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Inside Trees

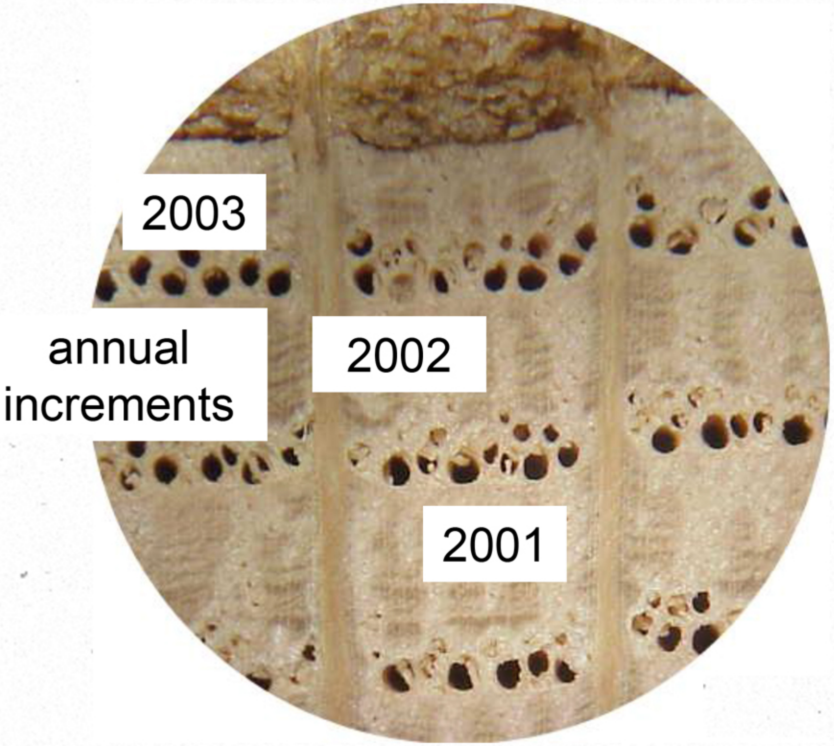
Tree Anatomy, Physiology, & the Translocation of Injected Dye in Trees using Trunk Injection Methods

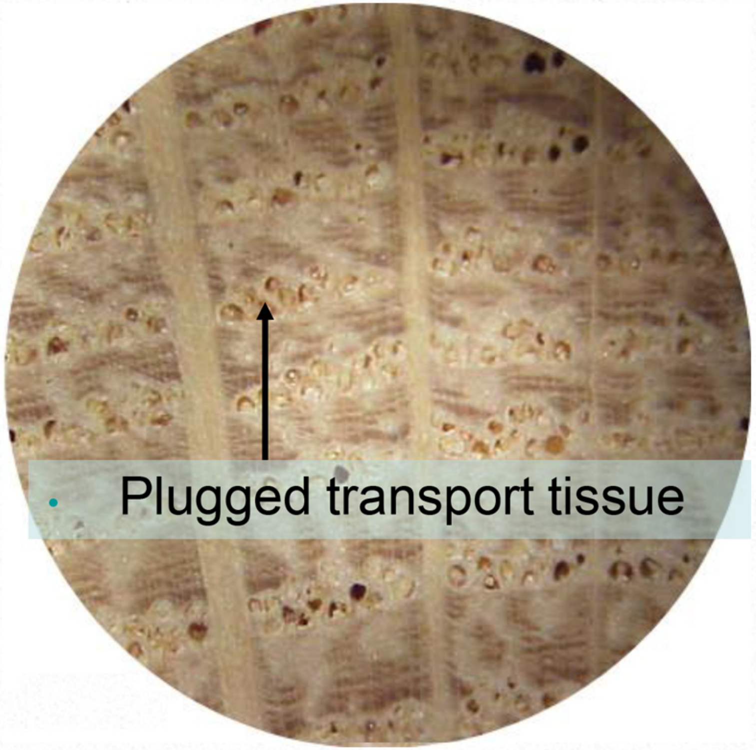
Ring Porous: Hardwoods

- Ring Porous
- Diffuse Porous
- Non-Porous

The following 3 anatomical images
were made at the same (20x) magnification
to illustrate the relative size of the vascular tissues

Ring Porous: Hardwoods

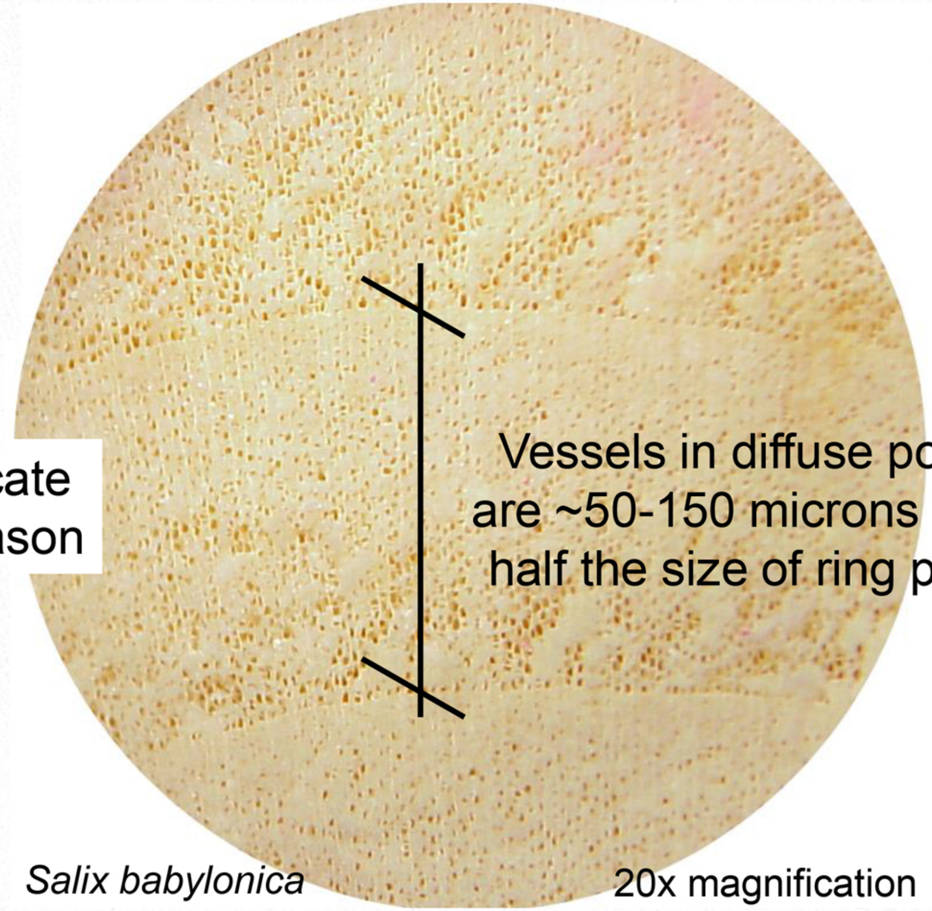




Quercus velutina

Vessels, large ~ 100-300 microns in diameter

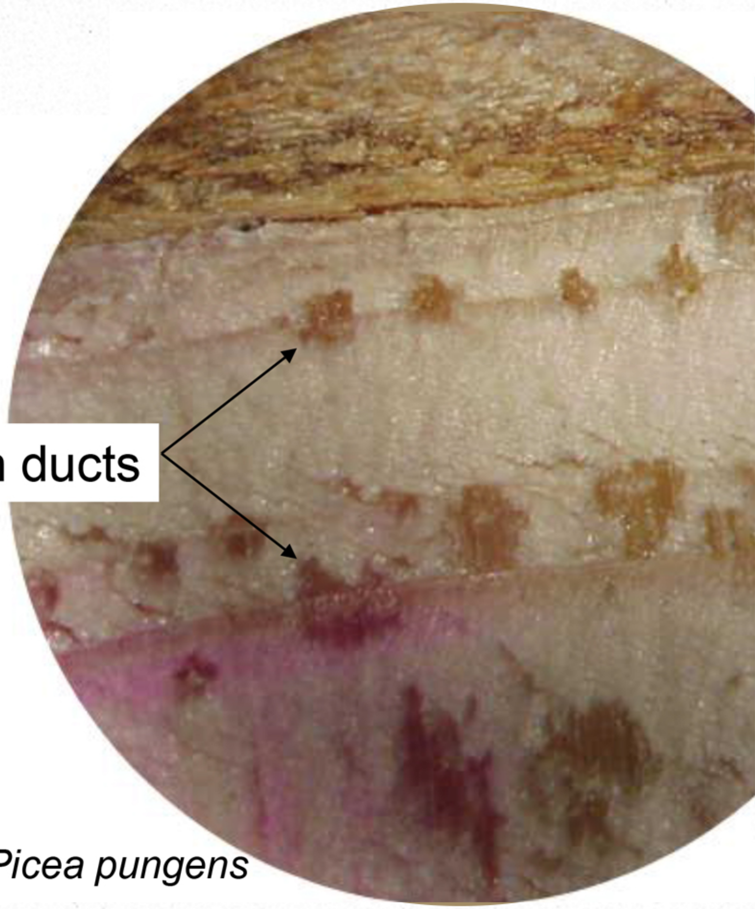
Diffuse Porous: Hardwoods



Salix babylonica

20x magnification

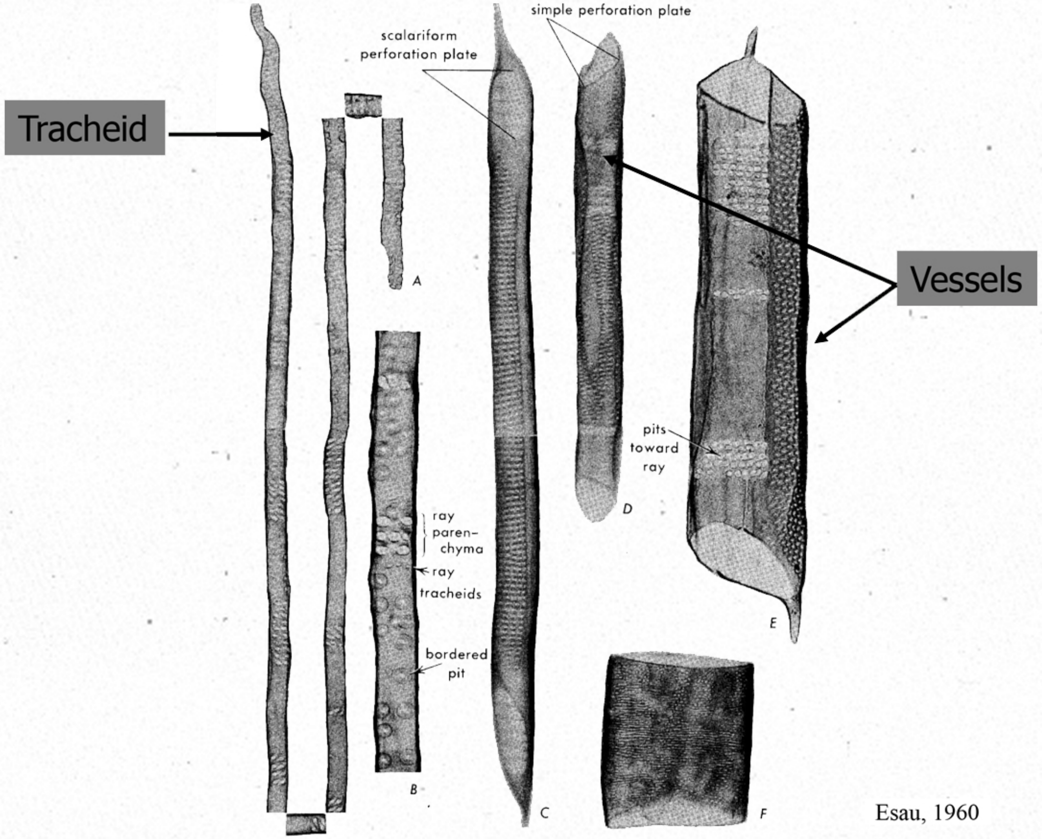
Non-Porous: Conifers



Picea pungens

- Movement of infused dye is via tracheids only
- Tracheids are 10-20x smaller than vessel elements, ~25-50 microns across
- Injections are more difficult in non-porous trees
- Dye appears pink

Gymnosperms (conifers) have only tracheids for water transport Angiosperms (flowering plants) have both vessels and tracheids, and rely primarily on vessels for water transport.

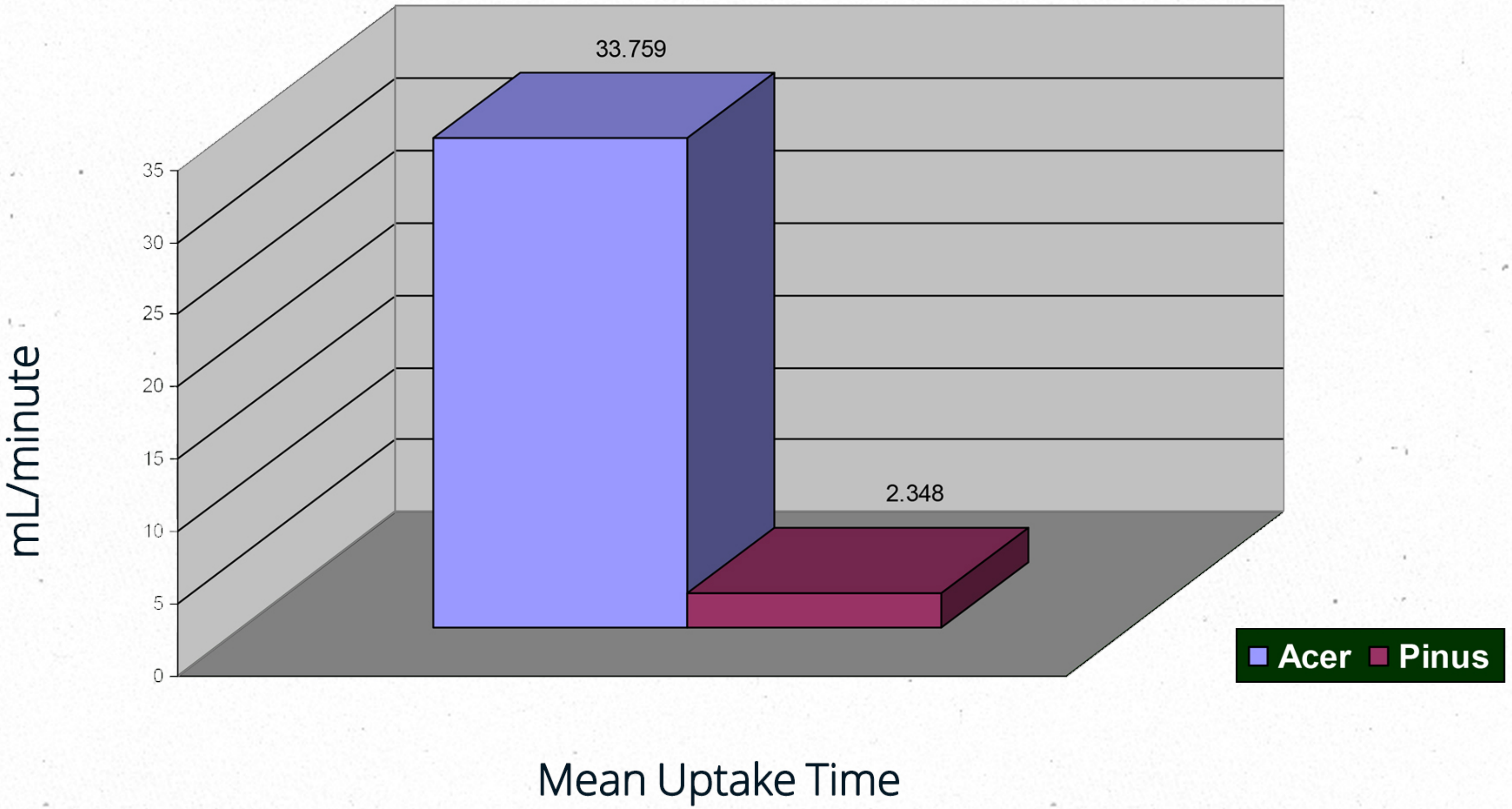


Note relative diameter size of Tracheid to Vessels

Applying the Hagen-Poiseuille equation to tracheids and vessels produces some highly significant results:

Conduit Type	Relative Diameter	Relative Flow Rate
Tracheid, 20 m	1x	1x
Vessel, 40 m	2x	16x
Vessel, 80 m	4x	256x

The Rate of Uptake in Maple is ~15X that in White Pine



Porosity of Various Tree Species

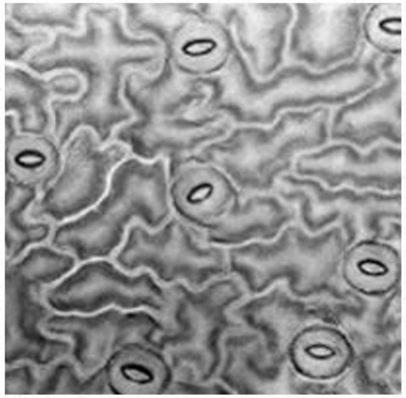
Ring Porous	Diffuse Porous	Non-Porous
Ash	American hornbeam	Conifers
Catalpa	Beech	
Chestnut	Birch	**Resinous Conifer Wood**
Elm	Cherry	Pine
Hackberry	Blackgum	Spruce
Hickory	Dogwood	Douglas-fir
Kentucky Coffeetree	Hophornbeam	Larch
Locust	Horsechestnut	
Mulberry	Linden	**Non-Resin Conifers**
Osage-orange	Live oak	Hemlock
Pin oak	Poplar	Fir
Red oak	Magnolia	Redwood
Sassafras	Maple	Cedar
White oak	Sourwood	Yew
	Sweetgum	
	Sycamore	
	Tulip poplar	
	Willow	

Stomata Physiology: **Plant-Water Relations**

- The Stomata: Function & Regulation
- Water
- Carbon Dioxide
- Root uptake of water and dissolved solutes
- Stomatal response to moisture loss
- Seasonal variations

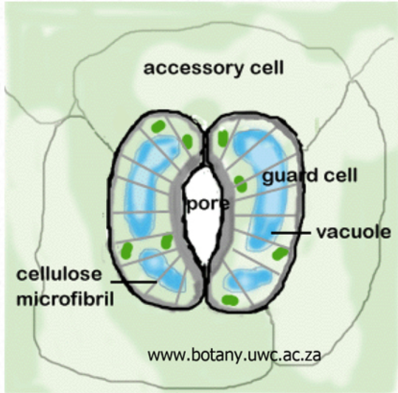
> - What's the matter with your stomata? -
>
> Joe Doccola Director of R&D

The Stomata



Stomata are the pores in the leaves that control:

1. moisture loss,
2. gas exchange and
3. evaporative cooling.

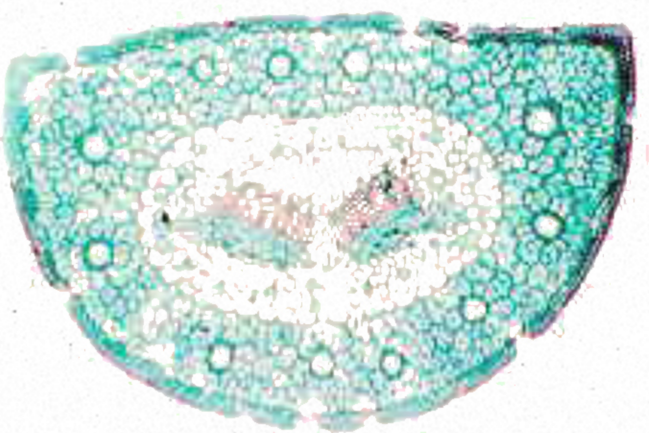


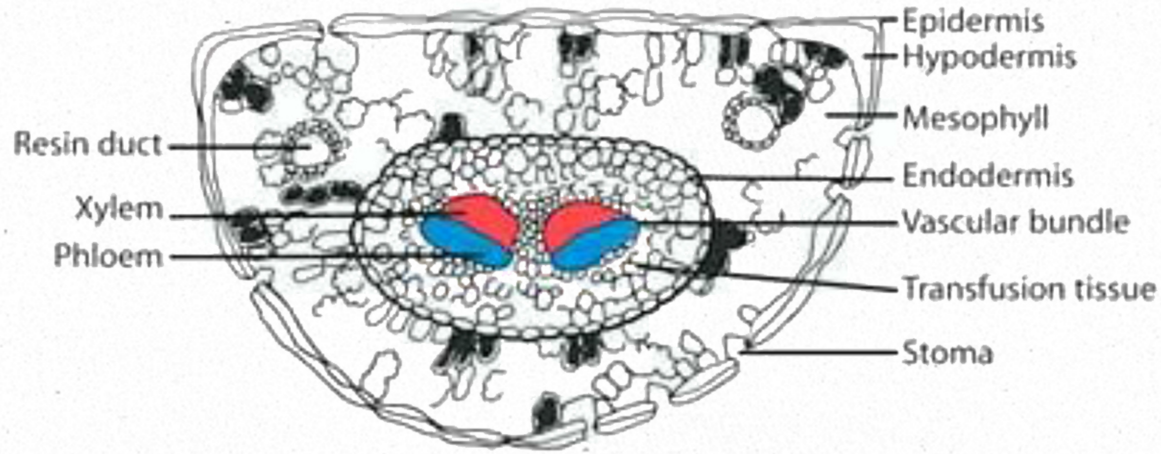
Stomata open and close in response to:

1. temperature changes
2. the water vapor pressure gradient of the leaf (inside:outside)
3. the plant's internal biological (circadian) rhythm.

The Functions of the Stomata

- Gas exchange (O2, CO2)
- Evaporative cooling
- Maintenance of leaf turgor pressure

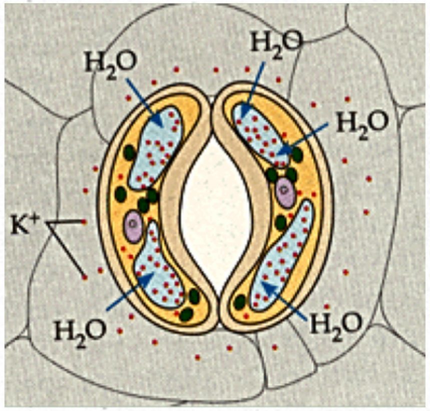


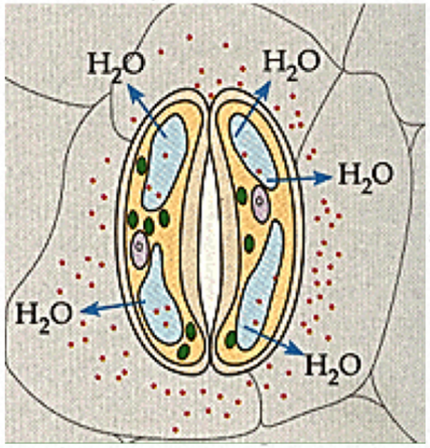


Regulation of Stomata

- Stomata open in humid environment, close when dry.
- When [CO_2] outside the leaf is low, the stomata open; when [CO_2] is high, stomata close.
- The stomata of most species are closed in darkness.
- Stomatal opening and closure can be ”patchy”.

Sequence of Events Leading to Guard Cell Movement





Stomatal opening

- H+ pumped out of guard cells in response to light stimulus.
- Electrochemical gradient drives K+ diffusion into guard cell.
- Cl- also taken up by guard cell.
- Malate (organic anion) produced in cytosol of guard cell.
- Buildup of K+, Cl-, and malate increases osmotic potential, causes influx of H2O.
- Guard cell volume increases, and stomate opens.

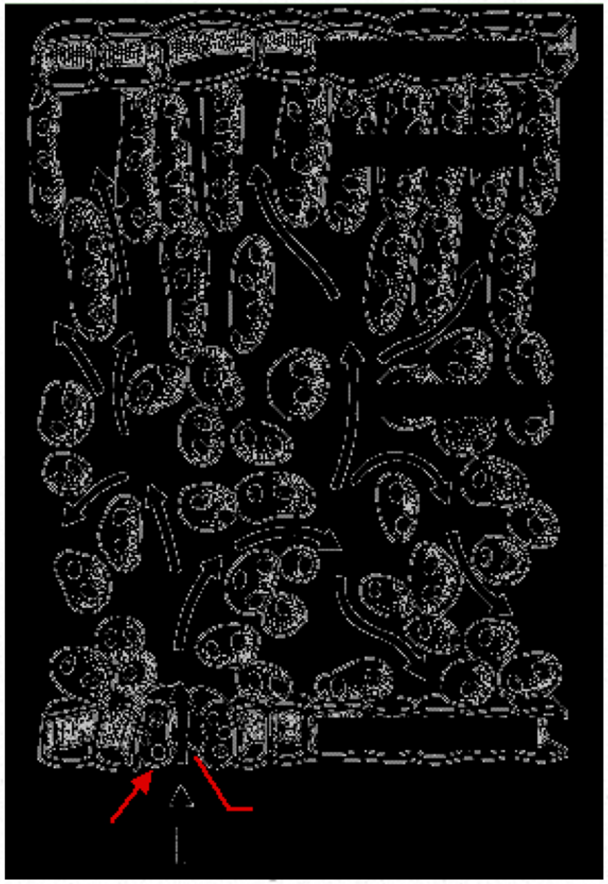
Stomatal Closing

- H+ pumps stop.
- K+ and Cl- diffuse out of cell.
- Malate is degraded.
- H2O moves out of cell as osmotic potential falls, and stomate closes.

Water

- Less than 1% of all the water absorbed by plants is used in photosynthesis.
  – Most of the remainder is transpired or incorporated into the plant.
- If water is in short supply, stomata usually close.
  – The supply of carbon dioxide available for photosynthesis is thus reduced.

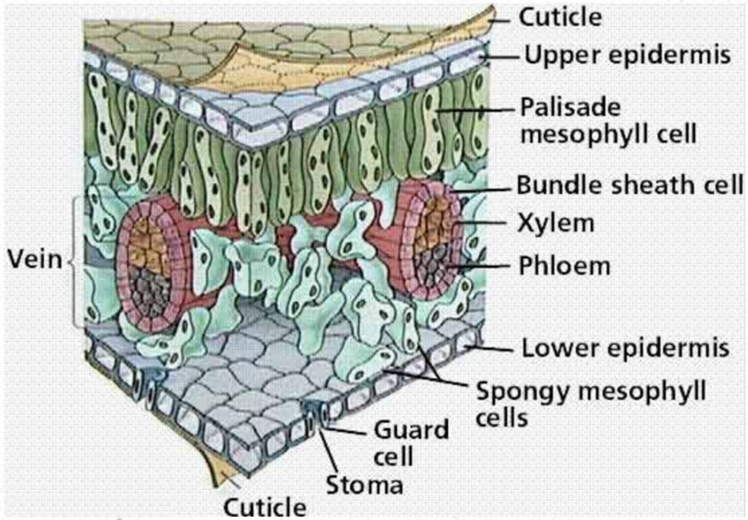
Rate of Water Loss Plants can regulate some aspects of fluid transport.



» A plant cannot control the direction, but can regulate the rate of xylem sap flow by changing the rate of evaporation from its leaves.

» Over 90% of the H2O that is lost to transpiration actually evaporates within the airspaces of the spongy parenchyma, and diffuses out the stomata into the atmosphere.

» Plants close their stomata during the night and open them again at dawn. These changes are triggered by both external factors (light and availability of CO2) and internal factors (biological clock).

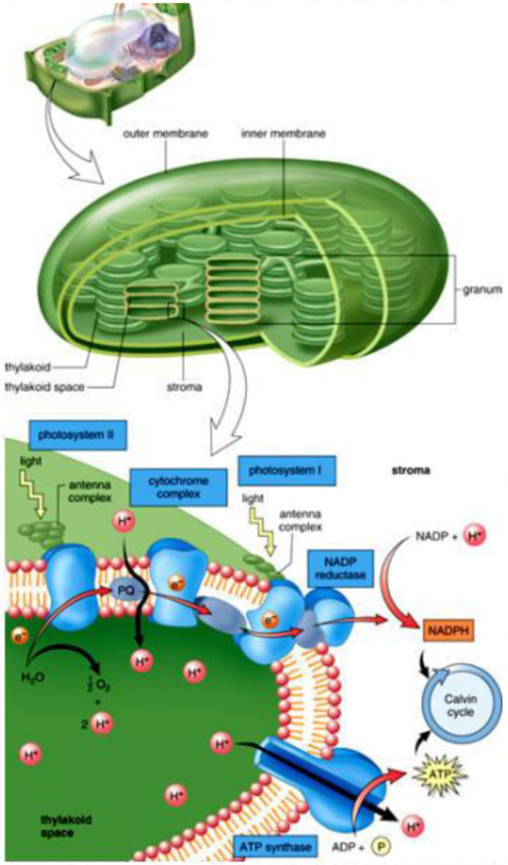


Carbon Dioxide

- Carbon dioxide reaches chloroplasts in the mesophyll cells by diffusing through the stomata into the leaf interior.

- Closing stomata conserves H_2O, but also cuts off atmospheric CO_2 to the photosynthetic cells.

Light Energy Captured as Sugars



• Light energy is captured in the form of glucose

– Trees are autotrophic ie., they

MAKE THEIR OWN FOOD

• Needles: site of photosynthesis

– Requires light energy, H2O and CO2 to synthesize sugars

Active Uptake of Inorganic Ions

• Inorganic ions do not simply flow with the water, passing into the roots.

• They are actively accumulated by epidermal cells, passed through cortical cells and finally secreted by the endodermis cells into the xylem stream

— this requires the expenditure of energy.

The Route (i.e., from root to shoot) of Inorganic Ions

Element	Ion (charge)
Nitrogen	NO_3^- or NH_4^+
Phosphorous	PO_4^{3-}
Potassium	K^+
Calcium	Ca^{2+}
Magnesium	Mg^{2+}
Sulfur	SO_4^{2-}

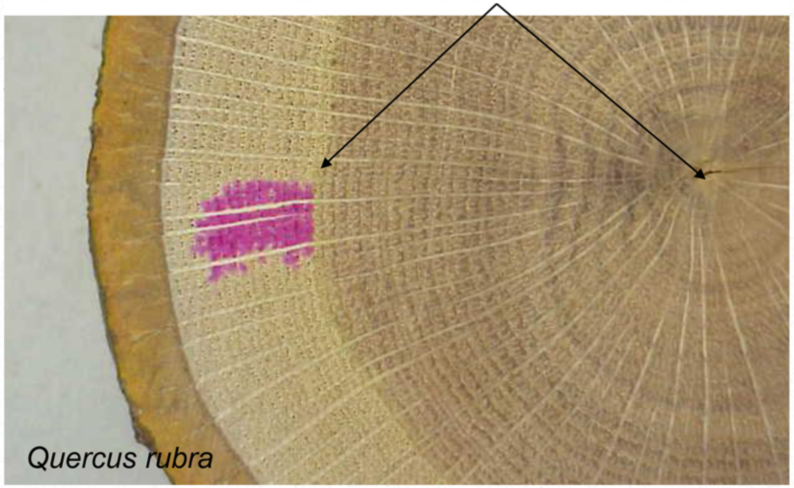
Implications for Trunk Injection

- Make applications when trees are transpiring
- Fall is the best season for uptake
- Spring is second best
- For hemlock, early morning and evenings are best
- Avoid heat of day, when stomata are likely to close
- During summer, irrigate trees prior to treatment

Movement of Injected Materials

Ping Porous Red oak

- Translocation of injected dye (pink) occurs in the sapwood
- Tyloses in red and black oaks occur naturally in heartwood
- Translocation does not occur in the heartwood



Ring Porous *Quercus rubra*

- Translocation of injected dye is associated with the infusion legs

Ring Porous *Quercus rubra*

White oak

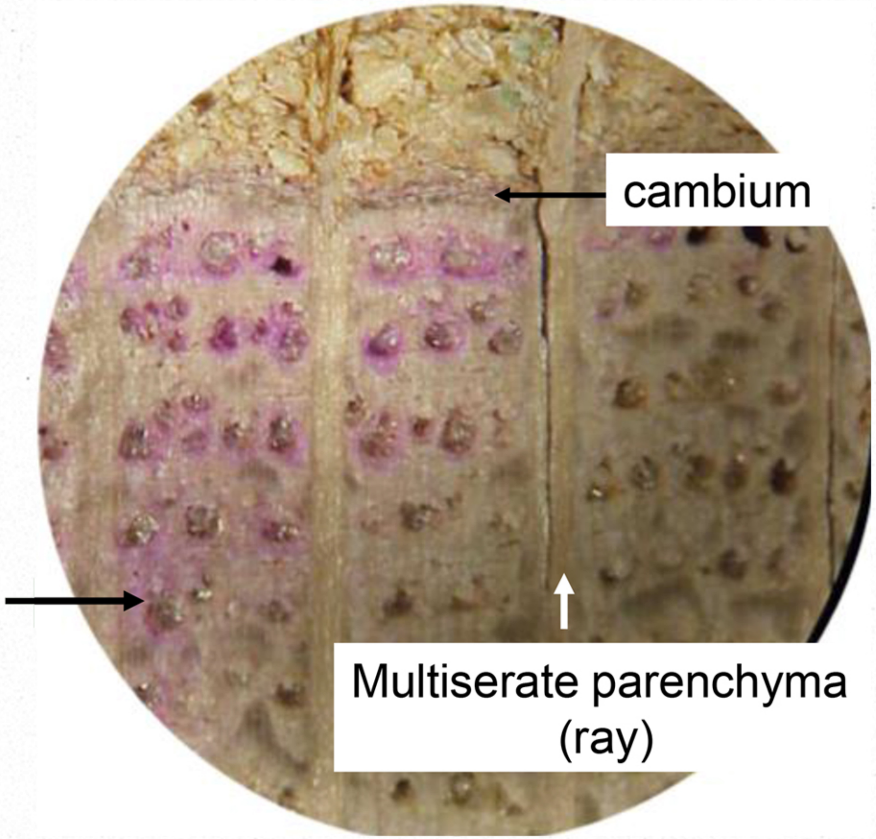
plugging of sapwood naturally

occurs after the first increment

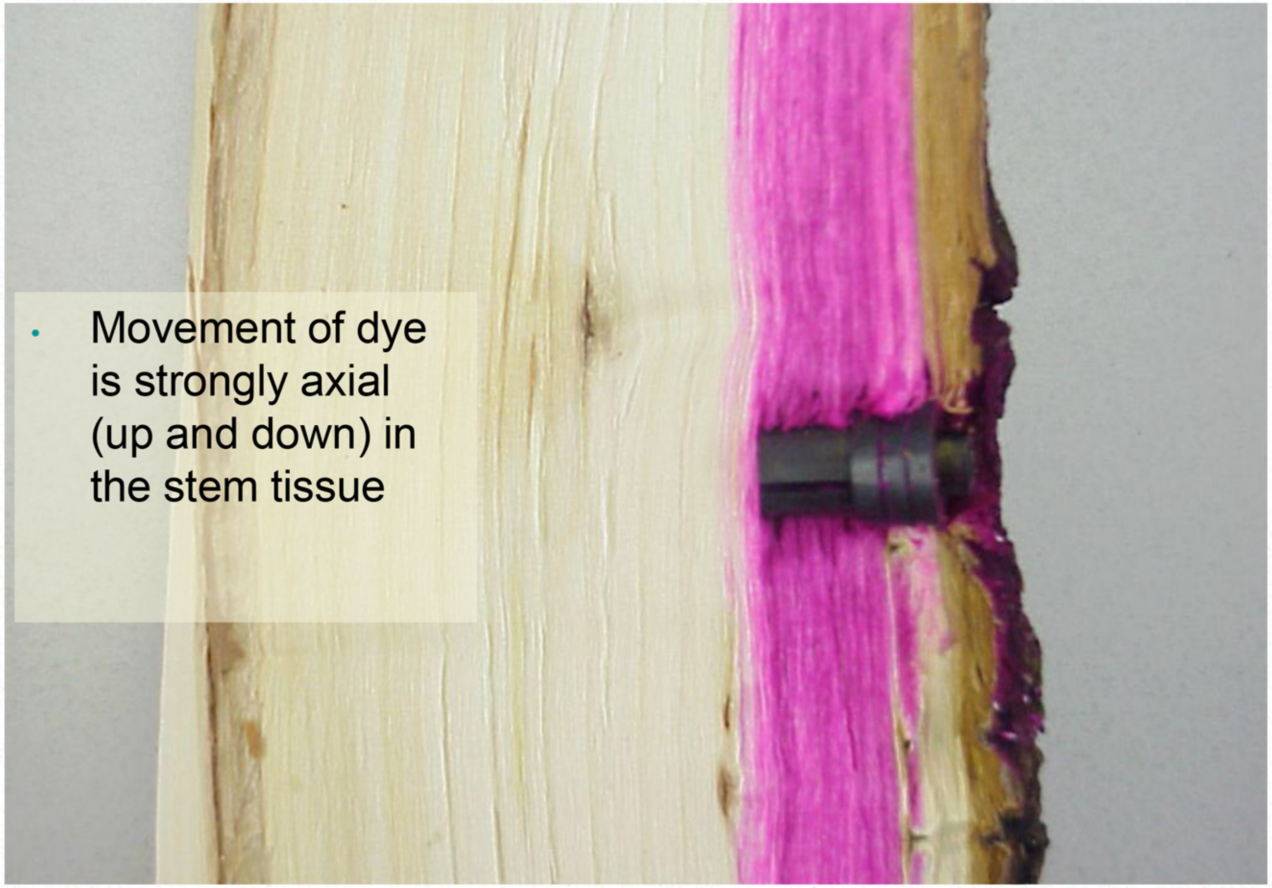
(growth season) movement of dye

in this sample occurred to the fifth

growth increment

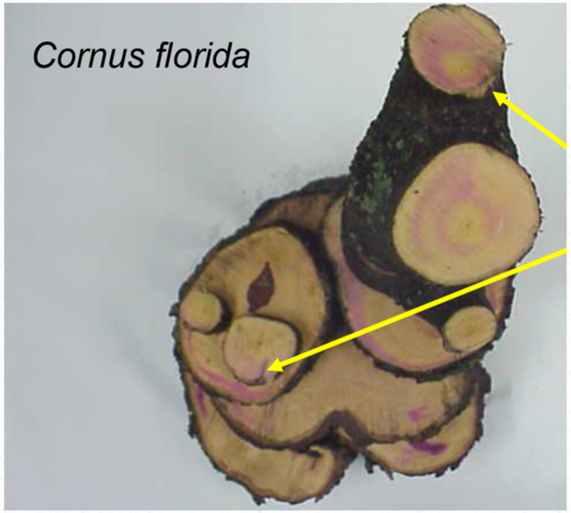


Diffuse Porous *Salix babylonica*

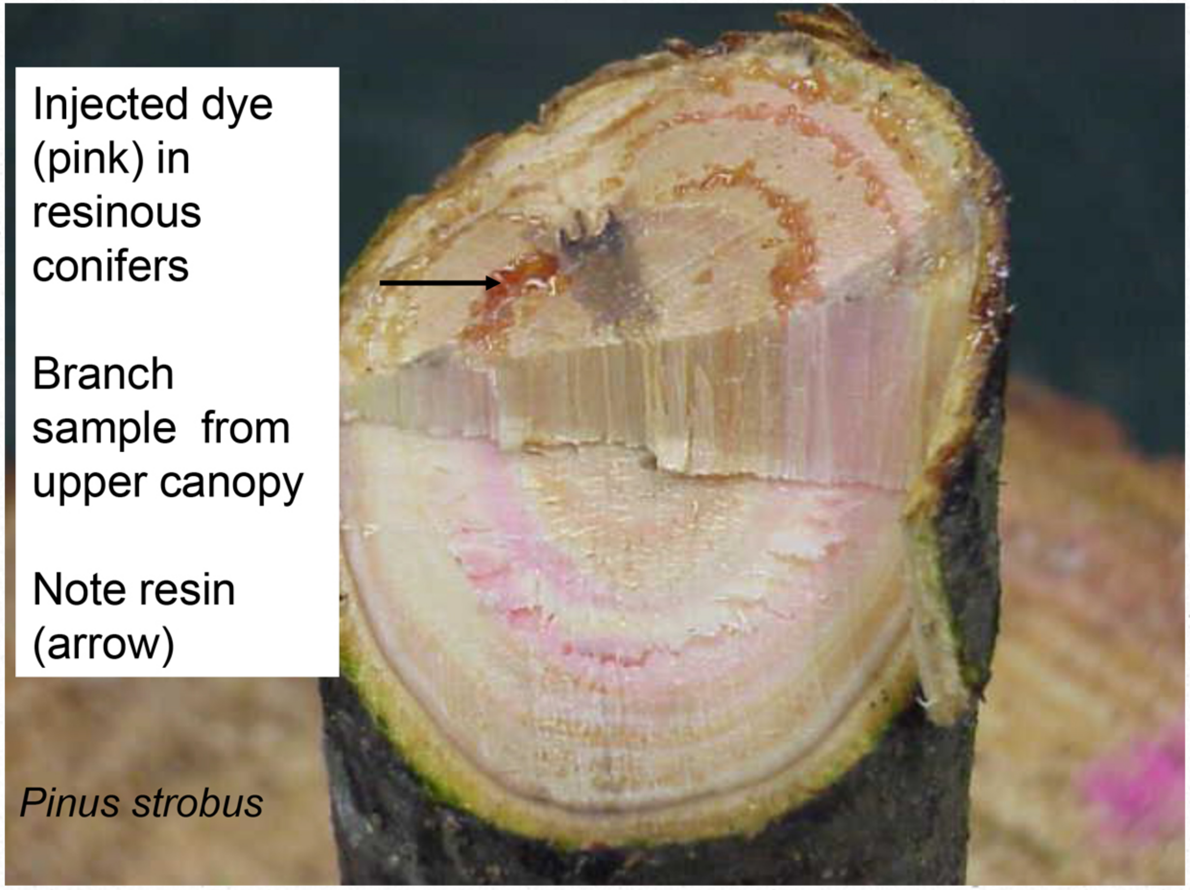


Diffuse Porous

- Trees are dissected following injection
- The distribution of dye is determined and related to number per DBH used
- Canopy sampling is also used to establish the presence of dye



Non-Porous Conifers



Non-Porous Conifers

- Resinous wood species, e.g. Pine & Spruce
  - Inject immediately after setting port
  - Port may fill with resin if injection is delayed

Non-Porous Conifers

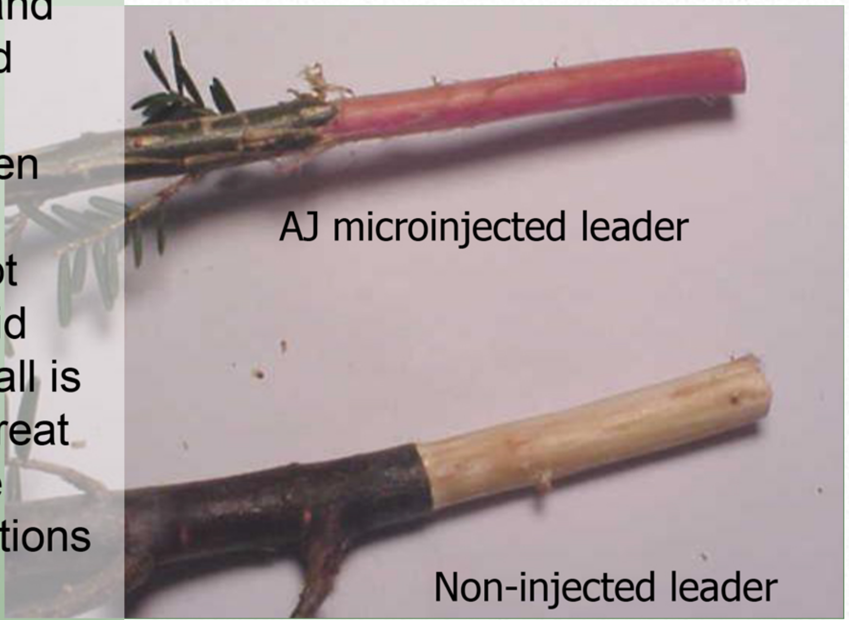
Tsuga canadensis

- Hemlock is non- resinous, but denser than pine or spruce.

- Use high volume, low pressure micro- infusion to make trunk applications.

Non-Porous Conifers

- Fall microinjection—conifers uptake and distribute injected materials preferentially when environmental conditions are not conducive to rapid moisture loss. Fall is an ideal time to treat conifers because moist, cool conditions are favorable to uptake.



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