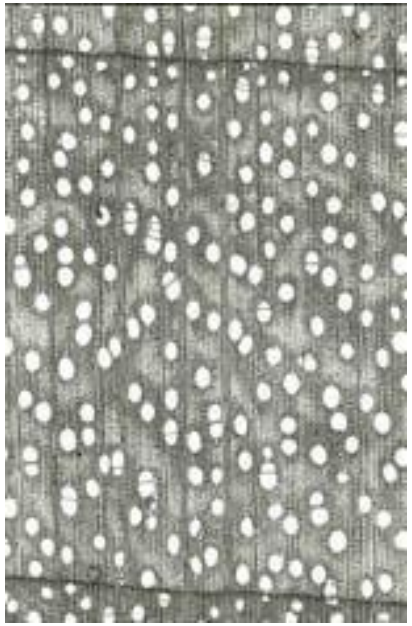
Source: InsideWood

Ray Cells

- Very large rays
- Uniseriate to multiseriate rays
- Up to 0.5 mm wide, 20 cells and 3 to 5 mm high



Acer saccharum



Transverse



Radial



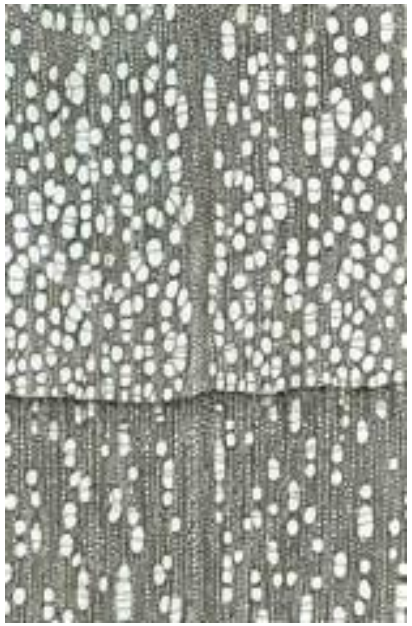
Tangential

Source: Schoch

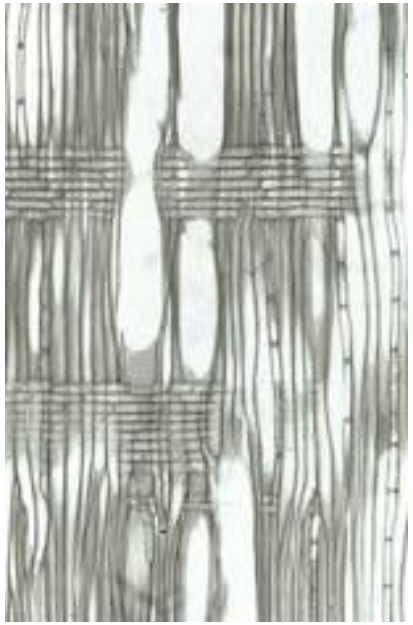
(*Acer saccharum)*

Diffuse-porous. Vessels moderately numerous and small, with simple perforation plates. Parenchyma sparse. Rays unstoried, homocellular; broad rays 5 - 7 seriate and narrow rays 1 - 2 seriate.

Alnus sp.



Transverse



Radial

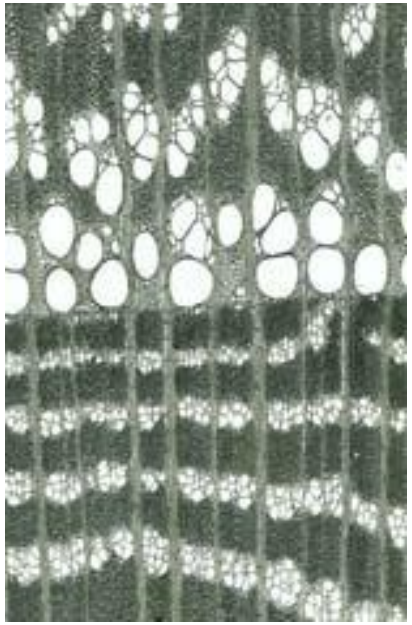


Tangential

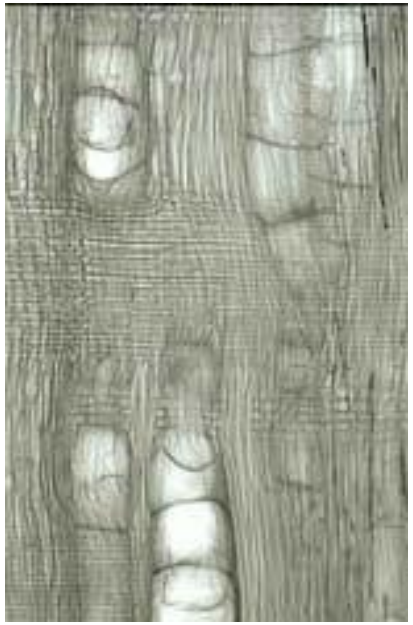
Source: Schoch

(*Alnus sp.*)
Diffuse-porous. Vessels numerous and small, with scalariform perforation plates. Parenchyma sparse. Rays unstoried, homocellular; aggregate rays with included fibers and vessels, narrow rays uniserate. English name: Alder

Ulmus sp.



Transverse



Radial



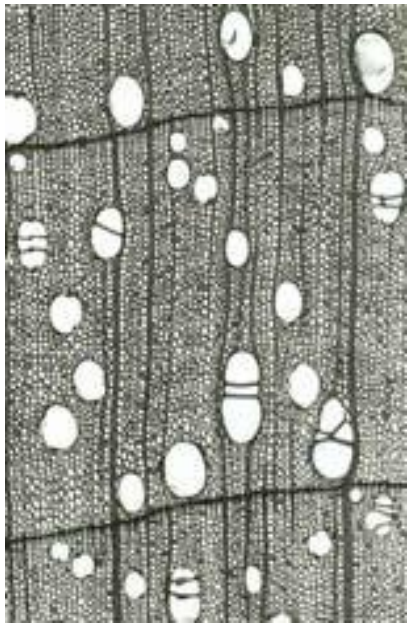
Tangential

Source: Schoch

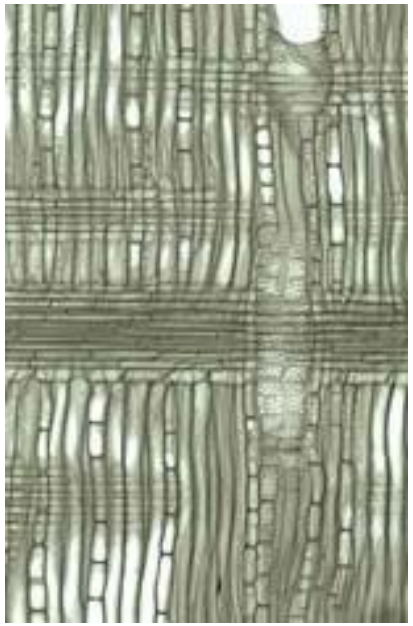
(Elm, Ulmus sp.)

Ring-porous. Vessels numerous in latewood and arranged in wavy bands; large to very large in earlywood; earlywood tyloses; simple perforation plates. Parenchyma sparse. Rays unstoried, homocellular, 4 – 6 seriate.

Juglans sp.



Transverse



Radial



Tangential

Source: Schoch

(Walnut, Juglans sp.)
Semi-ring-porous. Vessels sparse, very large in earlywood; earlywood tyloses; simple perforation plates. Parenchyma diffuse to banded and scanty to vasicentric. Rays homocellular to heterocellular, 1 – 5 seriate.

Microscopic anatomy

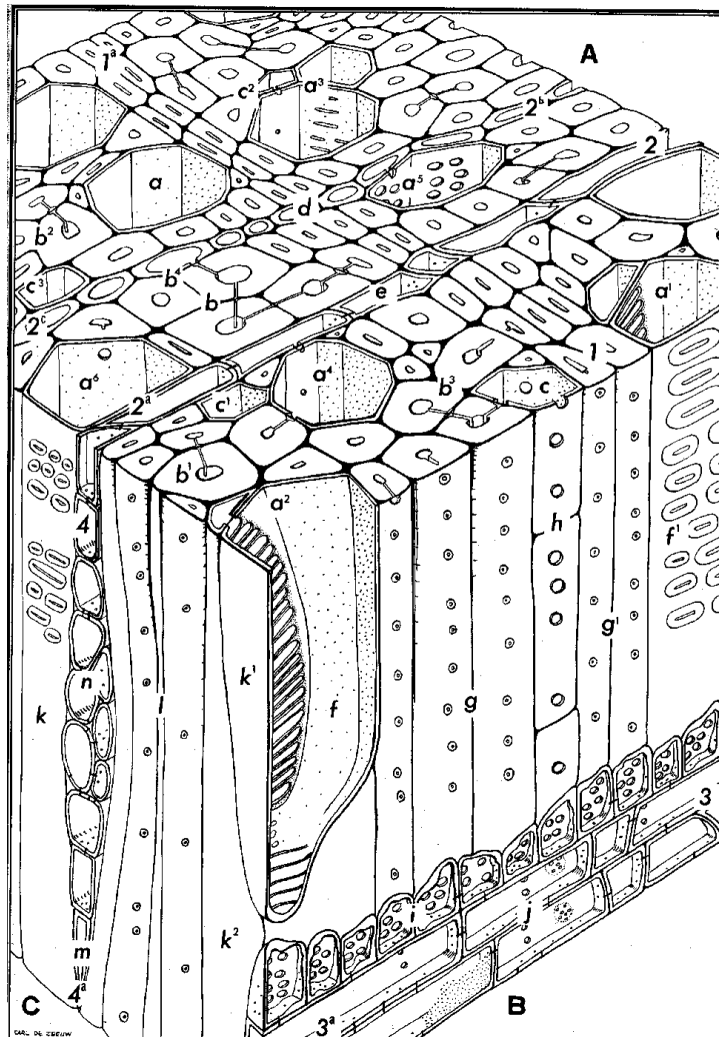


FIG. 5-3: Schematic three-plane drawing of the wood of sweetgum (Liquidambar styraciflua L.). (33OX.)

Surface A: 1-1a, boundary between two annual rings (growth proceeded from right to left); 2-2a, wood ray consisting of procumbent cells; 2b-2c, wood ray consisting of upright cells; a-a6, inclusive, pores (vessels in transverse section); b-b4, inclusive fiber tracheids; c-c3, inclusive, cells of longitudinal parenchyma; e, procumbent ray cell.

Surface B: f, f1, portions of vessel elements; g, g1, portions of fiber tracheids in lateral surface aspect; h, a strand of longitudinal parenchyma in lateral surface aspect; 3-3a, upper portion of a heterocellular wood ray in lateral sectional aspect; i, a marginal row of upright cells; j, two rows of procumbent cells.

Surface C: k, portion of a vessel element in tangential surface aspect; k1, k2, overlapping vessel elements in tangential surface aspect; 1, fiber tracheids in tangential surface aspect; 4-4a, portion of a wood ray in tangential sectional view; m, an upright cell in the lower margin; n,
procumbent cells in the body of the ray.

From Textbook of Wood Technology, 3rd Ed., Fig. 5-3

References

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- Bowyer, J. L., R. Smulsky, and J. G. Haygreen. 2007. *Forest Products and Wood Science: An Introduction,* 5th edition. Wiley-Blackwell, Ames, IA. 576 pp.
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