Forestry 240 – Wood Science

Lab 4 Ring-Porous Hardwoods

Separating Hardwoods – Ring Porosity
• Hardwoods are either Ring Porous, Semi-Ring Porous, or Diffuse Porous

Northern Red Oak (Quercus rubra)
Black Walnut (Juglans nigra)
Yellow Birch (Betula alleghaniensis)

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.

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.

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.

  - **Jelutong** (*Dyera costulata*)
  - **Cottonwood** (*Populus deltoides*)

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

  - **Holly** (*Ilex spp.*)

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

  - **Kentucky Coffeetree** (*Gymnocladus dioicus*)

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

  - **American Elm** (*Ulmus alata*)

**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.

- **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.

**Which one is White Oak?**

- **A**
- **B**

**Hardwoods**

- Hardwood ray widths vary within and between species.

**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.

**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

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

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.

Paratracheal Parenchyma Arrangement

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

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.

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 form a mesh or net-like pattern – hickory and persimmon.

Paratracheal Parenchyma Arrangement

- **White Ash**
- **Ramin**
- **Honeylocust**
- **Yellow-poplar**
- **Hickory (Carya spp.)**
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.

Hardwood Identification

- Ring Porous Hardwoods are broken down into Four Main groups, based on latewood pore arrangement and other factors.

Ring-Porous Subgroup I-1
Chestnut and Oak

- Latewood pores in more or less radial arrangement, in obvious radial rows, or in loose dendritic or flame-like patches.
- Rays either huge or barely visible with hand lens

Ring-Porous Subgroup I-2
Elm and Hackberry

- Latewood pores in regular wavy tangential patterns, appearing uniformly throughout latewood.

Ring-Porous Subgroup I-3
Ash, Sassafras, Locust et al.

- Latewood pores appear neither in strict radial nor in tangential arrangement, but rather as solitary pores, pore multiples, or pore/multiples.
- Joined with aliform parenchyma, or joined in outer latewood by confluent parenchyma.

Ring-Porous Subgroup I-3
Hickory and Pecan

- Latewood pores mostly solitary or in compact radial multiples.
- Latewood fiber mass lined with regular banded parenchyma.
- Row of earlywood pores discontinuous.
The Oak Group

- White Oak
  - Rays taller than 1.25” high
  - Abundant Tyloses in heartwood
  - Latewood pores grading in size to indistinctly small; too numerous and indistinct with lens to be counted
  - Vessel walls thin (not thicker than earlywood vessels)

The Oak Group

- Red Oak
  - Rays less than 1” high
  - Absent or sparse and sporadic tyloses
  - Latewood pores distinct with lens; few enough to be counted
  - Vessel walls thick (thicker than earlywood vessels)

The Elm Group – Hackberry/Sugarberry

- Earlywood 2-5 pores wide, pores generally visible with lens.
- Heartwood cream to light brown or yellowish grey.
- Largest rays up to 10-12 seriate, always some rays wider than 7-seriate

The Elm Group – Slippery Elm

- Earlywood 2-5 pores wide, pores generally visible with lens
- Heartwood brown to reddish brown.
- Largest rays generally 4-5 seriate, never wider than 7 seriate.

The Elm Group – American Elm

- Earlywood with a single row of largest pores than may or may not be visible without lens.
- Earlywood pores visible to the eye, mostly in a continuous row.
- Tyloses sparse.

The Elm Group – Hard Elm

- Earlywood pores not visible without lens, in a discontinuous row.
- Tyloses more abundant
Ring-Porous Subgroup I-1
Chestnut and Oak

- Latewood pores in more or less radial arrangement, in obvious radial rows, or in loose dendritic or flame-like patches.
- Rays either huge or barely visible with hand lens

Northern Red Oak
(Quercus rubra)

Red Oak (Quercus spp.)

- General Characteristics
  - Sapwood – whitish to grayish or pale reddish brown
  - Heartwood – pinkish to light reddish brown, the flesh-colored cast generally pronounced, occasionally light brown.
  - Wood is without characteristic odor or taste
  - Straight grained, heavy to very heavy and hard to very hard
  - Earlywood – 1-4 pores wide, pores large, visible to the naked eye.
  - Latewood – pores abundant, small, indistinct or barely visible to the naked eye, associated with light-colored tissue in radial, mostly uniserate, occasionally forking rows or scattered in radial alignment.
  - Tyloses rare
  - Rays broad and very conspicuous, separated by several to many narrow rays
- Remarks
  - Similar to white oak, thought lacking tyloses and differences in earlywood pores and ray height.
- Uses
  - Slack (dry) cooperage, containers, crates, pallets, veneer, furniture, flooring, interior trim, timber, fuel, planing mill products, paneling, plywood, cabinets, less durable than white oak.

White Oak (Quercus spp.)

- General Characteristics
  - Sapwood – whitish to light brown, thick or thin
  - Heartwood – rich light brown to dark brown.
  - Wood is without characteristic odor or taste
  - Straight grained, heavy to very heavy and hard to very hard
  - Earlywood – 1-3 pores wide, pores large, visible to the naked eye, occluded with tyloses.
  - Latewood – pores abundant, small, numerous, not sharply defined with a hand lens, scattered in radially aligned, flame-shaped tracts of light-colored tissue, thin-walled
  - Tyloses abundant
  - Rays broad and very conspicuous, separated by several to many narrow rays
- Remarks
  - Similar to red oak.
- Uses
  - Tight (wet) cooperage, railroad ties, fence posts, poles and pilings, firewood, flooring, containers, crates, pallets, veneer, furniture, interior trim, timber, fuel, planing mill products, paneling, plywood, cabinets, more durable than red oak.

Ring-Porous Subgroup I-2
Elm and Hackberry

- Latewood pores in regular wavy tangential patterns, appearing uniformly throughout latewood.

Slippery Elm (Ulmus rubra)

American Elm (Ulmus americana)

- General Characteristics
  - Sapwood – grayish white to light brown, thick
  - Heartwood – light brown to brown, frequently with a reddish tinge.
  - Wood is without characteristic odor or taste
  - Straight, sometimes interlocked grained, moderately heavy and moderately hard
  - Earlywood – 1 pore wide, pores large, visible to the naked eye, continuous row.
  - Latewood – pores small, arranged in more or less continuous, wavy, concentric bands
  - Tyloses present in earlywood, but usually sparse
  - Rays not distinct to naked eye
- Remarks
  - In the trade, elm is applied to the timbers of the Ulmus genus. American elm outstrips the other species in quantity consumed for timber uses. Commercial stands of elm have been seriously depleted by Dutch elm disease, to the extent that in many areas elm timber is no longer available in commercial quantities.
- Uses
  - Slack cooperage, boxes and crates (withstands rough handling), pallets, veneer, furniture (bent parts like rockers and arms), interior trim.

Hard Elm (Ulmus alata)

- General Characteristics
  - Sapwood – light brown to brown
  - Heartwood – light brown to brown, frequently with a reddish tinge.
  - Wood is without characteristic odor or taste
  - Straight, sometimes interlocked grained, heavy and hard
  - Earlywood – 1 pore wide, variable in size, larger pores scarcely visible to the naked eye, spaced at more or less irregular intervals in an interrupted row and separated by smaller pores.
  - Latewood – pores small, arranged in more or less continuous, wavy, concentric bands
  - Tyloses sparse in early wood
  - Rays not distinct to naked eye
- Remarks
  - Similar to American Elm, except earlywood pores are smaller and less visible, more discontinuous. Made up of 3 species, rock elm, winged elm, and cedar elm.
- Uses
  - Similar to American elm, preferred where hardness and ability to resist shock are of primary importance.
Slippery Elm (*Ulmus rubra*)

- **General Characteristics**
  - Sapwood - grayish white to light brown, narrow, with a faint characteristic odor resembling that of the inner bark
  - Heartwood - brown to dark brown, frequently with shades of red, usually odorless, sometimes contains yellow and orange compounds extracted with benzene.
  - Wood is without characteristic taste
  - Straight, sometimes interlocked grained, moderately heavy and moderately hard
  - Earlywood - 2-4 pores wide, large, distinctly visible to the naked eye, forming a conspicuous band.
  - Latewood - pores very small, arranged in more or less continuous, wavy, concentric bands.
  - Tyloses sparse in earlywood
  - Rays not distinct to naked eye

- **Remarks**
  - Similar to American Elm, except earlywood pores are smaller and less visible, more discontinuous. Made up of 3 species, rock elm, wiggled elm, and cedar elm.

- **Uses**
  - Similar to American elm, sometimes marketed as soft elm.

Hackberry (*Celtis occidentalis*)

- **General Characteristics**
  - Sapwood - pale yellow to grayish or greenish yellow, frequently discolored with blue sap stain, wide.
  - Heartwood - when present, yellowish gray to light brown streaked with yellow.
  - Wood is without characteristic odor or taste
  - Straight, sometimes interlocked grained, moderately heavy and moderately hard
  - Earlywood - 2-5 pores wide, large, distinctly visible to the naked eye, forming a conspicuous band.
  - Latewood - pores small, numerous, arranged in more or less continuous, wavy, concentric bands.
  - Rays distinctly visible to the naked eye

- **Remarks**
  - The woods of common hackberry and sugarberry (*Celtis laevigata*) are indistinguishable. Hackberry is sometimes confused with elm, but has a wider sapwood with distinct yellowish tinge and wider heterocellular rays.

- **Uses**
  - Similar to American elm, often marketed with the elms, better grades used for furniture, millwork, boxes, crates, and veneer.

Ring-Porous Subgroup I-3
Ash, Sassafras, Locust et al.

- Latewood pores appear neither in strict radial nor in tangential arrangement, but rather as solitary pores, pore multiples, or pore/multiples.
- Joined with aliform parenchyma, or joined in outer latewood by confluent parenchyma.
- Separated based on color, density, characteristic odors, etc.

White Ash (*Fraxinus americana*)

- **General Characteristics**
  - Sapwood - Creamy white, may be very wide
  - Heartwood - Light brown or grayish brown.
  - Wood is somewhat lustrous, without characteristic odor or taste
  - Straight grained, heavy and hard.
  - Earlywood - 2-4 pores wide, pores moderately large, surrounded by lighter colored tissue, abrupt transition to latewood.
  - Latewood - pores solitary and in radial multiples of 2-3, surrounded by vasicentric parenchyma or connected by confluent parenchyma in outer latewood.
  - Tyloses fairly abundant
  - Rays not distinct to eye, but clearly visible with hand lens

- **Remarks**
  - Species of ash are very similar.

- **Uses**
  - Handles (especially for shovel, spade, rake, and other long handles, straight grain, stiff, hard, strong, moderate weight, flexible, and wears smoothly) furniture, baseball bats and other athletic equipment, baskets, kitchen cabinets, woodenware and novelties, veneer.

Red Mulberry (*Morus rubra*)

- **General Characteristics**
  - Sapwood - yellowish, narrow
  - Heartwood - orange yellow to golden brown, turning russet-brown on exposure.
  - Wood is without characteristic odor or taste
  - Straight grained, heavy and hard
  - Earlywood - 2-8 pores wide, pores moderately large, may contain white deposits
  - Latewood - pores in nestlike groups, merging laterally to form wavy or interrupted bands, especially in outer latewood.
  - Tyloses fairly abundant with sparkle
  - Rays distinct to eye, radial surface shows conspicuous ray fleck
  - Parenchyma not visible

- **Uses**
  - Locally for fences, posts, furniture, interior finish, caskets, agricultural implements, cooperage.

Northern Catalpa (*Catalpa speciosa*)

- **General Characteristics**
  - Sapwood - pale gray, narrow, never over two growth rings wide
  - Heartwood - grayish brown, sometimes with faint lavender cast.
  - Wood has faint unique pungent, spicy odor, without characteristic taste
  - Straight grained, moderately light and moderately soft.
  - Earlywood - 2-8 pores wide, pores large, somewhat lighter in color than the denser latewood.
  - Latewood - pores variable to small, arranged in small groups which are further aggregated into interrupted or continuous concentric bands toward the outer margins of the ring.
  - Tyloses very abundant with sparkle
  - Rays usually indistinct to eye, but plainly visible with hand lens

- **Uses**
  - Fence posts and rails, general construction work, interior finish, cabinetwork, fuel.
Osage-Orange (*Maclura pomifera*)

- **General Characteristics**
  - Sapwood – light yellow, narrow
  - Heartwood – golden yellow to orange-brown, darkening on exposure, contains water-soluble dye, so shavings turn warm water yellow when soaked.
  - Wood is without characteristic odor or taste
  - Straight grained, exceedingly heavy and very hard.
  - Earlywood – 2-3 pores wide, completely occluded with tyloses in heartwood and contours of individual pores indistinct.
  - Latewood – pores small, arranged in nestlike groups which coalesce in the outer late wood, forming interrupted concentric bands.
  - Tyloses very abundant
  - Rays barely visible to eye

- **Remarks**
  - Wood similar to black locust.

- **Uses**
  - Fence posts, archery, machine parts, dyewood (dye uniforms in WWII to dull khaki), paving blocks, machinery parts.

Black Locust (*Robinia pseudoacacia*)

- **General Characteristics**
  - Sapwood – yellowish, narrow
  - Heartwood – light red to reddish brown.
  - Wood is without characteristic odor or taste
  - Straight grained, very heavy and very hard.
  - Earlywood – 2-5 pores wide, pores large, especially visible on longitudinal surface.
  - Latewood – pores solitary, in radial multiples of 2-3, grading to very small with aliform parenchyma in the outer latewood.
  - Rays conspicuous to the naked eye

- **Remarks**
  - Wood similar to Kentucky coffeetree.

- **Uses**
  - Fence posts and rails, general construction, furniture (attractive figure and color), interior trim.

Sassafras (*Sassafras albidum*)

- **General Characteristics**
  - Sapwood – light yellow
  - Heartwood – dull grayish brown to orange-brown or dark brown
  - Wood with odor of sassafras, spicy taste
  - Straight grained, moderately heavy and moderately hard.
  - Earlywood – 3-8 pores wide, pores medium to large
  - Latewood – pores solitary in radial multiples of 2-3, grading to very small with aliform parenchyma in the outer latewood.
  - Rays barely visible to eye

- **Remarks**
  - Wood similar to ash, but different color, odor, and aliform parenchyma.

- **Uses**
  - Fence posts, general millwork, rails, foundation posts, lumber.

Honey Locust (*Gleditsia triacanthos*)

- **General Characteristics**
  - Sapwood – yellowish, wide
  - Heartwood – light red to reddish brown.
  - Wood is without characteristic odor or taste
  - Straight grained, very heavy and very hard.
  - Earlywood – 2-5 pores wide, pores large, especially visible on longitudinal surface.
  - Latewood – pores solitary, in radial multiples, and especially in outer latewood, as nestlike groups and connected into bands by confluent parenchyma.
  - Rays conspicuous to the naked eye

- **Remarks**
  - Wood similar to Kentucky coffeetree.

- **Uses**
  - Fence posts and rails, general construction, furniture (attractive figure and color), interior trim.

Mesquite (*Prosopis spp.*)

- **General Characteristics**
  - Sapwood – yellowish, narrow
  - Heartwood – light reddish to dark brown.
  - Wood is without characteristic odor or taste
  - Straight grained, very heavy and very hard.
  - Earlywood – 2-5 pores wide.
  - Latewood – pores small, appearing almost semi-ring porous in certain individual specimens.
  - Rays rare

- **Remarks**
  - Conspicuous gum deposits on longitudinal surface.

- **Uses**
  - Fence posts, furniture wood (dimensionally stable), barbeque (smoke from wood adds distinctive flavor), hard, dense lumber (Texas ironwood), cabinetry.

Ring-Porous Subgroup I-3

- **Hickory and Pecan**
  - Latewood pores mostly solitary or in compact radial multiples.
  - Latewood fiber mass lined with regular banded parenchyma.
  - Row of earlywood pores discontinuous.

- **Hickory (*Carya spp.*)**
  - Sapwood – light yellow
  - Heartwood – light reddish to dark brown.
  - Wood is without characteristic odor or taste
  - Straight grained, very heavy and very hard.
  - Earlywood – 2-5 pores wide.
  - Latewood – pores small, appearing almost semi-ring porous in certain individual specimens.
  - Rays rare

- **Remarks**
  - Conspicuous gum deposits on longitudinal surface.

- **Uses**
  - Fence posts, furniture wood (dimensionally stable), barbeque (smoke from wood adds distinctive flavor), hard, dense lumber (Texas ironwood), cabinetry.
**True Hickory (Carya spp.)**

- **General Characteristics**
  - Sapwood – whitish to pale brown
  - Heartwood – pale brown to brown, or reddish brown.
  - Wood is without characteristic odor or taste
  - Straight grained, heavy to very heavy and very hard.
  - Earlywood – Large, thick walled, visible to naked eye.
  - Latewood – Pores not numerous, solitary and in radial multiples 2-5
  - Tyloses moderately abundant
  - Rays indistinct without handlens
  - Parenchyma conspicuous with a hand lens, in fine, continuous tangential lines which are arranged irrespective of pores, reticulate pattern. Absent in earlywood zone.

- **Remarks**
  - Woods of hickory species very similar and indistinguishable with macro-anatomy.
    - Pecan hickories exhibit apotracheal banded parenchyma in the early-wood zones, while true hickories differ in not showing parenchyma bands in the early-wood.
    - Pecan also displays a graduation in size of pores from early to late wood.

- **Uses**
  - Tool handles (especially for impact tools like hammers, axes, picks, and sledges, hickory is unsurpassed because of its inherent qualities of hardness, strength, toughness, and resiliency), ladders, furniture, sporting goods, woodware and novelties, barbeque and smoking wood, fuel wood.

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**Pecan (Carya illinoensis.)**

- **General Characteristics**
  - Sapwood – whitish to pale brown
  - Heartwood – brown to rich reddish brown, sometimes containing streaks of a slightly darker hue.
  - Wood is without characteristic odor or taste
  - Straight grained, heavy to very heavy and very hard.
  - Earlywood – Large, thick walled, visible to naked eye, interrupted along growth ring boundary by areas of fiber mass, more gradual transition to smaller latewood pores.
  - Latewood – Pores not numerous, solitary and in radial multiples 2-3
  - Tyloses moderately abundant
  - Rays indistinct without handlens
  - Parenchyma conspicuous with a hand lens, in fine, continuous tangential lines which are arranged irrespective of pores, reticulate pattern. Present in earlywood zone.

- **Remarks**
  - Pecan hickories exhibit apotracheal banded parenchyma in the early-wood zones, while true hickories differ in not showing parenchyma bands in the early-wood.
  - Pecan also displays a graduation in size of pores from early to late wood.

- **Uses**
  - Similar uses to hickory, also flooring, barbeque and smoking wood.