HARDWOOD ANATOMY

- Vessels for water conduction
- Fibers for support
- Rays 1 to many cells wide
- Axial parenchyma rare to abundant
- In a few species gum canals in rays or occurring longitudinally, but not both.

Presentation by E.A. Wheeler, NCSU
BASICS OF HARDWOOD ANATOMY

SEM, Light Microscope, and Hand Lens Views
Vessels, axial parenchyma, and ray features
Most of these hardwood features typically used in hand lens wood identification
Enable you to interpret descriptions

Birch (genus *Betula*)
Top: SEM from SUNY,
Middle: Light microscope view, E. Wheeler,
Bottom: Hand lens view, FFPRI
More Cell Types in Hardwoods Than in Softwoods
Arrangement & Proportions More Variable

Below data for U.S. Hardwoods,

Vessel elements = 7-55 %
Fibers = 27-56 %
Ray parenchyma = 5-25%
Axial parenchyma = 0-23%

In Tropics where more species, even more variation
Right: pan-African species
Bauhinia thonningii
(Abuklameira, Kharub, Tambarib)
High proportion of axial parenchyma

Photo courtesy of L.Y.T. Westra, Utrecht University
The proportion of cell types (fibers, vessel elements, and rays) AND

The thickness of the cell walls

Affect the density of wood and its physical/mechanical properties

COTTONWOOD (genus *Populus*) with high proportion of vessels and fibers with thin cell walls, so very low density

\( X = \text{cross sectional surface (end grain)} \)

\( R = \text{radial surface} \)

\( r = \text{on top of a ray on the radial surface, looking at ray from a “side view”} \)

\( T = \text{tangential surface} \)

\( V = \text{vessel, vessels are “long ‘tubes”} \)

SEM from SUNY,
VESSEL DIAMETER AND FREQUENCY
Cell sizes determine texture
Woods with many narrow vessels usually fine textured.

Japanese Boxwood
*Buxus japonica*

Surface
End Grain. Cross Section
Cross Section

FFPRI Photos
VESSSEL DIAMETER AND FREQUENCY
Woods with few wide vessels usually coarse textured.

*Gluta renghas* (Anacardiaceae) RENGAS

End Grain. Cross Section  
Tangential surface  
Radial surface

Photos courtesy of L.Y.T. Westra, Utrecht University
VESSEL FEATURES
Visible in Cross Sections

- Porosity
- Groupings
- Arrangement
RING POROUS

- Earlywood zone with wide vessels (pores)
- Earlywood zone about same size each year.
- Abrupt transition from earlywood to a latewood zone with narrow vessels (pores), latewood zone is of variable width
- Common in temperate US woods, rare in tropical trees. Teak (*Tectona grandis*) grows in tropical monsoonal climates and sometimes is ring porous.
SEMI-RING POROUS
Vessel diameter **gradually** decreases from earlywood to latewood.

Staghorn sumac. *Rhus typhina*
Photo: L.Y.T. Westra, Utrecht University

Persimmon. *Diospyros virginiana*
DIFFUSE POROUS

- Vessel diameter about the same in earlywood and latewood

Birch, *Betula papyrifera*
Photo: E.A. Wheeler, NCSU
POROSITY
RING POROUS VS. SEMI-RING POROUS VS. DIFFUSE POROUS
Sometimes obvious which category wood fits into, but there are intermediates.

*Quercus robur* (Fagaceae) English Oak, a White Oak

*Juglans regia*: Circassian Walnut, European Walnut

*Entandrophragma candelolli* (Meliaceae) Kosipo, Omu

Photos courtesy of L.Y.T. Westra, Utrecht University
PORE GROUPINGS

- SOLITARY
- RADIAL MULTIPLES
- CLUSTERS
EXCLUSIVELY SOLITARY VESSELS

Lithocarpus solerianus (Fagaceae)
Tikalod, Mempening (L.Westra photo)

Lithocarpus edulis (Fagaceae)
Japanese Stone Oak (Photo: E.A. Wheeler)
Quercus rubra (Fagaceae)
Red Oak (L. Westra photo)

Calophyllum brasiliense (Clusiaceae)
Aceite, Leche, Palo de Maria, Santa Maria
(E.A. Wheeler photo)
MOST WOODS HAVE A MIXTURE OF SOLITARY VESSELS AND VESSELS IN RADIAL MULTIPLES (Radial multiple – 2 or more vessels grouped parallel to the rays, vessels have common walls). Below a “True Mahogany”

Swietenia macrophylla (Meliaceae)  
(photos: Left, L.Y.T. Westra, right: P. Gasson, Kew)
Maples (genus *Acer*) characterized by having some solitary pores and some radial multiples (usually 2-3 vessel per multiple). There is variation in what proportion of vessels are solitary and what proportion are in radial multiples.

Left photo: L.Y.T. Westra, Utrecht University, right: E.A. Wheeler, NCSU
VESSEL GROUPINGS: CLUSTERS

Cluster = a group of vessels, some side by side tangentially as well as radially. Vessel clusters occur in combination with solitary vessels and radial multiples.

Black Locust (*Robinia pseudoacacia*, Legume Family) Latewood vessels in clusters

Photo: E.A. Wheeler, NCSU
PORE ARRANGEMENT

- RANDOM
- TANGENTIAL
- RADIAL
- OBLIQUE / DIAGONAL
- DENDRITIC / FLAMELIKE

NOTE: THESE VESSEL ARRANGEMENT PATTERNS OFTEN INTERGRADE, ESPECIALLY RADIAL AND OBLIQUE / DIAGONAL
RANDOM. The most common arrangement

*Hymenaea courbaril* (Leguminosae)
Brazilian Cherry, Jatoba

*Koempassia malaccensis* (Leguminosae)
Kempas

Photos courtesy of L.Y.T. Westra, Utrecht University
Vessel Arrangement: Tangential (wavy – straight bands of vessels more or less arranged at right angles to rays)

If the wood is ring porous, check the latewood for vessel arrangement.

*Ulmus alata* Winged Elm, a Hard Elm

Left: E.A. Wheeler, NCSU. Right: L.Y.T. Westra, Utrecht University
Radial -- Diagonal -- Oblique

Lithocarpus solerianus (Fagaceae)
Tikalod, Mempening (L.Westra photo)

Calophyllum (Clusiaceae)
Santa Maria (L.Westra photo)
Vessel Arrangement: Dendritic (Branching) or Flamelike

*Castanea* (Fagaceae) Chestnut

*Castanopsis* (Fagaceae)

Photo L.Y.T. Westra, Utrecht University

Photo. E.A. Wheeler, NCSU
Quercus robur (Fagaceae) White Oak

Castanea sativa (Fagaceae) Chestnut

Photos: L.Y. Westra, Utrecht
TYLOSES

Outgrowths from adjacent parenchyma into a vessel, partially or completely blocking the vessel lumen.

Formed when air gets into a vessel.

L.Y. Westra photo

White Oak. SEM view of cross section. Photo.SUNY
Most hardwoods have 1--4 cell wide rays, will be barely visible to hand lens, and ray flecks not obvious.

*Betula lutea*
Yellow Birch

Tangential section  Radial section  Cross section

Hough Collection, NCSU Library
MAPLES: Ray width useful in id of maples. HARD MAPLES WIDEST RAYS > 4 CELLS WIDE, APPEAR AS WIDE or WIDER THAN THE PORES. Rays more obvious in hard maples than in soft maples, ray flecks on radial surfaces more obvious in hard maples.

Sycamore Maple.
Photo: L.Y. Westra, Utrecht

A Hard Maple
A Soft Maple

Acer saccharum
Acer pensylvanicum
RAY WIDTHS: If rays are 10 or more cells wide, they are easy to see with the eye on all surfaces. *Fagus* (Beech) has wide rays.
Some hardwoods have 1 cell wide rays (e.g. cottonwoods (*Populus*), willows (*Salix*), Chestnuts (*Castanea*). Rays would NOT be visible to naked eye and not obvious with hand lens.
**STORIED STRUCTURE** = cells arranged in tiers (horizontal series as viewed on the **tangential** surface).

Shown here all rays storiéd.

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Tiers of rays visible with hand lens

*Pterogyne nitens*: L.Y.T. Westra
*(Leguminosae - Caesalpinoideae)*

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*Bergeronia sericea*: P.E. Gasson
*(Leguminosae - Papilionoideae)*
AXIAL PARENCHYMA ARRANGEMENT

CATEGORIES:

APOTRACHEAL

'Away from' / **NOT** associated with the vessels

PARATRACHEAL

'Paired With' / Associated with the vessels

BANDED

In general, axial parenchyma more abundant in Tropical Woods than in Temperate Woods.

Many woods have a combination of parenchyma patterns, with both apotracheal and paratracheal parenchyma present.
Diffuse-in-Aggregates: parenchyma strands grouped into short discontinuous tangential or oblique lines.

Usually diffuse-in-aggregates axial parenchyma arrangement not visible to eye, sometimes can see with handlens, when abundant.

Persimmon. *Diospyros virginiana*
PARATRACHEAL

Vasicentric: parenchyma cells forming a complete circular to oval sheath around a vessel or vessel multiple.

Handlens view of XS of *Acacia*. Vasicentric parenchyma appears as yellow halos around the solitary vessels and the vessels in radial multiples. Note the ray parenchyma and the axial parenchyma appear the same color.

*Chlorocardium rodiei* Lauraceae
Greenheart. L.Y.T. Westra photo
Width of vasicentric sheath varies and can intergrade with Aliform (next slide).

*Inga* (Leguminosae)
L.Y.T. Westra photos

*Balizia pedicellaris* (Leguminosae)
Tamalin
PARATRACHEAL

- **Aliform**: parenchyma surrounding a vessel or vessel multiple & with lateral extensions.

- **Confluent**: parenchyma surrounding different vessels or vessel groups coalesce.

Handlens view of XS of Tropical Legume. Wood has both aliform (parenchyma around the vessels with wing-like extensions) and confluent parenchyma (wings around vessels close to one another meld together).
PARATRACHEAL

- Ash has vasicentric, aliform and confluent parenchyma.
- Confluent in the ‘latest’ latewood.
- Vasicentric in first part of latewood.

Ash, *Fraxinus*
MARGINAL PARENCHYMA

- Axial parenchyma right along the growth ring boundary.
- Also called boundary parenchyma

True Mahogany, Swietenia. Light colored line at growth ring boundary. Some Paratracheal parenchyma also present. Photo: L.Y.T. Westra

Yellow Poplar, Liriodendron tulipifera. Light colored line at growth ring boundary (at right angles to rays). Diffuse porous wood with many narrow vessels.
BANDED PARENCHYMA

Bands can be paratracheal or apotracheal.
Width of bands varies. Spacing between bands varies.
HARDWOOD ANATOMY

- Vessels for water conduction
- Fibers for support
- Rays 1 to many cells wide
- Axial parenchyma rare to abundant

Have met some of the hand lens features, there are microscopic features as well, which are important for wood id.