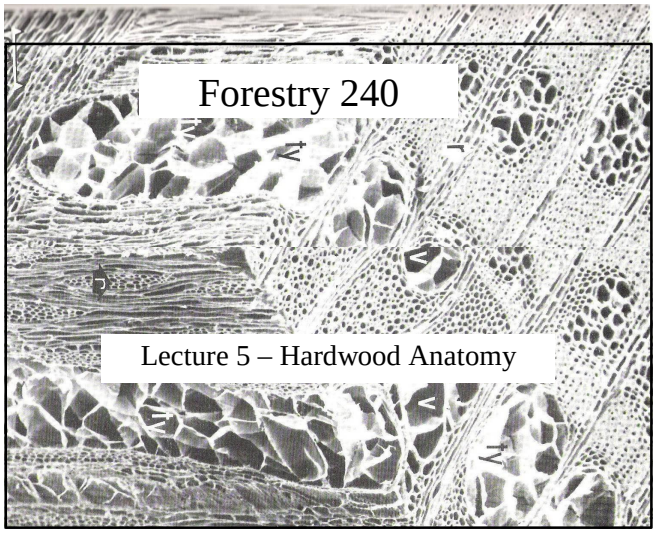
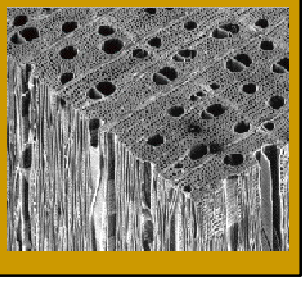


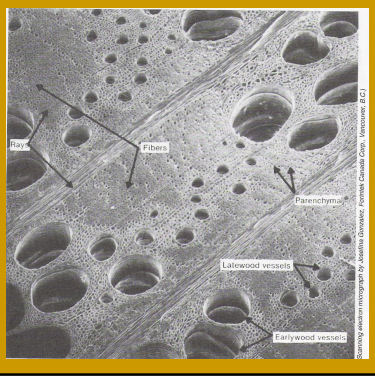
Softwood vs. Hardwood Structure

- CONIFERS / SOFTWOODS
  - Conduction Longitudinal tracheid
  - Support Longitudinal tracheid
  - Storage Parenchyma (ray) ~10%
  - Rays always narrow
- DICOTYLEDONS / HARDWOODS
  - Conduction Vessel element
  - Support Fibers
  - Storage Parenchyma
  - Rays short & narrow to wide & tall, varies by species



Hardwoods versus Softwoods

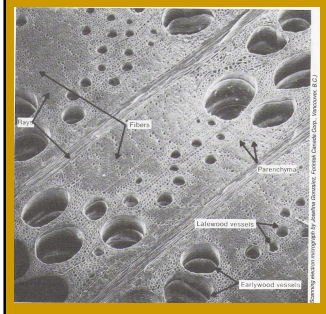
- Hardwood ray widths vary within and between species.

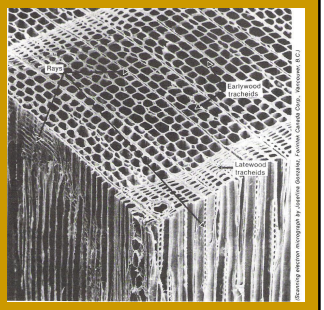


Hardwoods versus Softwoods

- Straight radial rows of cells characterize softwoods, but generally not hardwoods.
- Softwood cells are aligned in straight radial rows in parallel form, with straight spoke-like rays, each row of cells is formed by a single fusiform initial in the cambium
- Hardwood rays are seldom aligned in straight radial rows. Deviations occur in the vicinity of large vessel elements.
- After formation, vessel elements may expand 2 to 50 times their original diameter, pushing other cells out of radial alignment.

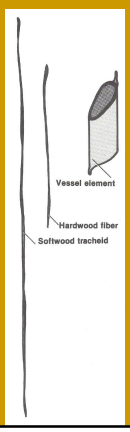
Hardwoods versus Softwoods





Hardwoods versus Softwoods

- Hardwood fibers are shorter than softwood tracheids.
  - Softwood tracheids are preferred for paper, since longer fiber length is important for paper strength.



Hardwood versus Softwood

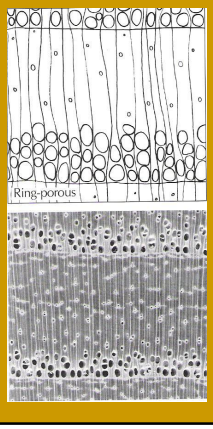
- The terms “hardwood” and “softwood” have no relevance to the actual hardness of the wood produced.
- Many softwoods produce wood that is harder and denser than wood produced by some hardwood.

Hardwood Cell Types – Vessels (Pores)

- **Vessel** – articulated, tube-like structure of indeterminate length in porous woods; formed through the fusion of the cells in a longitudinal row and perforation of common walls in a number of ways.
- **Vessel Element** – one of the cellular components of a vessel.
- Vessel elements link end to end along the grain to form vessels.
- Vessels are not arranged in precise parallel and vertical alignment.
- This arrangement ensures that each branch of the crown receives water from many different roots, providing a safety feature against crown damage from root damage.

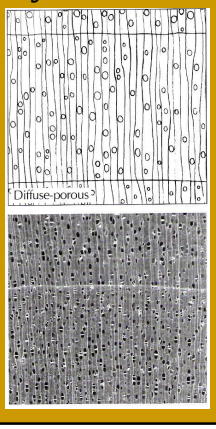
Ring Porosity

- **Ring-Porous Wood** – porous wood in which the pores formed at the beginning of the growing season (in the early wood) are much larger than those farther out in the ring, if the transition from one to the other type is abrupt.



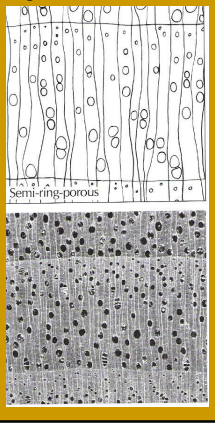
Ring Porosity

- **Diffuse-Porous Wood** – a hardwood in which the pores exhibit little or no variation in size within a growth ring, as viewed in a cross section.
  - The majority of hardwoods are diffuse-porous.



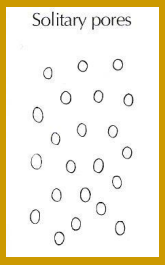
Ring Porosity

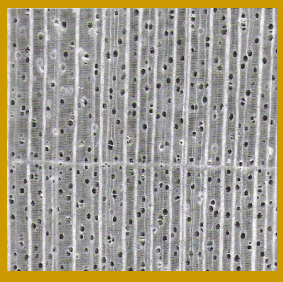
- **Semi-Ring-Porous Wood** – wood intermediate between diffuse-porous and ring porous wood.



Pore Arrangement

- **Solitary pore** – a single pore that does not touch any others.

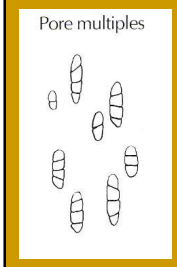




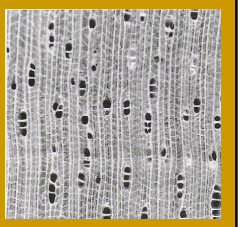
Maple (*Acer* spp.)

Pore Arrangement

- **Pore Multiple** – two or more pores come in contact with one another, typically, in radial alignment.



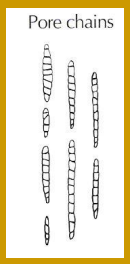
Cottonwood (*Populus deltoides*)

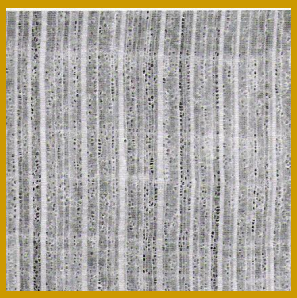


Jelutong (*Dyera costulata*)

Pore Arrangement

- **Pore Chains** – A distinct radial series or alignment of several to many solitary pores or pore multiples.

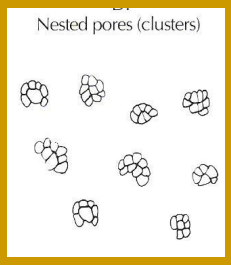


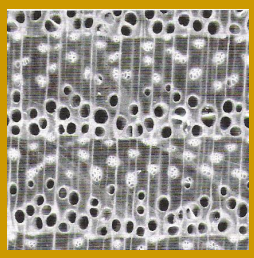


Holly (*Ilex* spp.)

Pore Arrangement

- **Nested Pores (clusters)** – Pore multiples where larger numbers of pores contact one another both radially and tangentially.

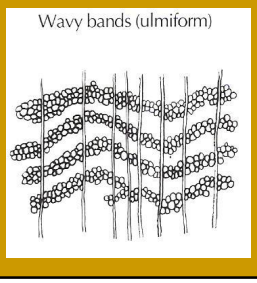




Kentucky Coffeetree (*Gymnocladus dioicus.*)

Pore Arrangement

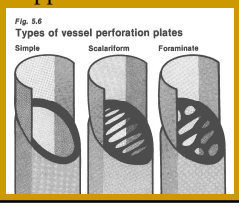
- **Wavy Bands (ulmiform)** – Pores arranged in undulating bands approximately parallel to the growth rings, characteristic of elm and hackberry.



American Elm (*Ulmus alata*)

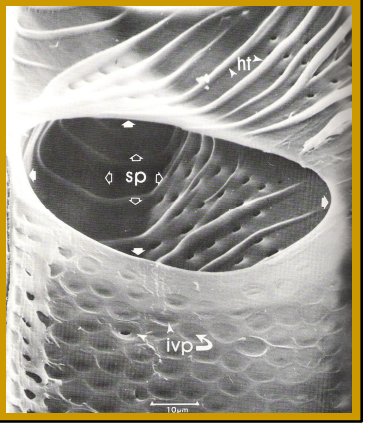
End to End Vessel Connections

- One of the primary functions of vessels are as avenues of conduction
- Common end walls of longitudinally linked vessel elements are perforated by unrestricted holes.
- These perforations form in the perforation plate near the end of the cell maturation process, as certain enzymes dissolve portions of the perforation plate.
- These perforations vary in appearance:
  - Simple
  - Scalariform
  - Foraminate



Simple Perforation

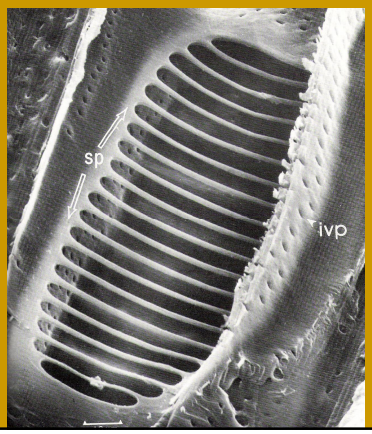
- A single and usually large and more or less rounded opening in the perforation plate.
- Best viewed in tangential section



American Basswood (*Tilia americana*)

Scaliform Perforation Plate

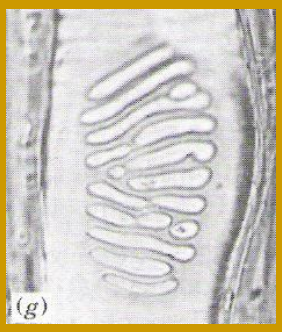
- A perforation plate with multiple elongated and parallel perforations, with bar-like remnants of the plate between openings.
- Best viewed in radial section



Red Alder (*Alnus Rubra*)

Foraminate (Reticulate) Perforation Plate

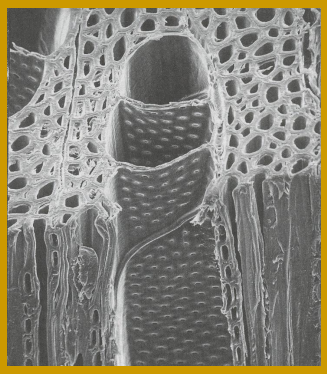
- A multiple perforation plate, with netlike appearance.



Sparkleberry (*Vaccinium arboreum*)

Intervessel pitting

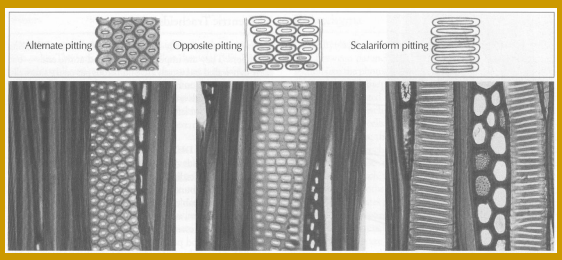
- Pitting between adjacent vessel elements
- When vessels are in multiples, there will be bordered pits along their common walls.



Populus spp.

Intervessel Pitting Arrangement

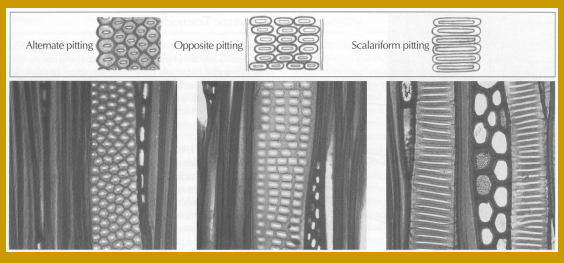
- **Alternate Pitting** – pits that are crowded together resulting in an irregular or diagonal arrangement.



Aspen Yellow-Poplar Magnolia

Intervessel Pitting Arrangement

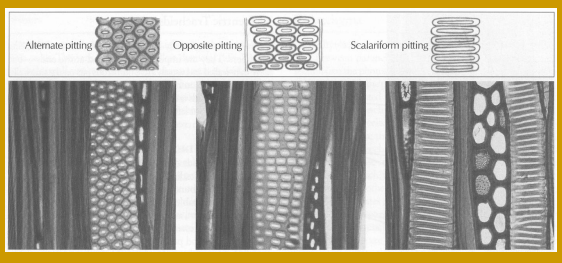
- **Opposite Pitting** – short rectangular or slightly rounded pits in distinct horizontal arrangement.



Aspen Yellow-Poplar Magnolia

Intervessel Pitting Arrangement

- **Scaliform Pitting** – Elongated bar-like pits in parallel, ladder-like arrangement



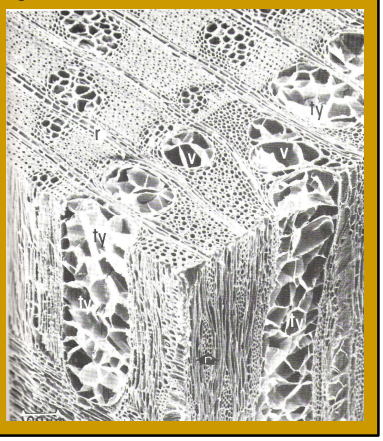
Aspen Yellow-Poplar Magnolia

Tyloses

- Saclike or cystlike structures that sometimes develop in a vessel and rarely in a fiber through the proliferation of the protoplast of a parenchyma cell through a pit pair.
- They commonly form in hardwoods as a result of wounding and effectively act to prevent water loss from the area around damaged tissues.
- They may also develop as a result of infection from fungi or bacteria, again to prevent water loss.

Tyloses

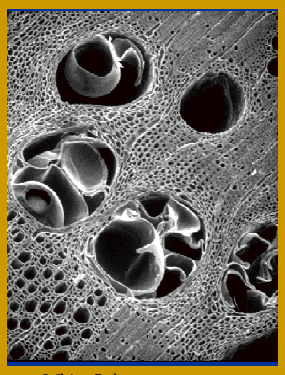
- Bubble-like structures that form in the vessel elements of certain hardwood species, usually in conjunction with heartwood formation.



Black locust

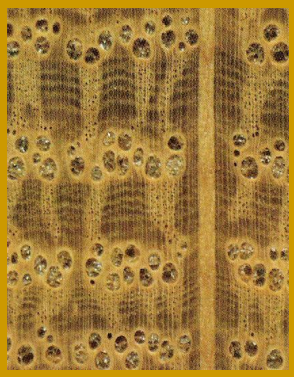
Tyloses

- Tyloses partially or completely block the vessels in which they occur.
  - This makes species like white oak preferred in the manufacture of barrels, casks, and tanks.
  - This makes white oak difficult to dry or impregnate with decay-preventive or stabilizing chemical.

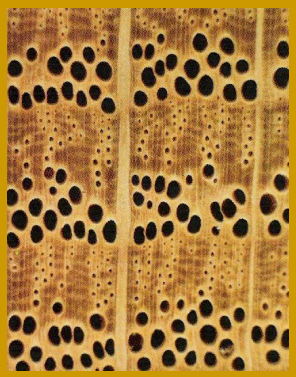


White Oak

Which one is White Oak?



A



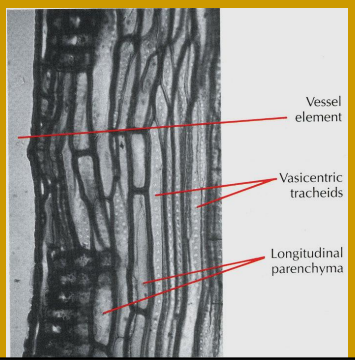
B

Vasicentric Tracheids

- Short, irregularly shaped fibrous cells with conspicuous bordered pits; vasicentric tracheids abound in the proximity of the large early-wood vessels of certain ring-porous hardwoods; they differ from vascular tracheids not only in shape but in arrangement (they are not arranged in definite longitudinal rows like vascular tracheids).

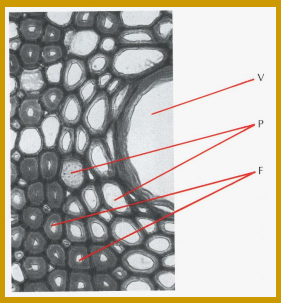
Vasicentric Tracheid

- Forms a light colored tissue seen with hand lens.



Fibers

- An elongated cell with pointed ends and a thick or not infrequently thin wall, Includes:
  - Fiber tracheids with bordered pits.
  - Libriform fibers with simple pits.

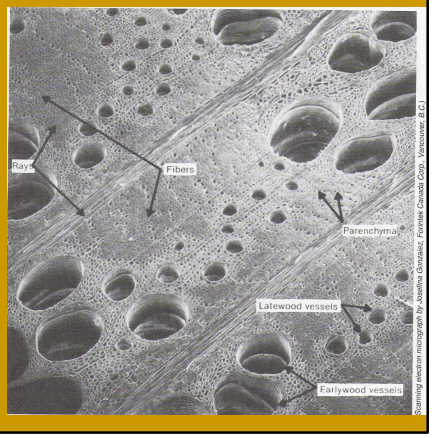


Fibers

- Hardwood fibers are similar to softwood tracheids with these differences:
  - Hardwood fibers are rounded in cross section compared to the nearly rectangular shape of softwood tracheids.
  - Fibers are typically thick walled and have bordered pits with less-developed borders than softwood tracheids.

Fibers

- Fibers appear as dark masses when viewed with a hand lens

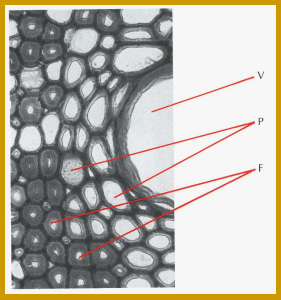


Fiber Functions

- Softwood tracheids are responsible for conduction and wood strength.
  - Thin walled early wood tracheids result in low wood strength compared with latewood.
- In Hardwoods vessel elements are responsible for conduction, while the thick-walled fibers are responsible for mechanical support.
- Density and strength of hardwoods is more related to the portion of wood volume occupied by fibers relative to that accounted for by vessels than with softwoods

Parenchyma

- Parenchyma cells are thin-walled storage units.
- In hardwoods, parenchyma is long, tapered longitudinal cells, brick shaped epithelium around gum canals, and ray cells.

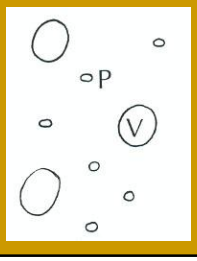


Parenchyma

- **Paratracheal Parenchyma** – axial parenchyma the cells of which are obviously associated with the vessels (pores in cross section)
- **Apotracheal Parenchyma** – axial parenchyma cells which are separated from the pores by rays or fibers.

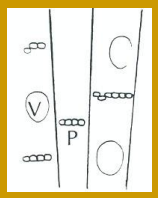
Apotracheal Parenchyma Arrangement

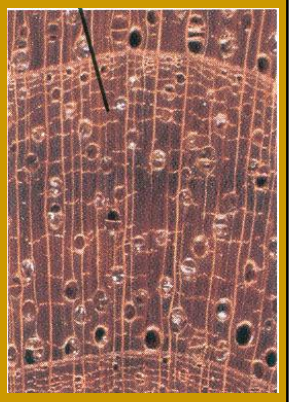
- **Diffuse parenchyma** – single, isolated apotracheal parenchyma. Typically cannot be seen without a microscope.



Apotracheal Parenchyma Arrangement

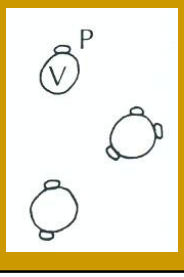
- **Diffuse-in-Aggregates Parenchyma** – apotracheal parenchyma occurring in short tangential lines. Seen with a microscope in basswood and birch, visible with hand lens in black walnut and butternut.





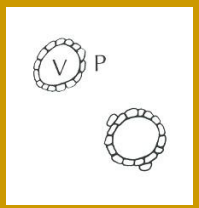
Paratracheal Parenchyma Arrangement

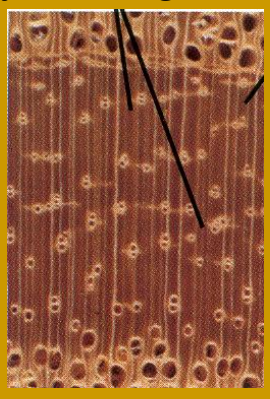
- Paratracheal Scanty – single, isolated cells of paratracheal parenchyma. Cannot be seen with hand lens magnification.



Paratracheal Parenchyma Arrangement

- **Paratrachael vasicentric** – parenchyma cells numerous enough to form a complete or partially complete sheath around a pore.

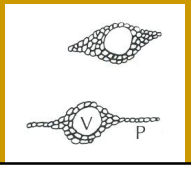


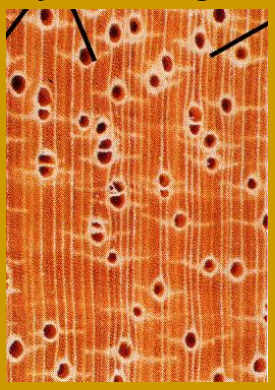


White Ash

Paratracheal Parenchyma Arrangement

- Aliform Parenchyma – Vascentric parenchyma that occurs in a well-developed layer with additional cells forming tangential wing-like extensions on either side.

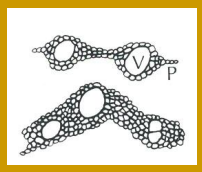


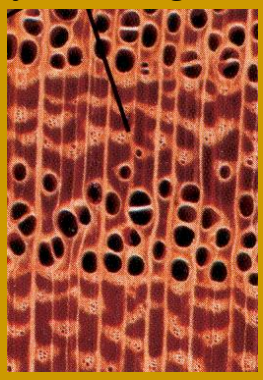


Ramin

Paratracheal Parenchyma Arrangement

- **Paratracheal Confluent** – Parenchyma that forms a continuous tangential or diagonal zone connecting two or more pores.

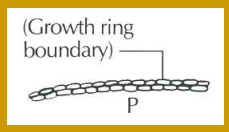


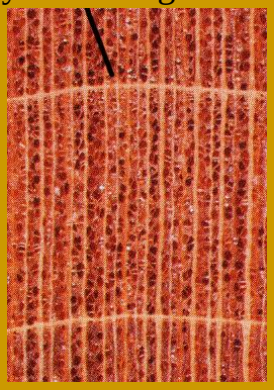


Honeylocust

Paratracheal Parenchyma Arrangement

- **Marginal Parenchyma** – parenchyma occurring at the growth-ring boundary, sometimes called initial or terminal parenchyma. Conspicuous in yellow-poplar and American mahogany.

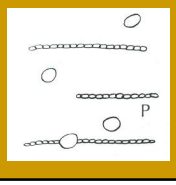


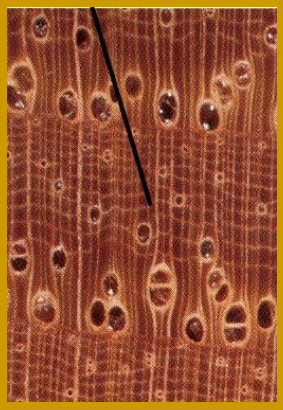


Yellow-poplar

Paratracheal Parenchyma Arrangement

- **Banded parenchyma** – distinct tangential lines of cells, usually occurring with fairly regular spacing.
- **Reticulate parenchyma** – lines of banded parenchyma join with ray lines of approximately the same width to from a mesh or net-like pattern – hickory and persimmon.





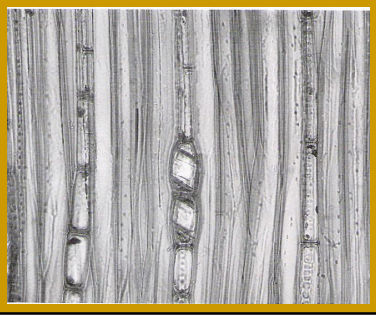
Hickory

Strand Parenchyma

- **Axial Strand Parenchyma** – cells of axial parenchyma arranged in a row along the grain; such a row is formed through further (postcambial) division of a single axial (longitudinal) cell cut off from a fusiform initial in the cambium.

Crystals

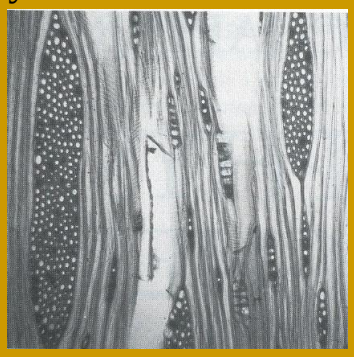
- Deposits of crystalline or gummy deposits found in parenchyma cells, useful for differentiating black walnut from butternut and English walnut.



Rays

Ray Width

- In Hardwoods, Rays may be:
  - Uniserate – one cell wide
  - Biserate – two cells wide
  - Multi-serate – many cells wide.
- Ray width varies between and within species.



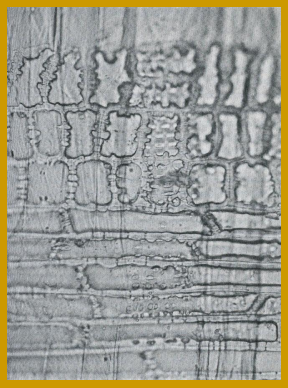
Sugar Maple

Hardwood Ray Parenchyma Cells

- Softwoods rays may contain ray tracheids as well as ray parenchyma, where hardwood rays consist entirely of ray parenchyma cells.
- There are two types of ray parenchyma cells in hardwoods.

Ray cells

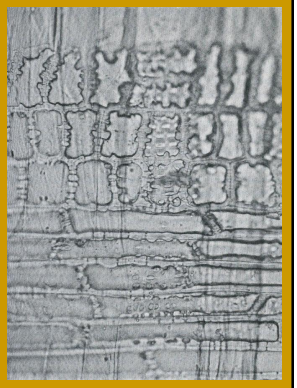
- In radial view, **procumbent ray cells** are elongated horizontally.
- **Upright ray cells** are either squarish or vertically oriented



Yellow-poplar

Heterocellular

- Hardwood rays that contain both upright and procumbent ray cells are called **heterocellular** or **heterogenous**, where the upright cells are usually located in one or more rows along the margins of the rays.



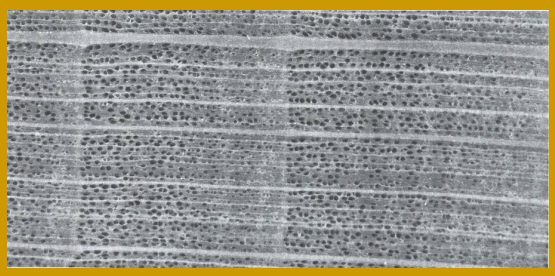
Yellow-poplar

Homocellular

- **Homocellular** or **homogenous** rays are composed of only one type of cells, typically only porcumbent cells.

Node Rays

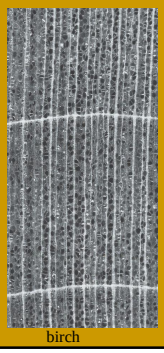
- Rays that swell at the growth-ring boundary.



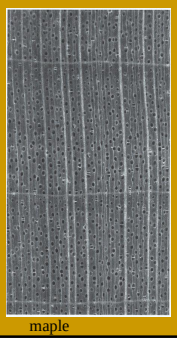
Beech

Ray Width Comparisons

- Comparing ray with to pore diameter quickly distinguishes species, like maple (the largest rays are about the same width as the largest pores) and birch (the largest rays are narrower than the largest pores).

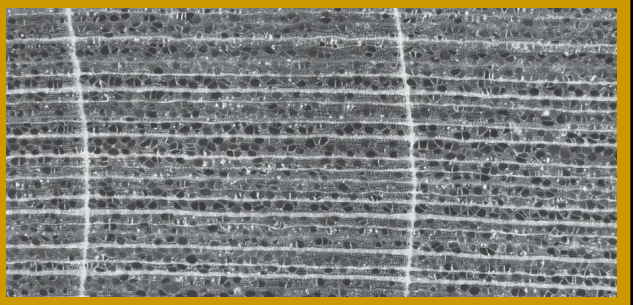


birch



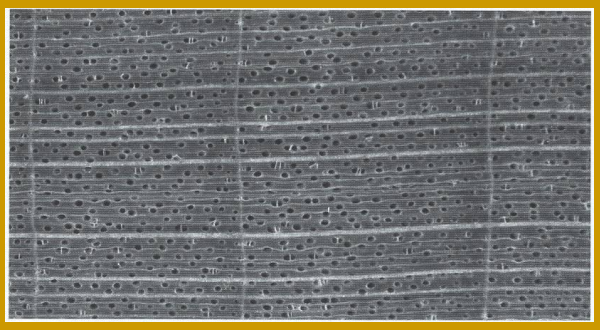
maple

Widest ray is narrower than largest pore



Birch

Widest rays are about the same as the largest pores



Maple – Diffuse porous or ring porous?

Rays

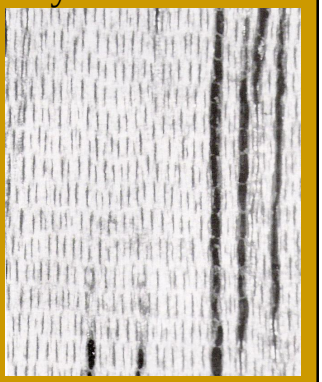
- **Ray Fleck** – portion of ray as it appears on the quarter surface

Aggregate Rays

- Composite structure, consisting of a number of small rays, fibers, and sometimes also vessels, which to the unaided eye or at low magnification appears as a single broad ray.

Storied Rays

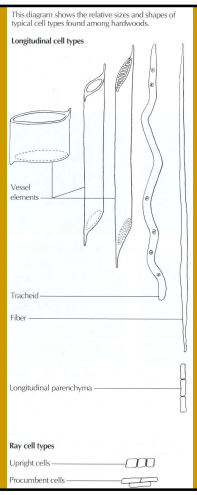
- Rays arranged in tiers or in echelons, as viewed on a tengential surface or in a tangential section, forming ripple marks



Ripple Marks

- Striations across the grain on the tangential surface of a wood, occasioned by storied rays or by these and other storied elements.

In Summary



Better STUDY for the Test!