Tree Biology

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with
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Overview

- Water
- Roots
- Root Collar
- Trunks/Branches
- CODIT
- Leaves
- Photosynthesis and Respiration

Many 'general' concepts

- There are always exceptions in nature / biology
- The real answer to any biological questions is: "It depends…"
- All general rules will differ slightly based on:
  - Species
  - Weather
  - Growing conditions / Environment
  - Age, growth stage
  - Vigor
  - And more…

What is a tree?

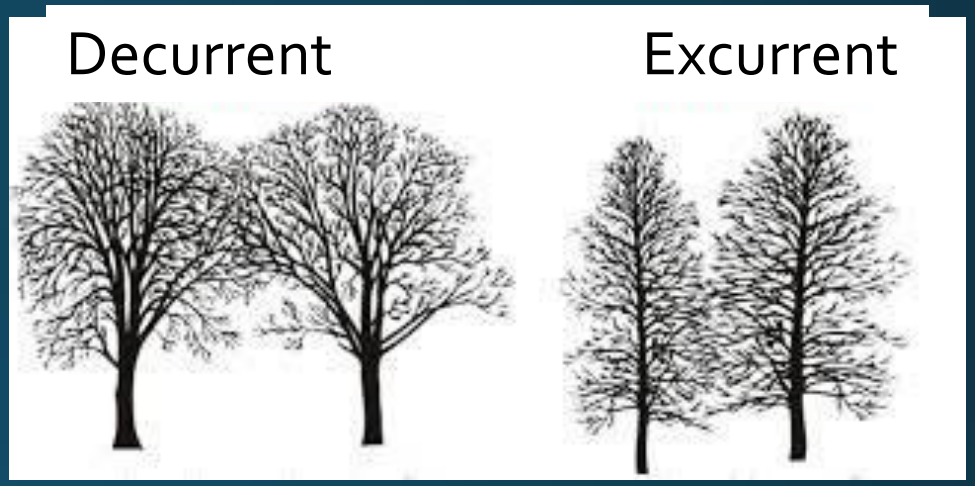
- A woody perennial plant with a single or multiple trunks.
- Alex Shigo:
  - Woody
  - Long-lived
  - Compartmentalizing perennial that resists attack

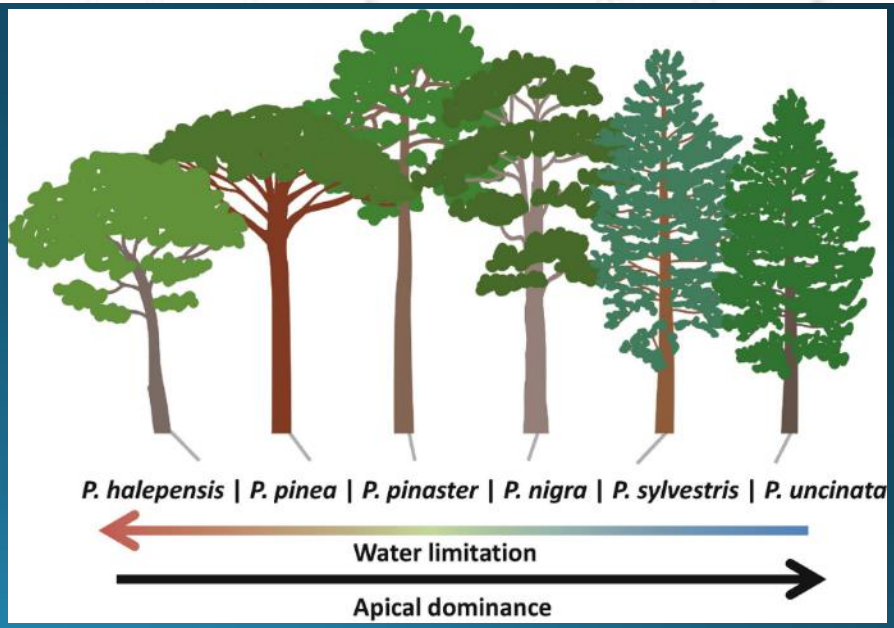
Gardening = how to grow plants
Physiology = how plants grow

- **Goal**: be able to explain the physiological basis for any practice / recommendation.
  - pruning
  - soil management
  - disease & insect management
  - cultural practices
  - planting
  - irrigation
  - species selection

Morphology influenced by Physiology

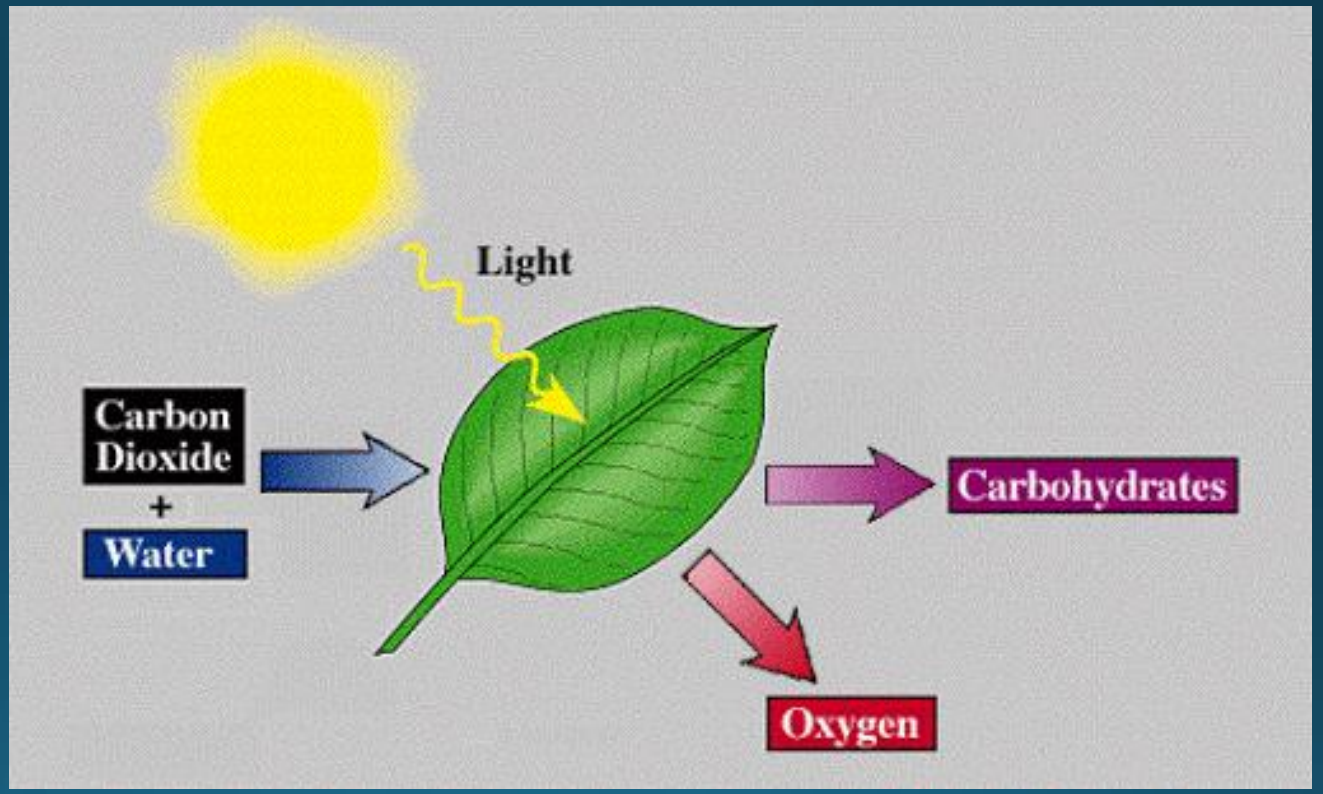
- Excurrent vs. Decurrent tree growth
- Species dependent apical dominance
- But, same species in forest vs. field can show excurrent or decurrent growth form
  - Light driven, which is really hormone driven
  - Water availability can also drive growth form
- Tropism- Geotropism and Phototropism
- Pruning can temporarily change form.
  - Alters hormone balances





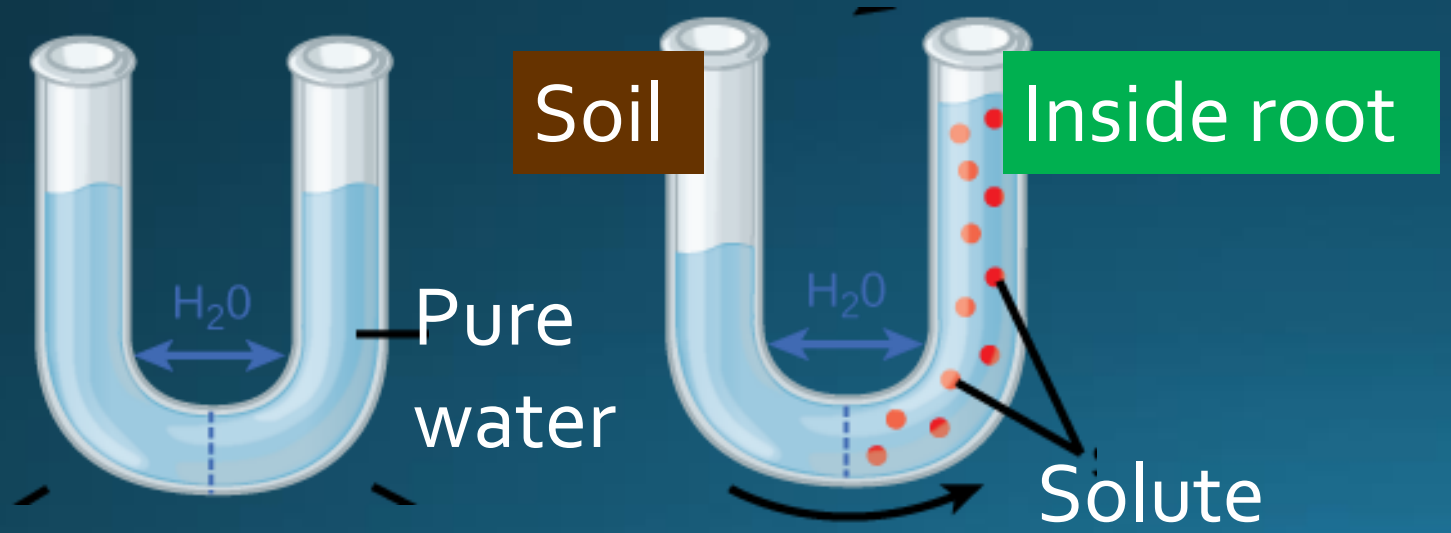
What do plants *need* to live & grow?

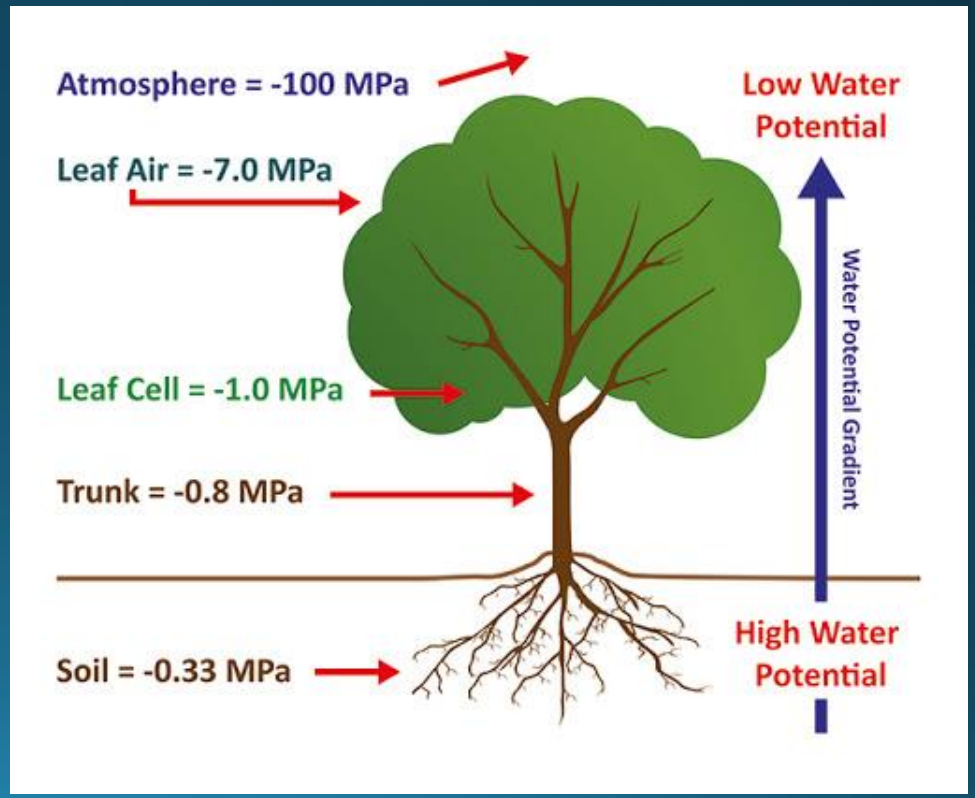
- Sunlight
- Water
- Carbon dioxide
- Oxygen
- Nutrients
- Space
- Microbes



Water

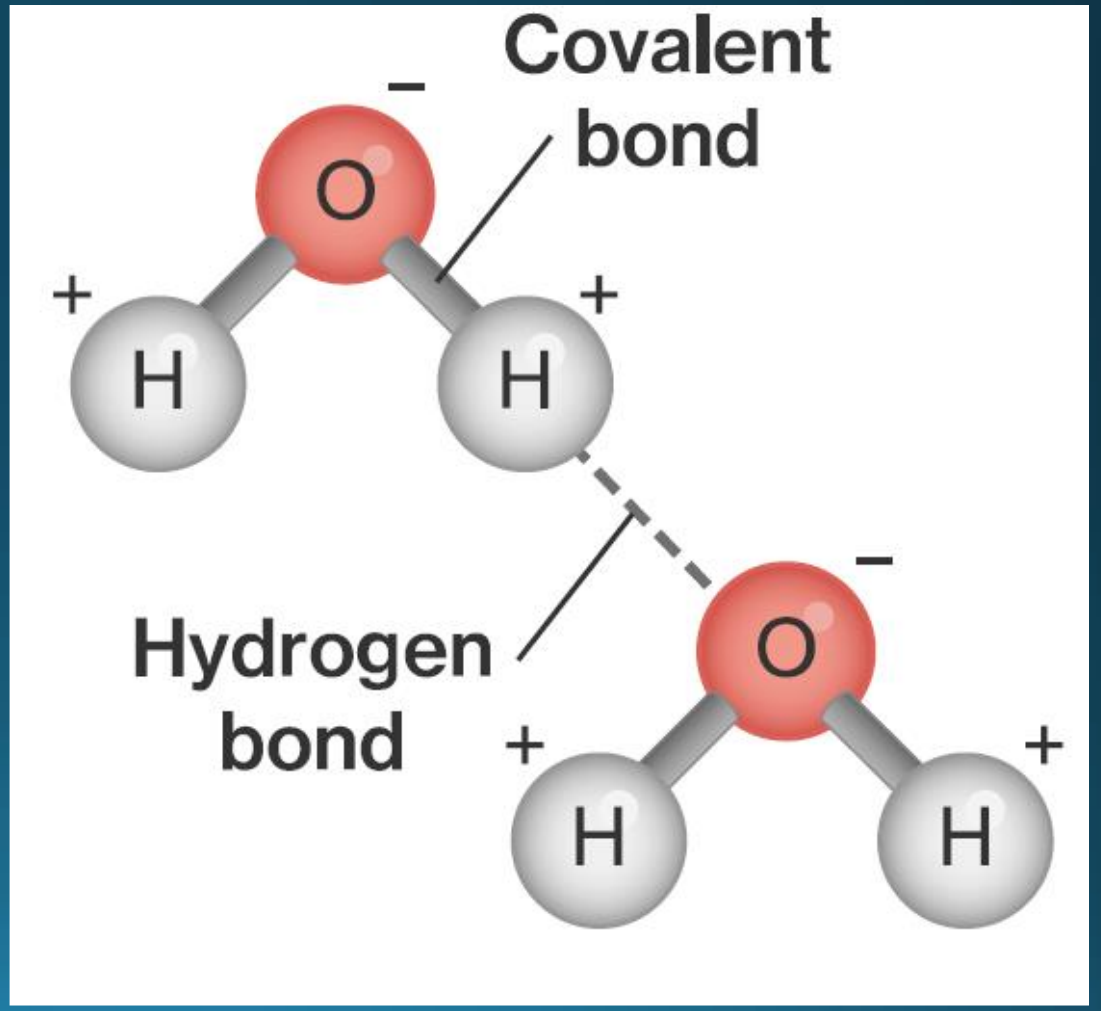
- Gradients dictate the flow of all things…
- Water (and all liquids and gasses) will move from high to low 'potentials'
  - Dissolved solutes will 'pull' water
  - Low vapor pressure (humidity) will 'pull' water





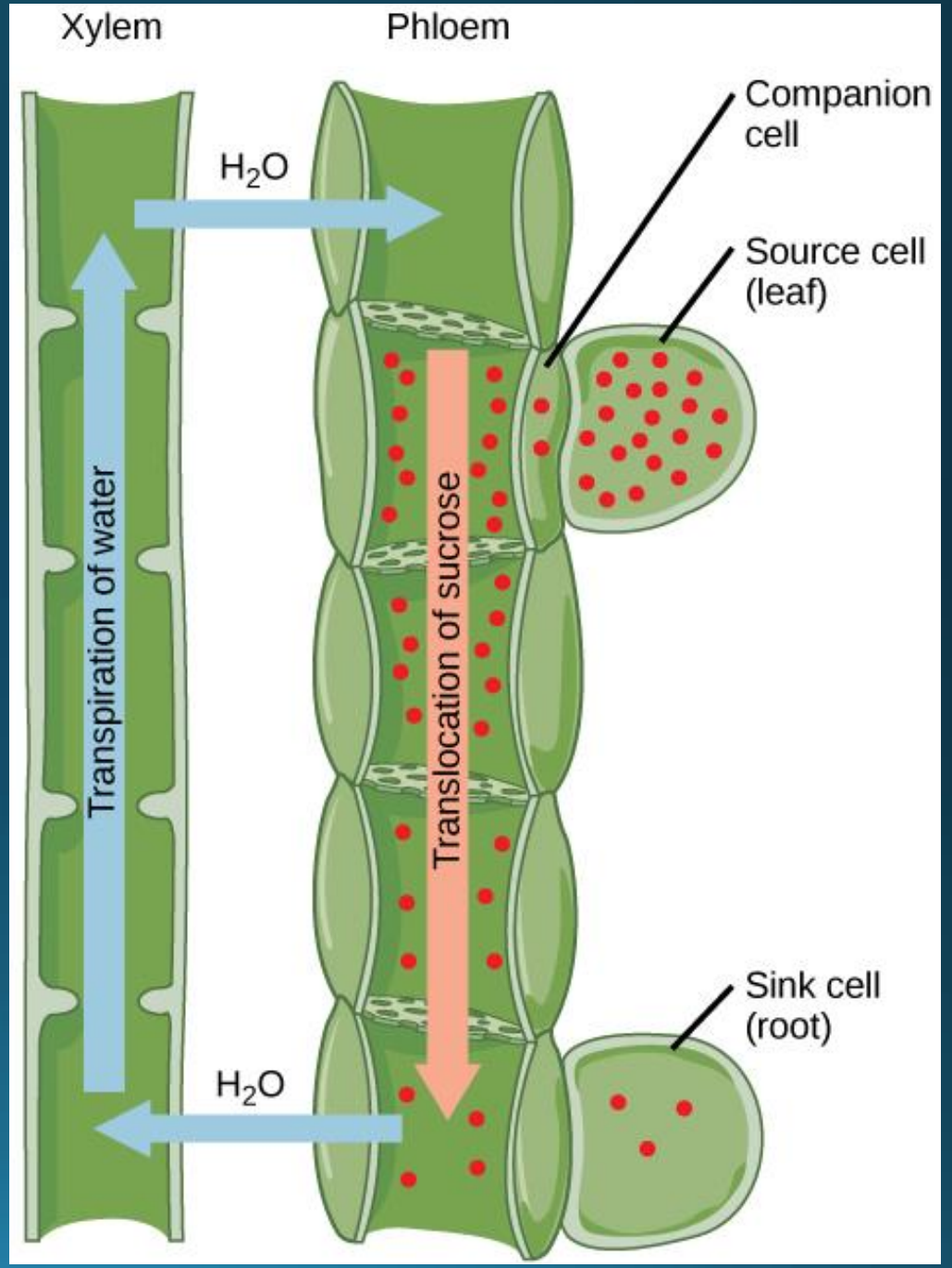
How can water be 'pulled'?

- **Water is 'sticky'**
- **Hydrogen bonds**
  - Electrons 'hang out' near oxygen more than hydrogen, imparting a slight polar charge to the molecule
  - Opposite charges attract
  - This is why water can be 'pulled'
  - This is why water dissolves other molecules (good solvent)
- This is how straws work
  - Xylem is essentially a bundle of straws



Xylem and Phloem

- Xylem moves water up
  - Located to inside of cambium
  - Cells are dead when in use
  - Straws – water pulled up
  - Water can leave laterally
  - Solutes can enter xylem
- Phloem can move materials in any direction
  - Located to outside of cambium
  - Cells are alive
  - Source to sink - ***gradient***

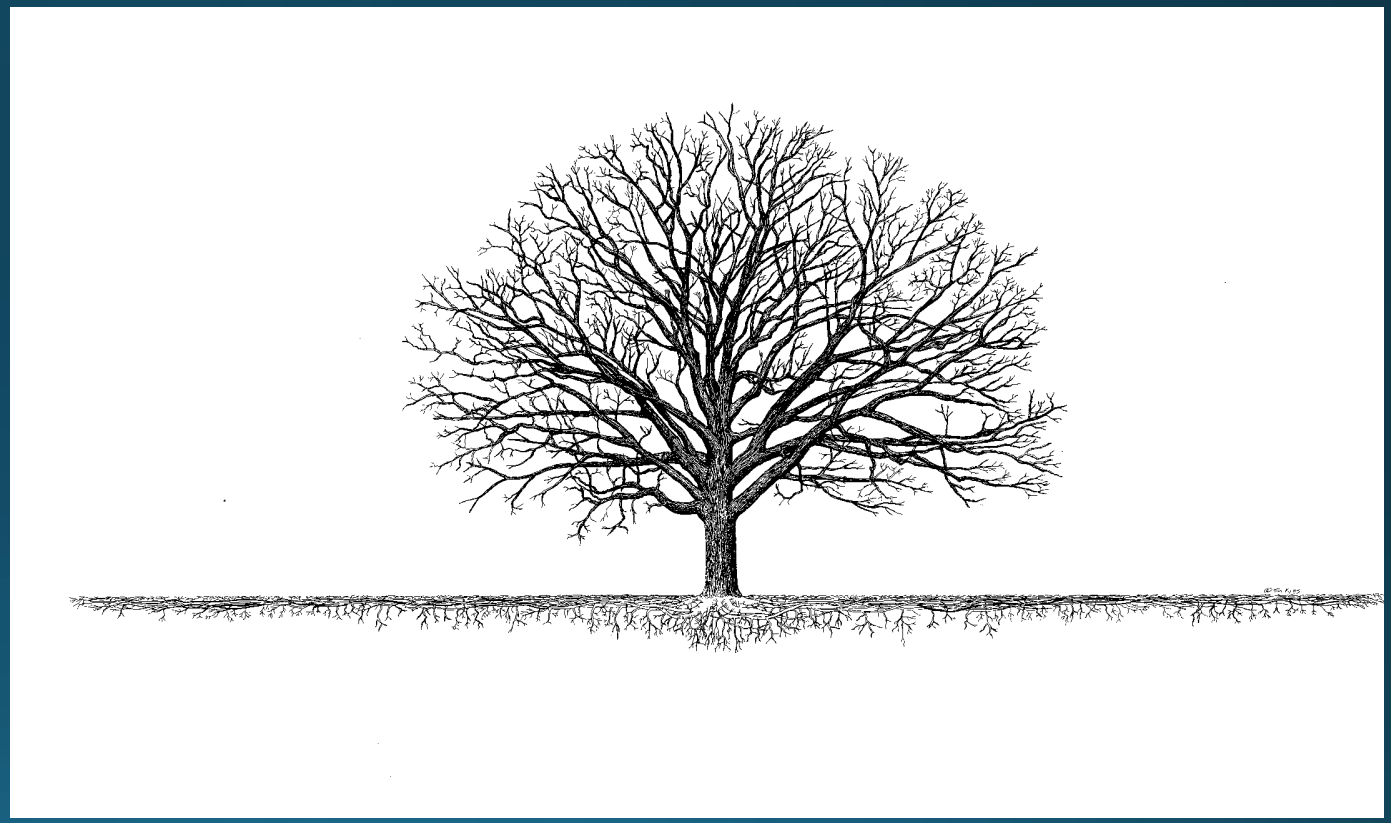


What is water doing in plants?

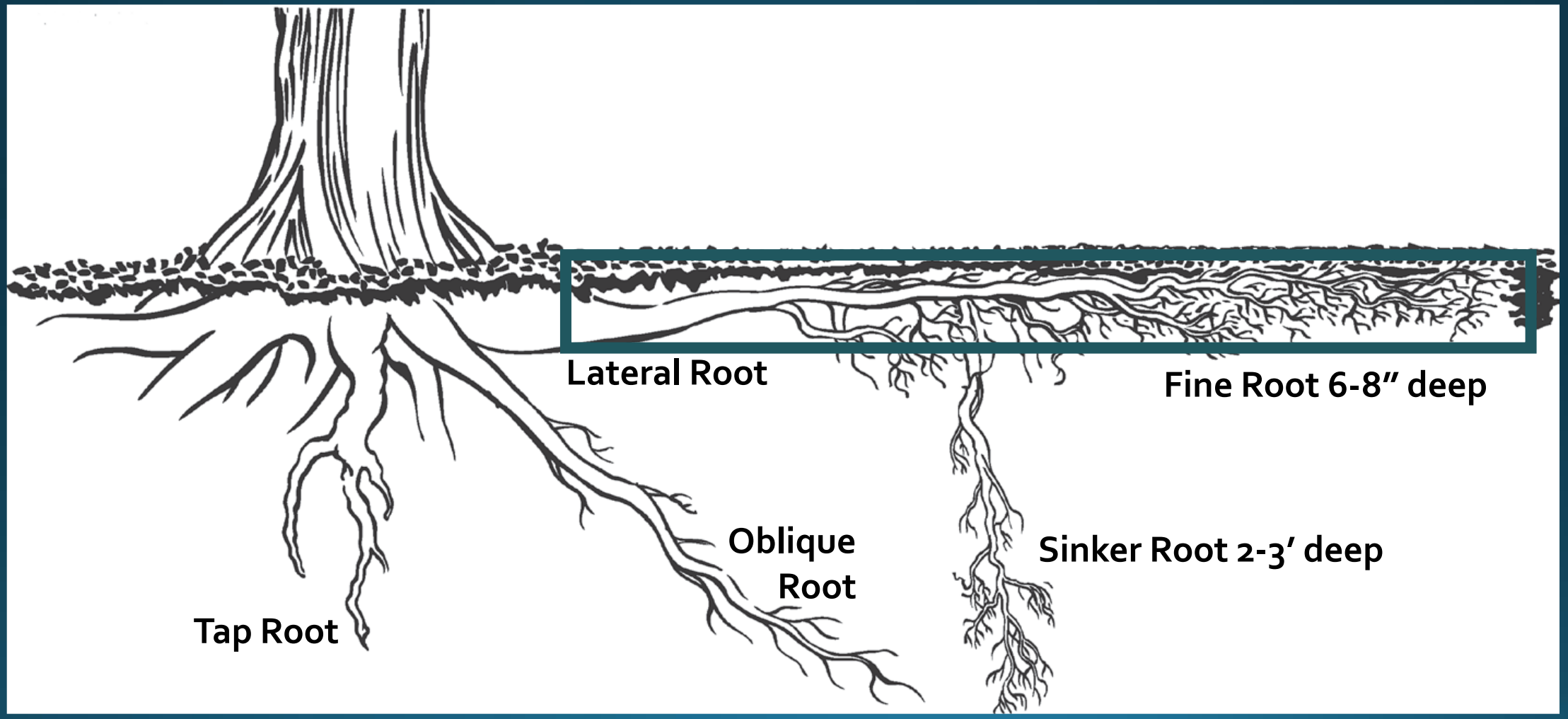
- Life requires water – all living cells are mostly water
- Cell expansion – turgor (hydraulic) pressure expands cells
- Transport – anything* that moves in plants is in water
  - Nutrients, carbohydrates, hormones / signals*, pesticides / herbicides, pathogens (*Verticillium* spores), *carbon dioxide*, *oxygen*
- Photosynthesis – water splitting reaction (negligible amount)
  - But very important if you like to breath oxygen…
- **VAST MAJORITY of water is 'lost' via stomata / transpiration**
  - **Necessary part of gaining carbon dioxide.**

Morphology – Roots

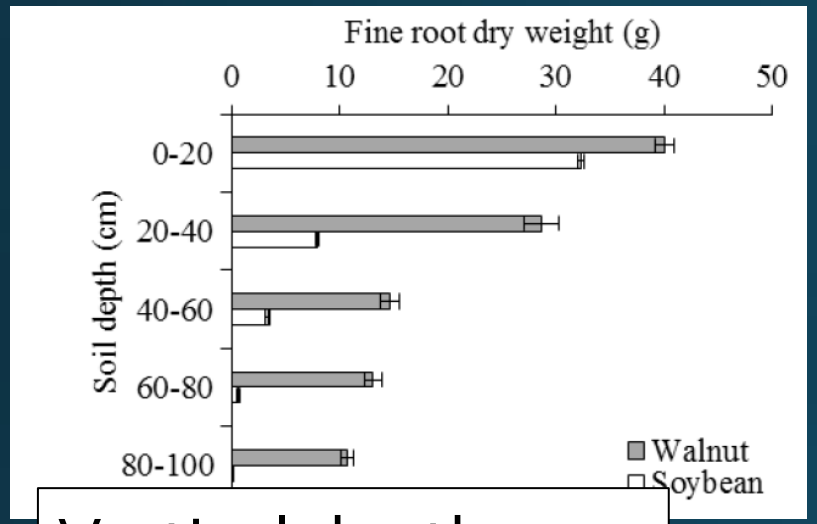
- Where are they?
- Roots *can* grow anywhere!
  - Water, oxygen, nutrients
  - Soil density – not restrictive
- What do they do?
  - Uptake water, nutrients
  - Stability, structure
  - Storage
  - Communicate / Partner

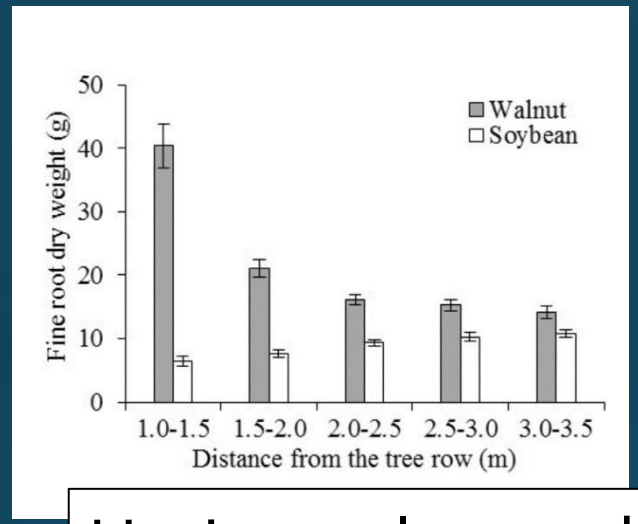


5 basic types of tree roots

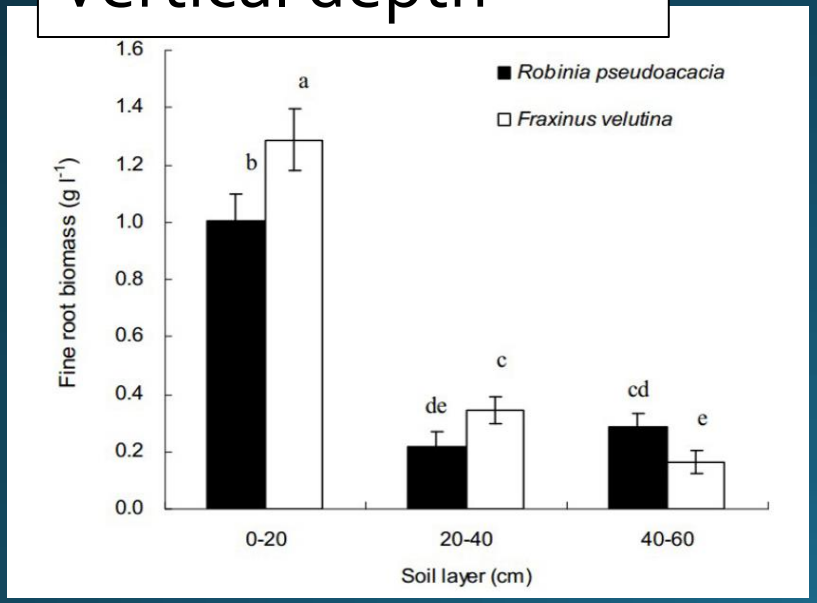


Distribution of fine roots

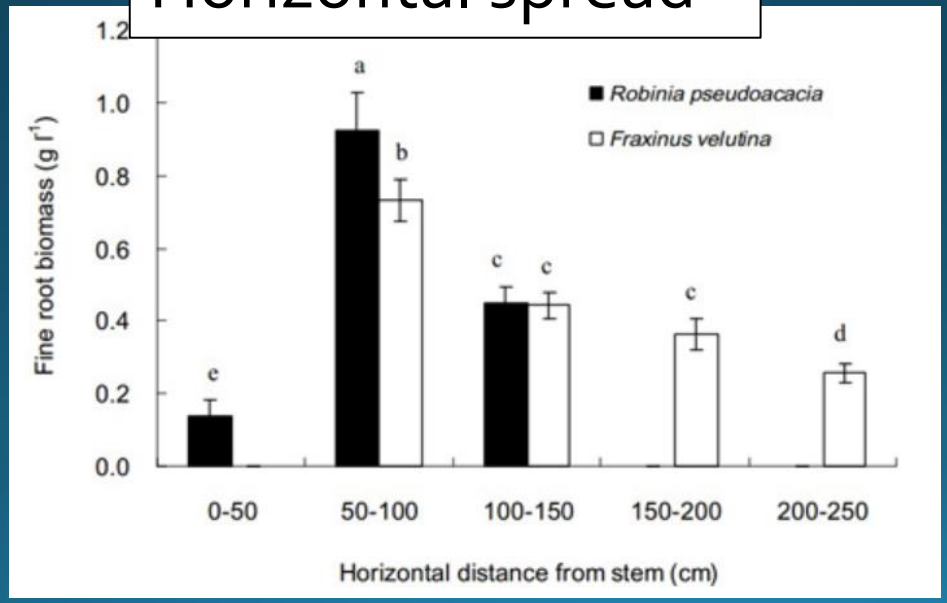




Vertical depth



Horizontal spread



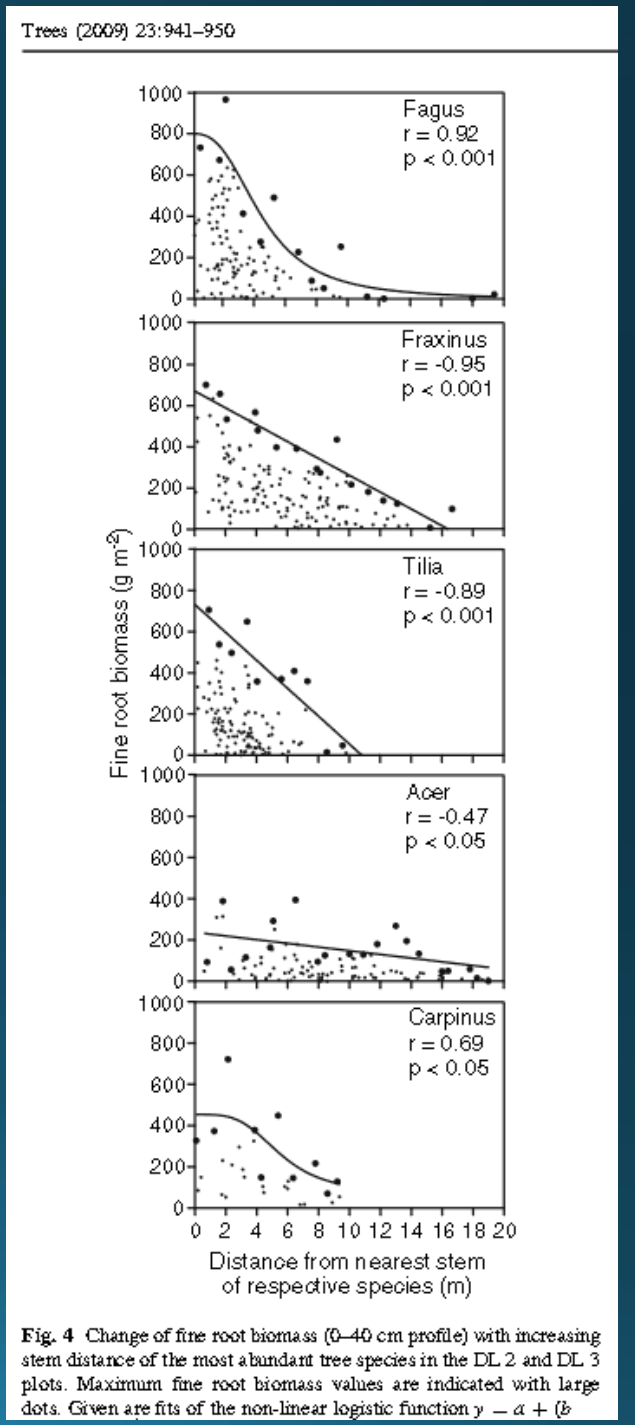
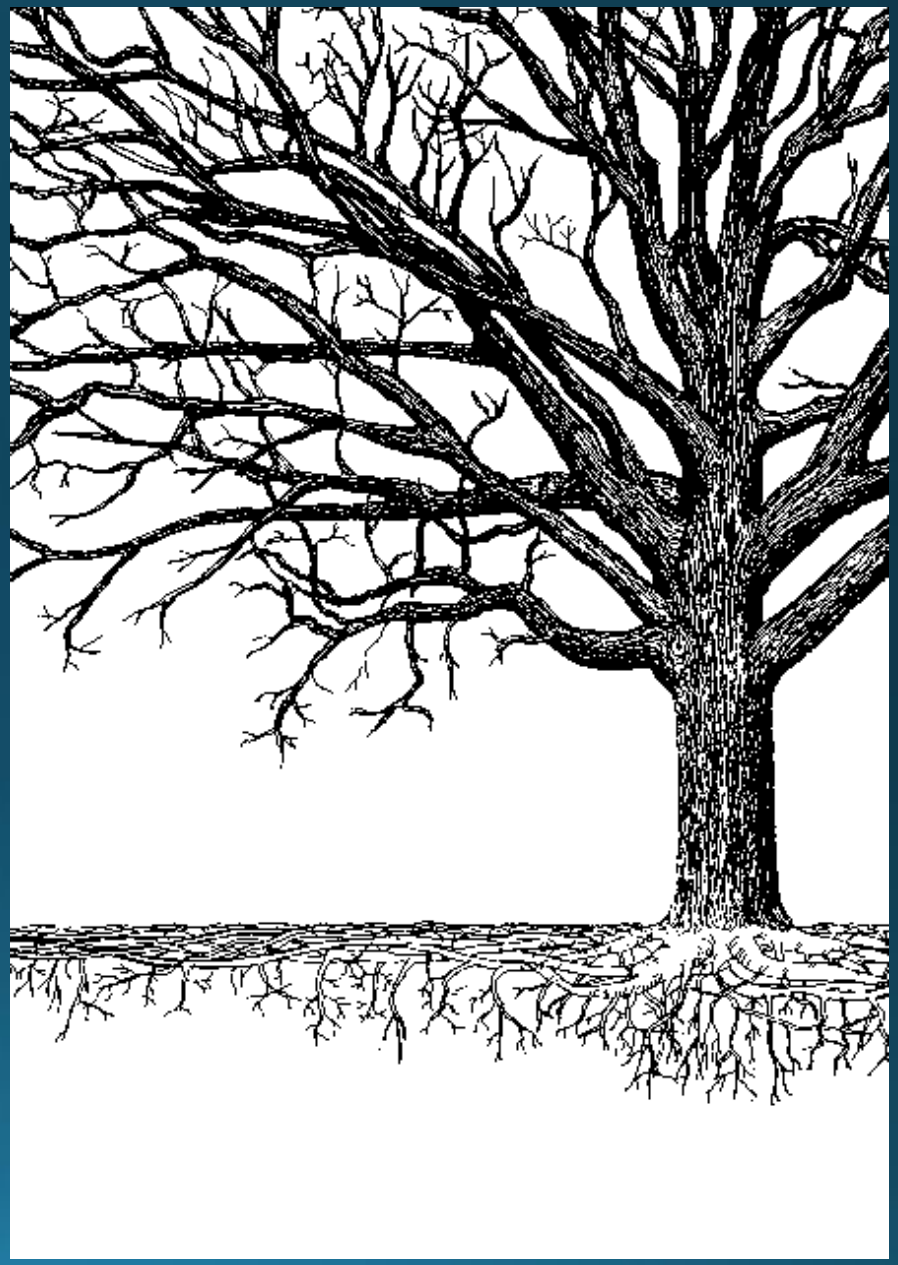


Fig. 4 Change of fine root biomass (0–40 cm profile) with increasing stem distance of the most abundant tree species in the DL 2 and DL 3 plots. Maximum fine root biomass values are indicated with large dots. Given are fits of the non-linear logistic function $y = a + (b$

Highest density of fine roots

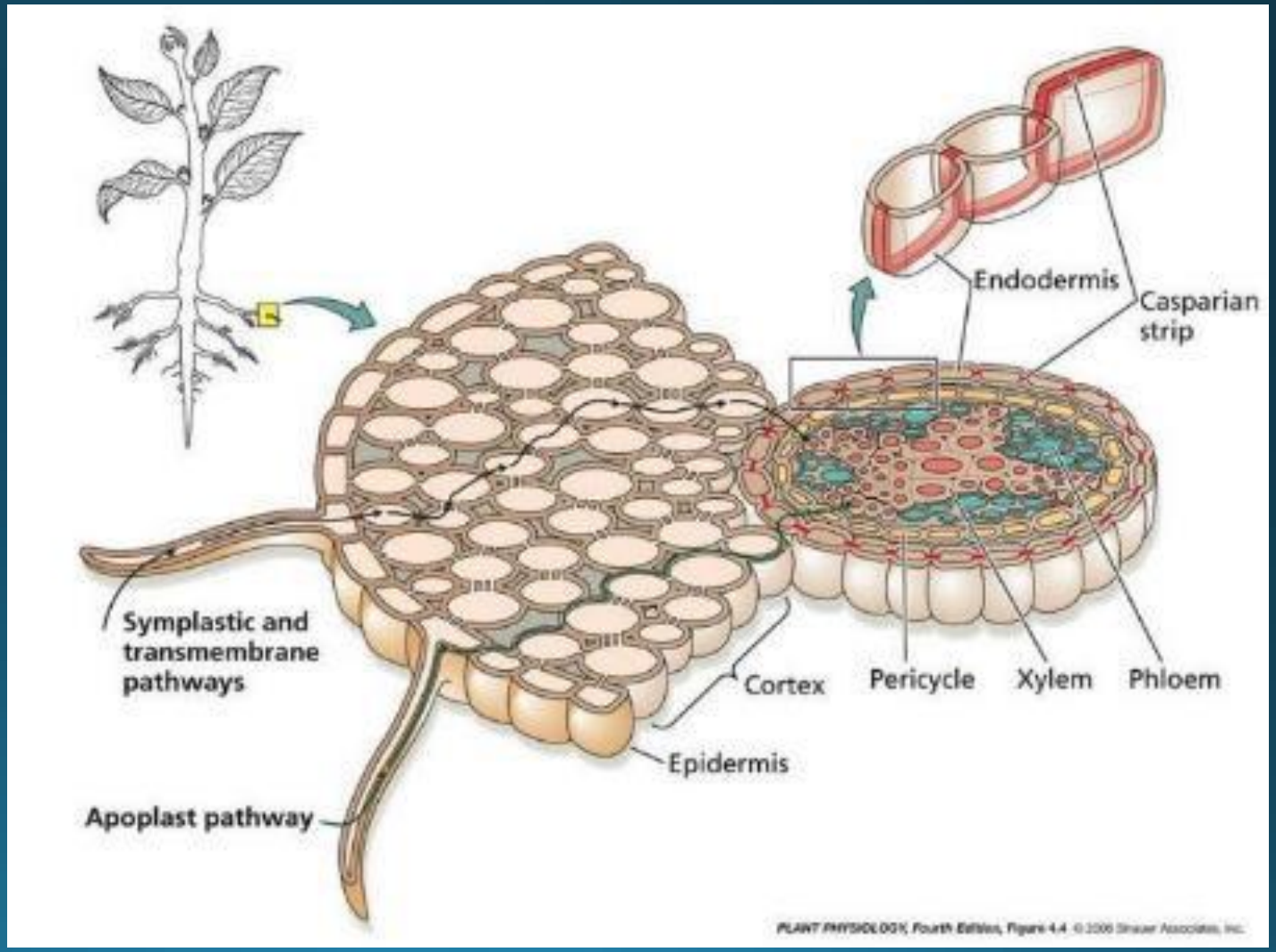
- Upper 8 – 12 inches of soil (20-cm)
- Within 3-6 feet of trunk (1-2 m)

- This is why many 'drench' applications are made at the base of trees.
  - Fortiphite
  - Cambistat
  - Xytect / Transtect



Root internal morphology

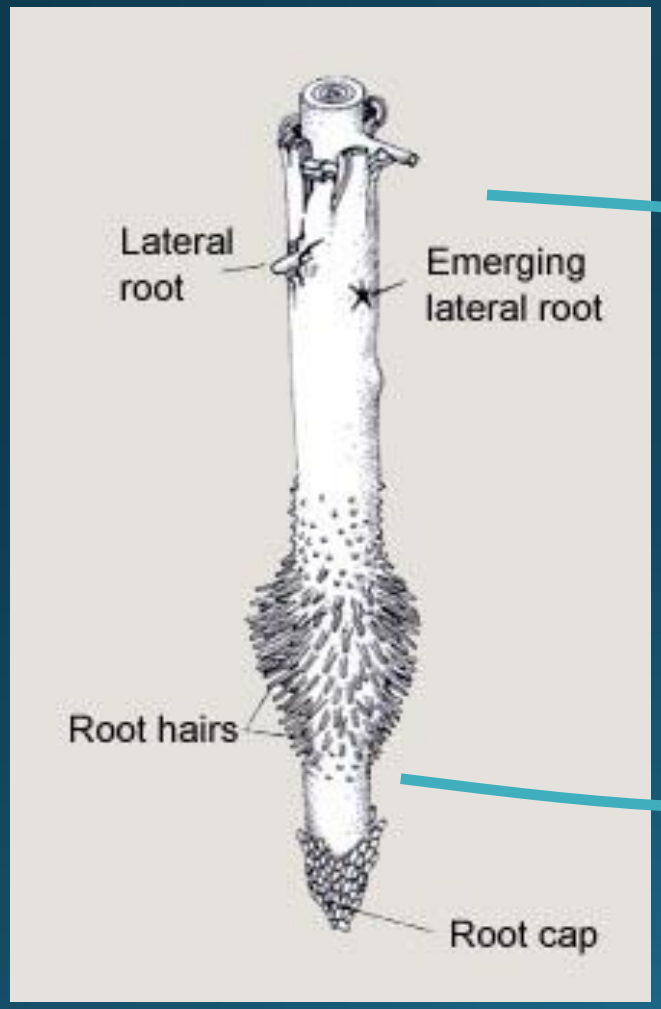
- Epidermis- outer layer where root hairs come from.
- Cortex mostly storage cells
- Endodermis – all pathways must go through this layer.
- Casparian strip – protective layer in endodermis cells

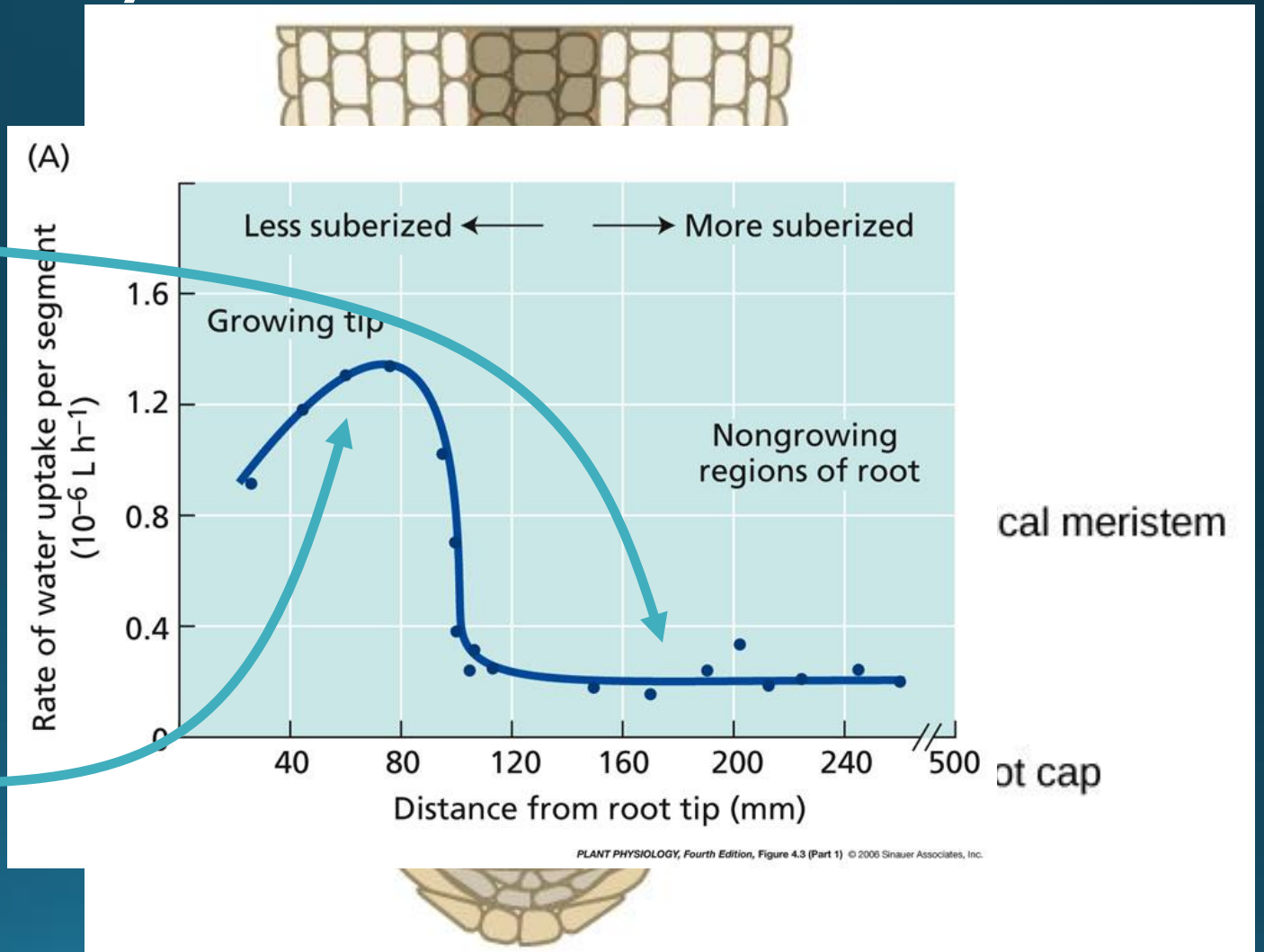


Movement into roots

- Roots are selectively permeable: channels and gateways in cell membranes control flow in / out of roots
  - Some are active (pumps, require energy) / against gradients
  - Some are passive (still selective) / gradients determine flow
- Root cells are full of solutes – water from soil moves into root cells
  - Water from bulk soils 'pulled' to roots because root uptake has made that soil dryer – created a gradient
- For 'natural' uptake (nutrients, water, oxygen), plants evolved specific channels, pumps, gateways.

Root tips-Primary Growth





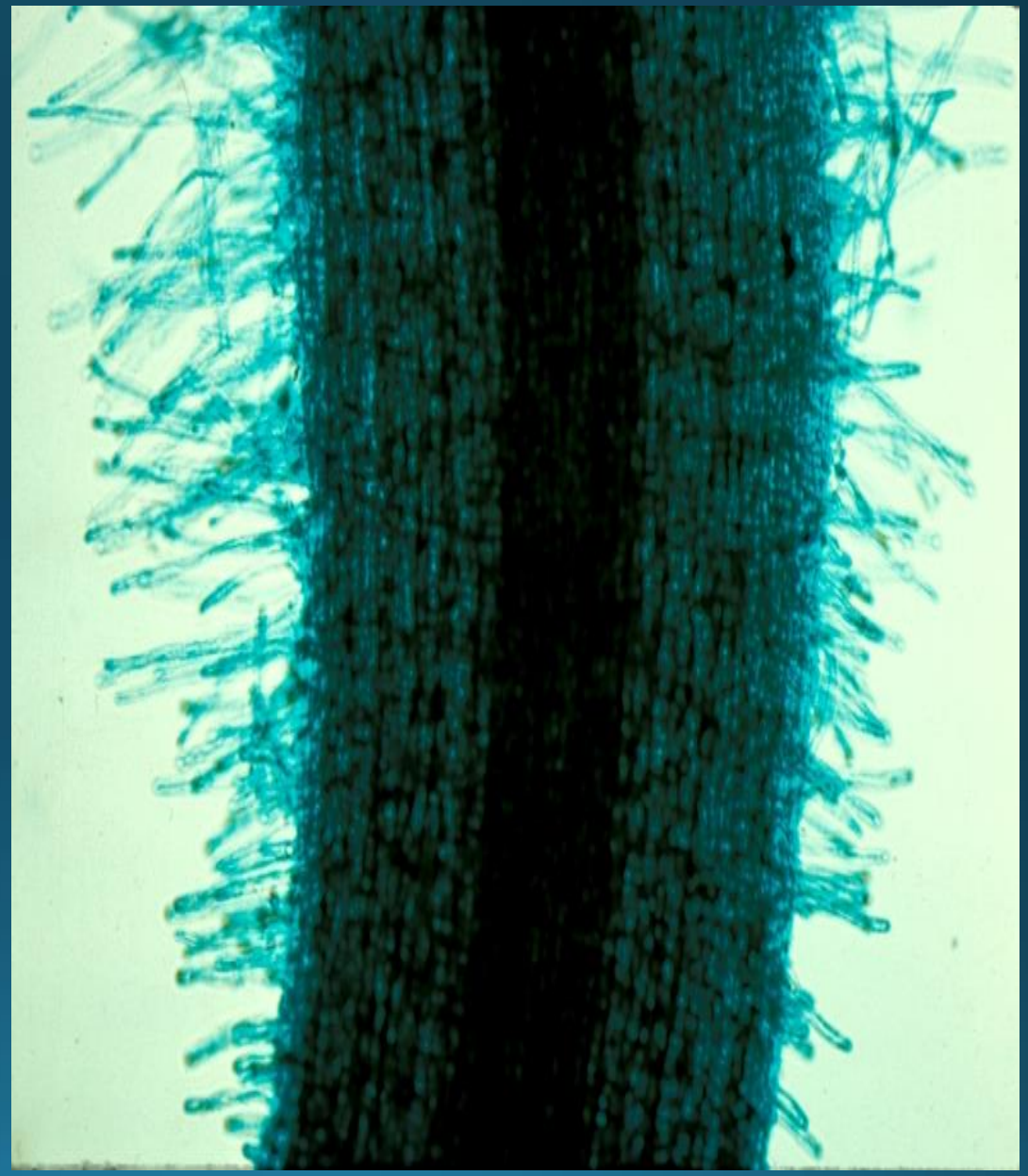
cal meristem

ot cap

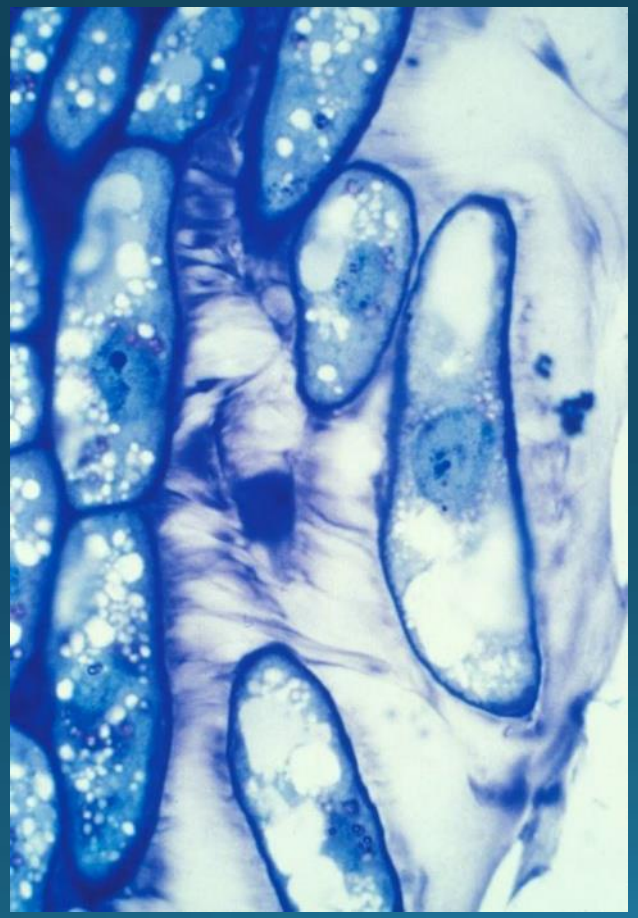
White zone is where uptake occurs

Root hairs

- Increase root surface area – extensions of epidermal cells
- Uptake
- Secrete acid (H+) and carbohydrates
  - Nutrient uptake



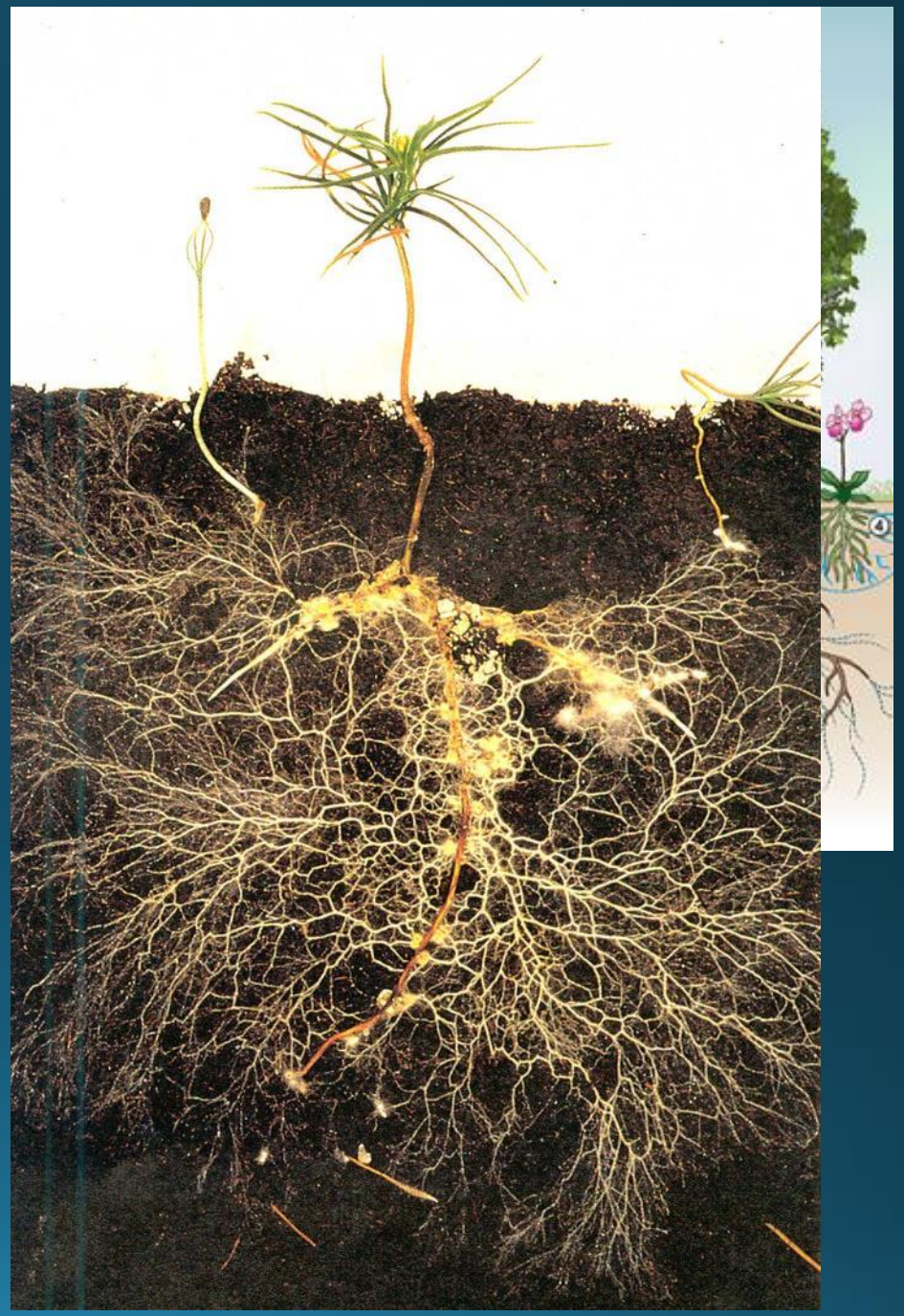
Root tips are constantly shedding cells and losing, or 'donating' carbohydrates



- Root exudates and sloughed cells feed the rhizosphere's biome (beneficial bacteria and fungi).
- But, they also attract and feed pathogens (*Phytophthora*)

Roots don’t work alone

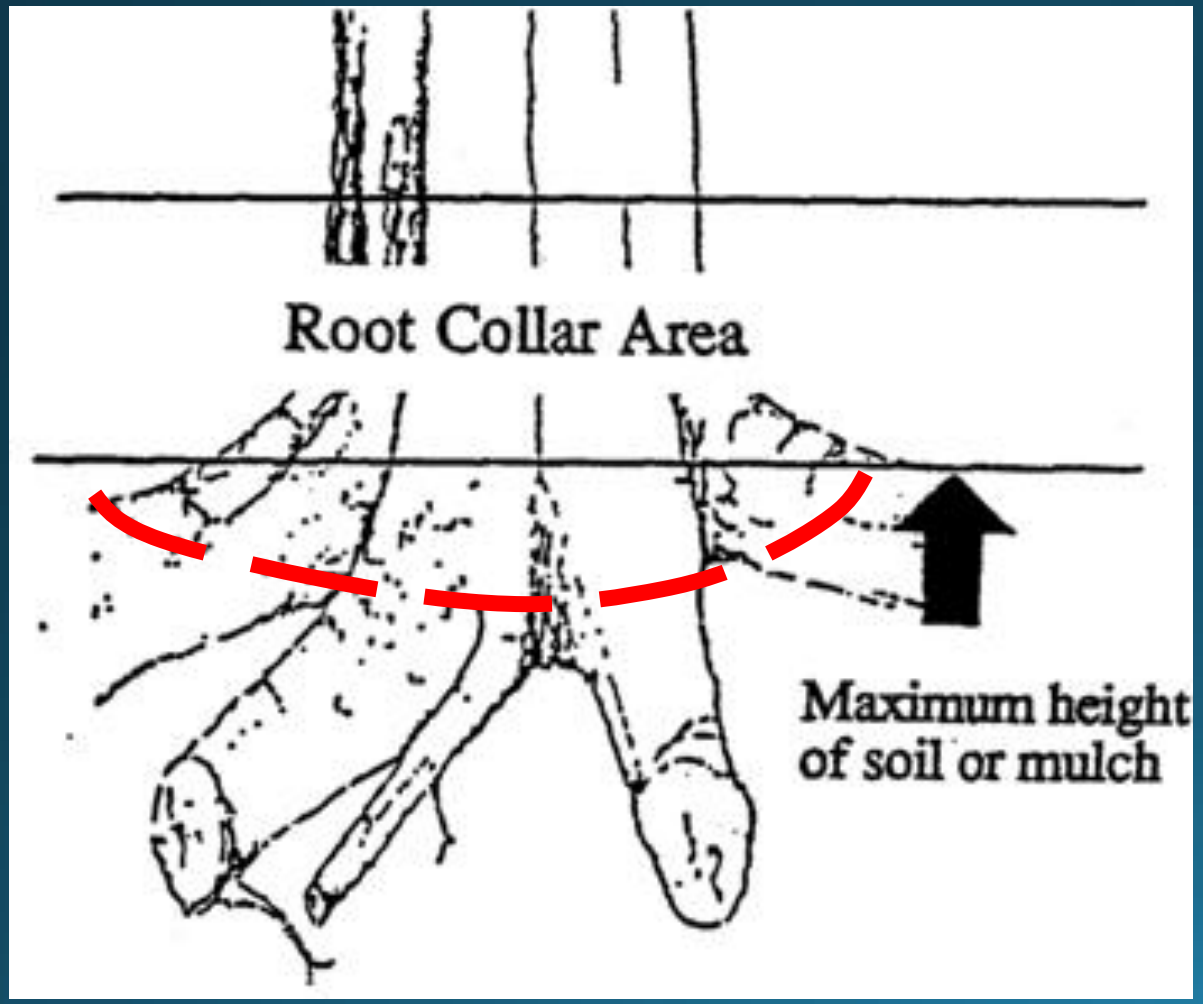
- Mycorrhizas
  - Symbiotic relation between roots and fungi
  - Plants provide carbon (sugar, food)
  - Fungus provides uptake, dramatically expands volume of soil available to plant.
  - Also involved in communication
- Unbelievably complex relationships
  - Associates change over time
  - Associates change with growing conditions
  - Link same and different species together



Field considerations – Roots

- Landscape soils are often unsuitable for healthy root growth
  - Compaction physically restricts root growth, leads to poor drainage
    - Too much water, not enough oxygen
  - Nutrients are often limited, pH is often outside ideal range
  - Organic matter is critical for healthy root-zone microbial community
  - **Root Invigoration address all of the common root zone limitations**
- Fine roots are most concentrated in top 10”, within 6’ of trunk
  - PHC applications in this zone balance efficacy with efficiency
  - Subject to drying, heating, freezing, compaction, etc.

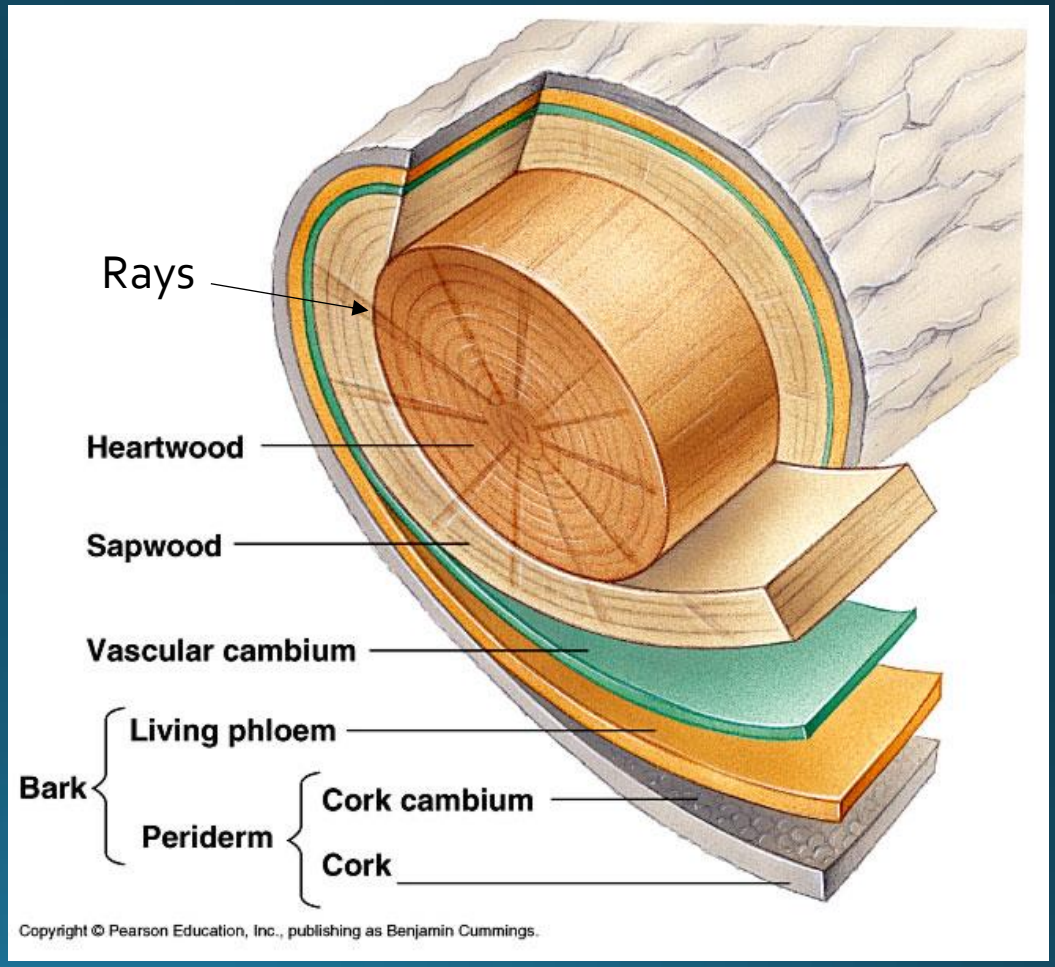
Fine roots lead to lateral roots, lateral roots lead to the Root Collar (Root Crown)

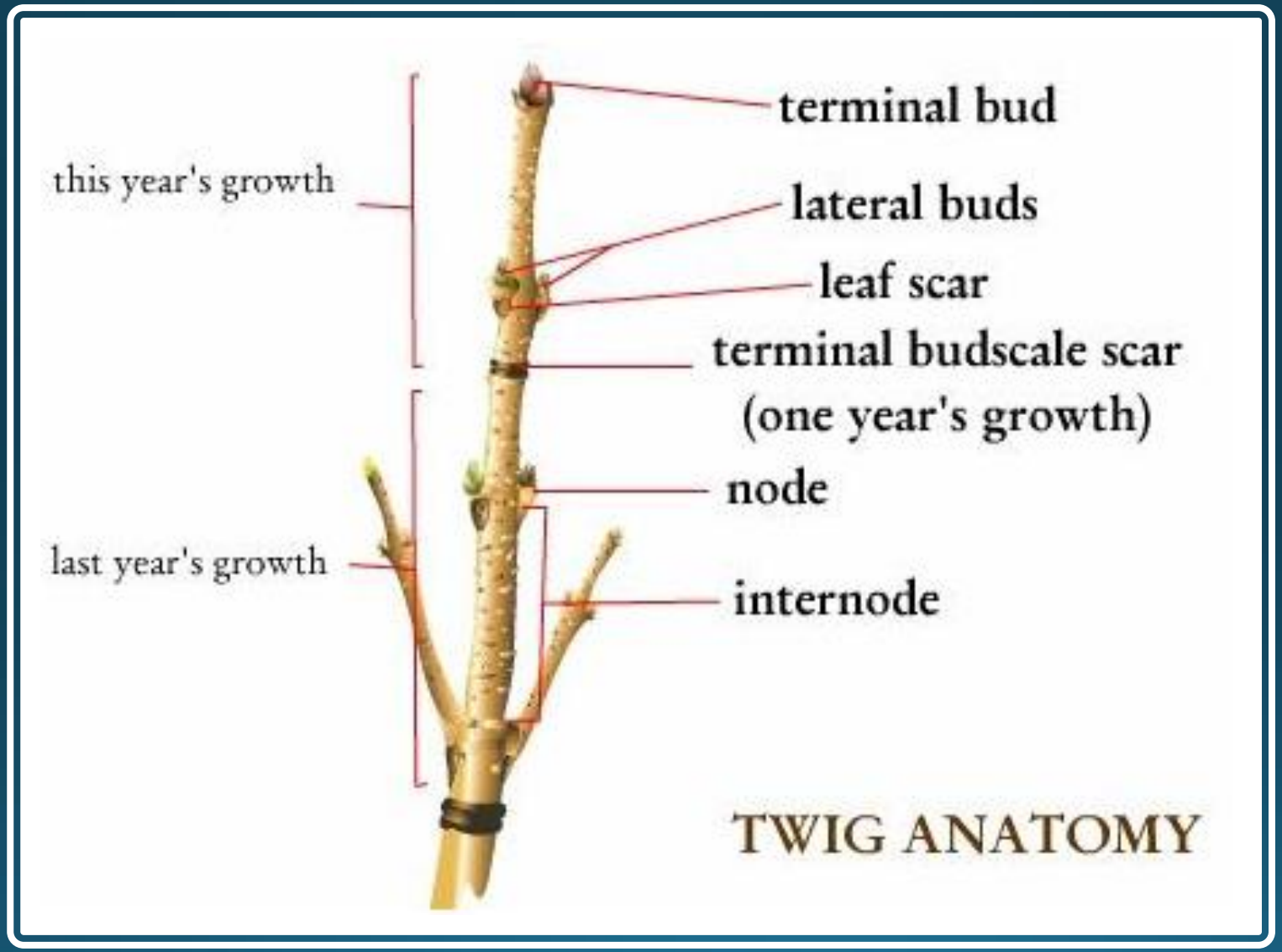


- Critical area to inspect for health and structural concerns.
- Best place for injected treatments.
  - Why?
  - Better distribution
  - Faster wound closure
    - Secondary Growth

Anatomy of a stem / trunk / branch

- Cambium is where new cells are produced.
- Cork Cambium: produces bark (cork)
- Vascular Cambium produces –
  - Xylem to the inside
  - Phloem to the outside
- There are different types of xylem, but for simplicity, they are dead cells lined up end to end, creating a straw.
- Rays are living cells that form in a pattern like spokes on a wheel.



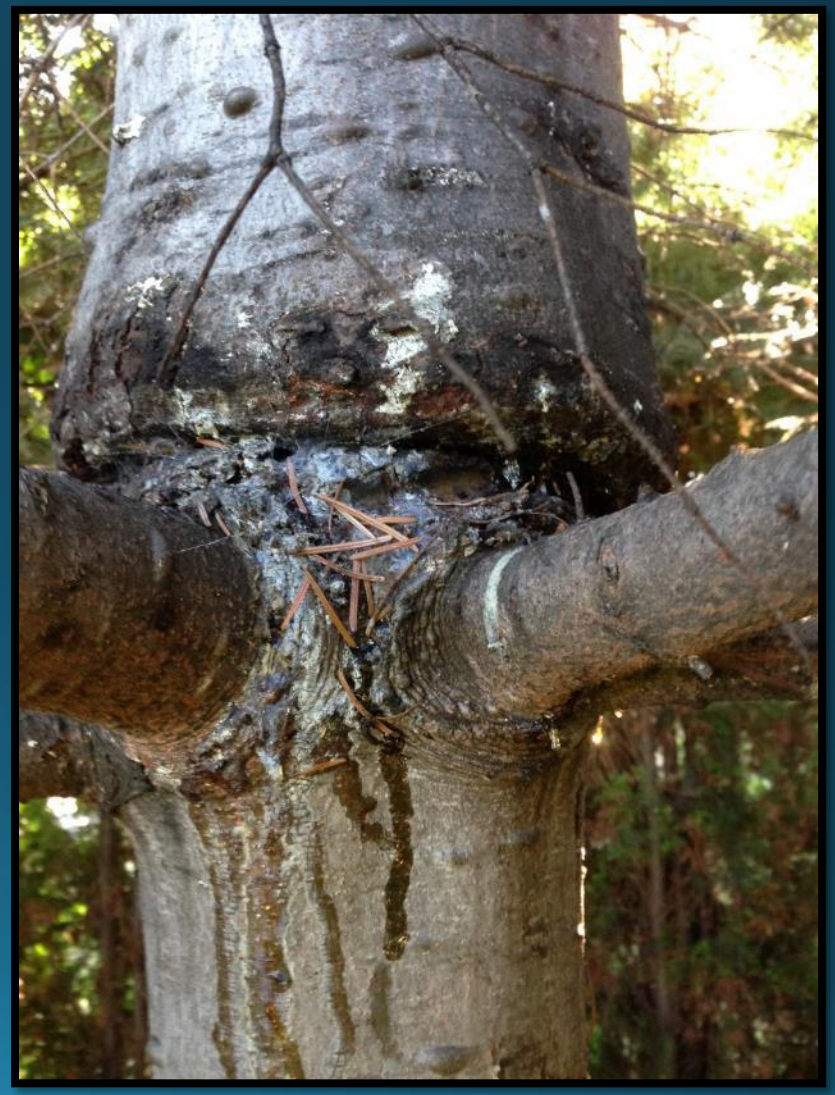

terminal bud
this year's growth
lateral buds
leaf scar
terminal budscale scar
(one year's growth)
node
last year's growth
internode
TWIG ANATOMY

Lenticels

- Small openings in the bark to permit gas exchange of oxygen and carbon dioxide

Key features of trunk / branches

- All the 'living' cells are very close to the surface.
- Sunscald, fire, physical injury, freezing, and many other factors can injure these 'shallow' living cells.
- Girdling (early on) has more impact on phloem than xylem.
  - Phloem is on the outside of xylem, and xylem cells are more reinforced.

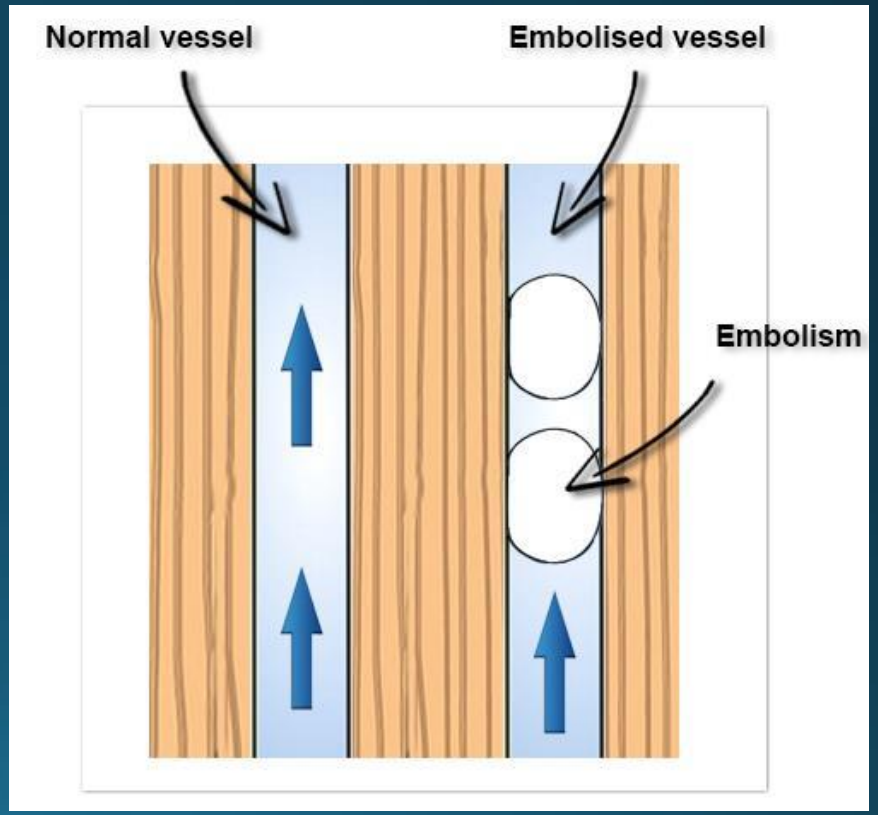


Field considerations

- Injected treatments move in xylem with water flow.
  - Tree must be transpiring (have water) to move material
  - Depth of hole, placement of plugs is critical
  - The faster you can inject after drilling, the better

Cavitation causes xylem dysfunction

- Air embolism that forms in xylem, breaks continuum / column of water
  - In some cases this can be repaired or water is 'routed around' the blockage
- Physical damage
  - Drilling, saw blade, borers
- Extreme moisture stress – 'pulling too hard' on water column
  - Breaks hydrogen bonds
- Freezing – usually re-dissolved in spring



Trunk & Branches main focus of pruning

- **Safety**, aesthetics, function
- Relevant topics that are covered in pruning lecture:
  - Co-dominant stems
  - Branch aspect ratios
  - Branch collars, proper cut locations
  - Branch protection zones
  - Branch spacing
  - Branch extension
  - Subordination

Morphology & Physiology of pruning

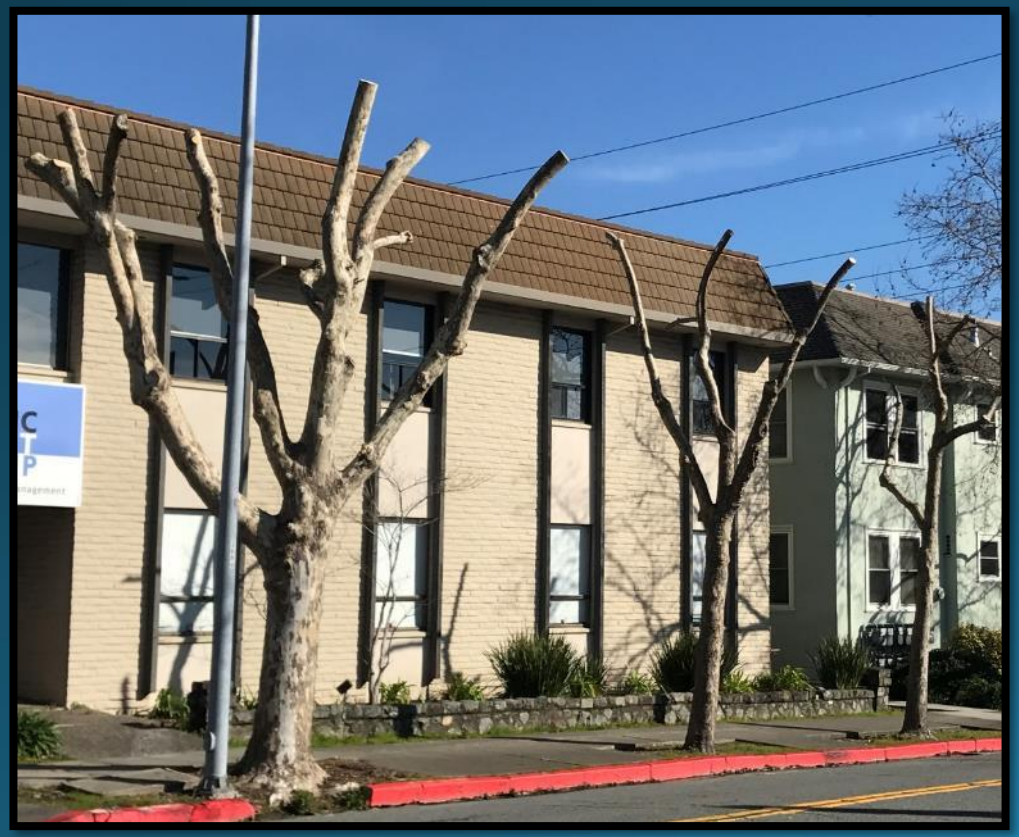
- How pruning affects morphology
  - Hormones
  - Light considerations
- How trees respond to wounding
- Branches and Trunks are storage organs for water and carbohydrates

Pruning effects on hormones

- Growth occurs at meristems
  - Apical meristem (tips) usually dominate
  - Balance of Auxin (hormone) suppresses or releases axillary buds
    - Cytokinin –involved in cell division, leaf expansion, and other physiological processes
- Side branches are 'released' as they get further from apical meristem
  - In forest, lowest branches then get shaded out
- Topping or heading cuts remove apical dominance, change growth form
  - So do some disease and insect issues

Examples

- Topping or heading releases axillary buds from apical dominance
  - Sprouts compete to be new 'leader'

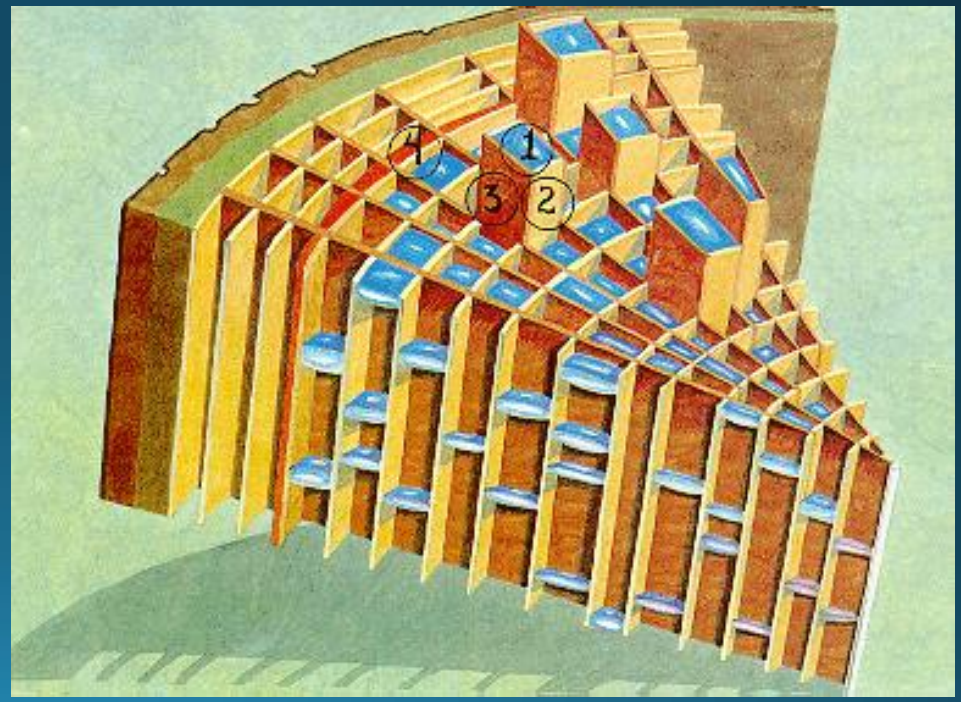


Example

- White pine weevil / Spruce tip weevil
  - *Pissodes strobi*
- Kills terminals (apices)
- Leads to ‘bushy’ growth

Tree reaction to wounding / pruning

- CODIT – Compartmentalization Of Decay In Trees
  - Concept / theory
  - Species, wound type, vigor, location will all affect 'CODIT'
- Wall 1 – prevents vertical spread (xylem)
- Wall 2 – prevents inward spread (xylem)
- Wall 3 – prevents radial spread (ray cells)
- Wall 4 – new growth outside of wound



Trees don't 'heal', they 'seal'

Highly variable in real life

- Wall 1 – weakest
  - Vertical spread of decay (decay column) is common
- Wall 2 – weak
  - Decay often makes it to middle of trunk
- Wall 3 – stronger
  - Living ray cells actively produce defense compounds
- Wall 4 – strongest
  - If it can form…

Response to pruning: Wall 4

- Ideal situation pictured
- If wall 4 does not form:
  - Cut was inside Branch Protection Zone (flush cut)
  - Tree is not healthy, growing well
  - Removed branch was ‘too big’ in relation to parent stem / branch
    - Branch aspect ratio too close to 1

Lion’s tailing

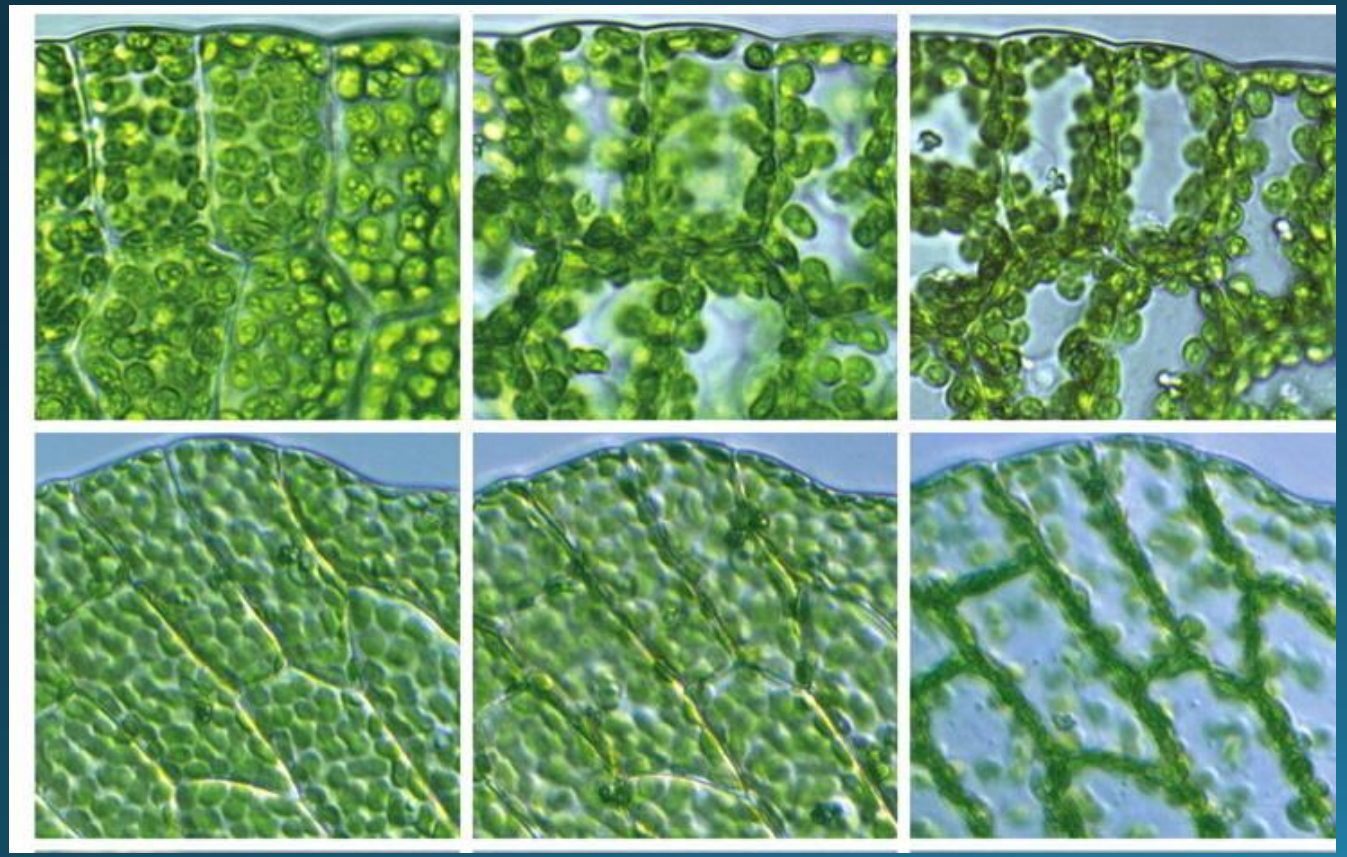
- Not an acceptable practice (ANSI)
- Bad for structure, but also bad for health

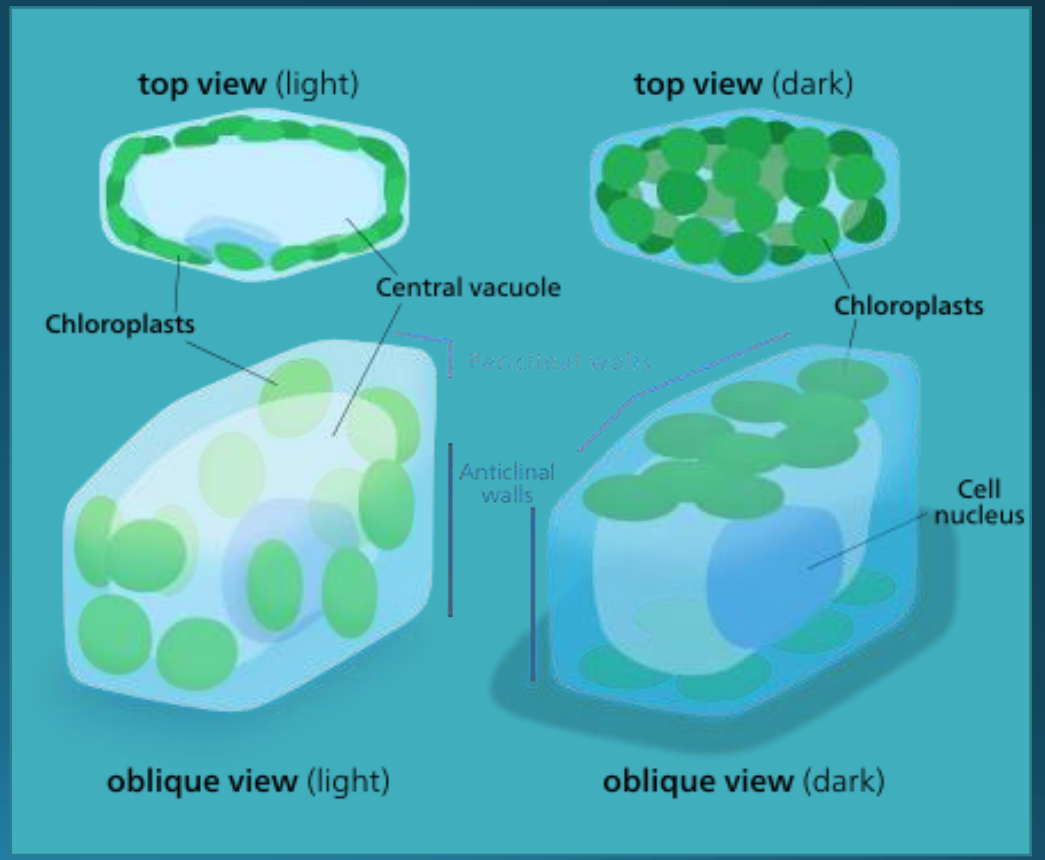
Filtered light (not direct full-sun) is most efficient driver of photochemistry

- Full intense sun can be 'too much to handle'
  - Too much energy with no water or CO_2 leads to problems
- By mid-day in summer, outer canopy is shut down
  - Inner canopy continues to photosynthesize, produce carbohydrates
- Inner canopy is more humid and receives filtered light
  - This is also why foliar disease (fungal) is most prevalent in interior and lower canopy
- Healthy trees NEED interior canopies, don't 'strip' branches

Even on a cellular level, plants ‘shade’ chlorophyll to improve photosynthesis

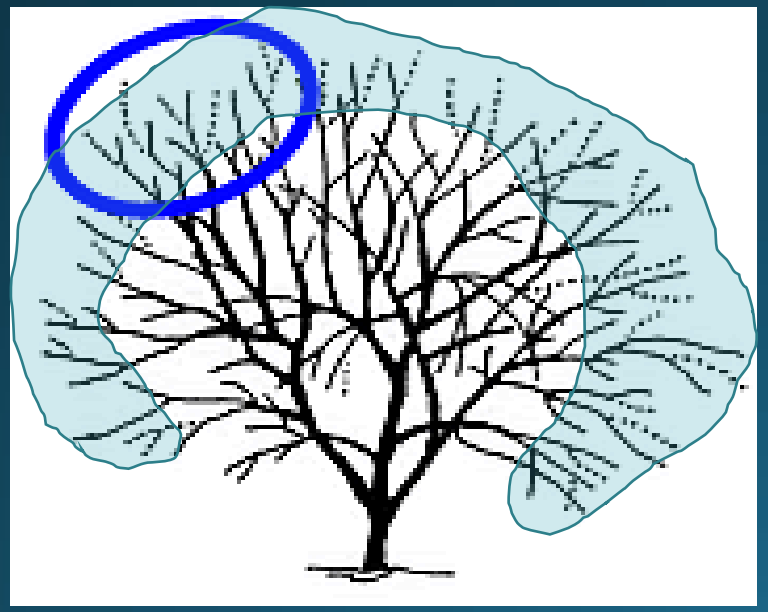
LOW light MED light HIGH light





Branches & Trunks of all size are also **storage organs**

- Trees store both carbohydrates and water in above-ground parts
- Removal of live tissue is 'stealing' carbon reserves
  - If live tissue is to be removed, favor more small cuts over more big cuts



From the ANSI standard:

- "The smallest diameter cut that meets the objective should be preferred"
- "When removing live branches, the majority of cuts should be in the outer portion of the crown"
- "Interior and lower branches should be retained when compatible with objectives and systems"

Bigger trees take longer to die

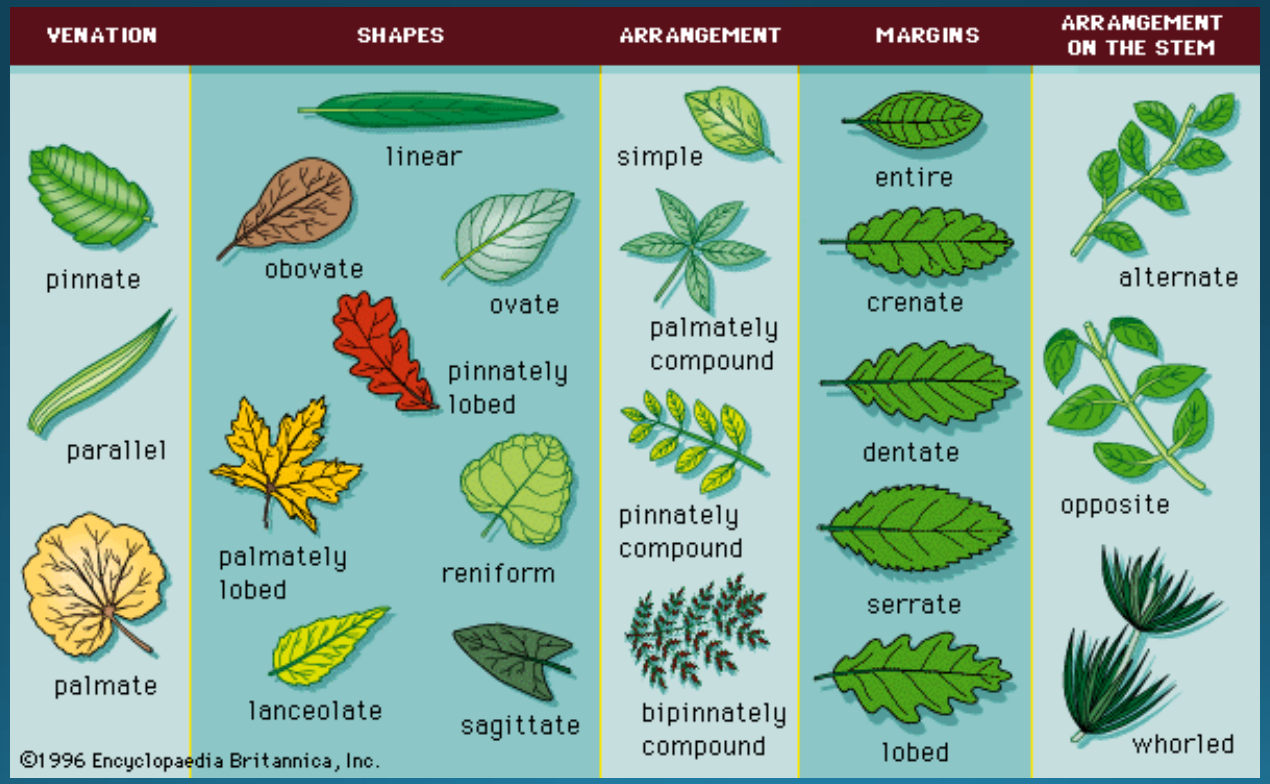
- Following major changes / stresses
  - Or general declines will take longer to result in mortality
- Big trees might appear to survive things like drought, fire, transplanting, defoliations, over-pruning, etc.
  - Really ‘deficit spending’ stored carbohydrates

Physiology of pruning review

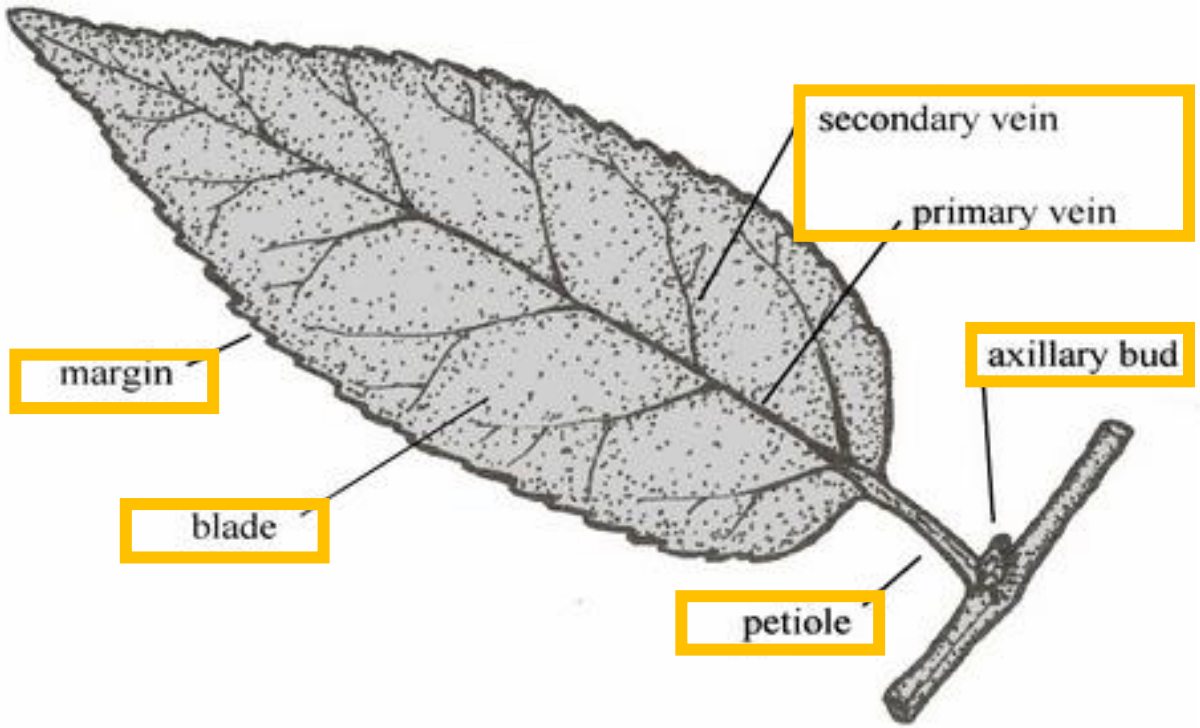
- Removal of large live branches = removal of energy and water
  - Only when necessary for safety, pruning objectives
- Wound closure is impacted by
  - Size of cut
  - Location (branch collar, flush, stub)
  - Overall tree health / vigor
  - Species
- Trees need interior foliage

Leaf Morphology

- Lots of terms to describe various shapes and patterns.
- To be covered in Plant ID session.



Parts of a leaf



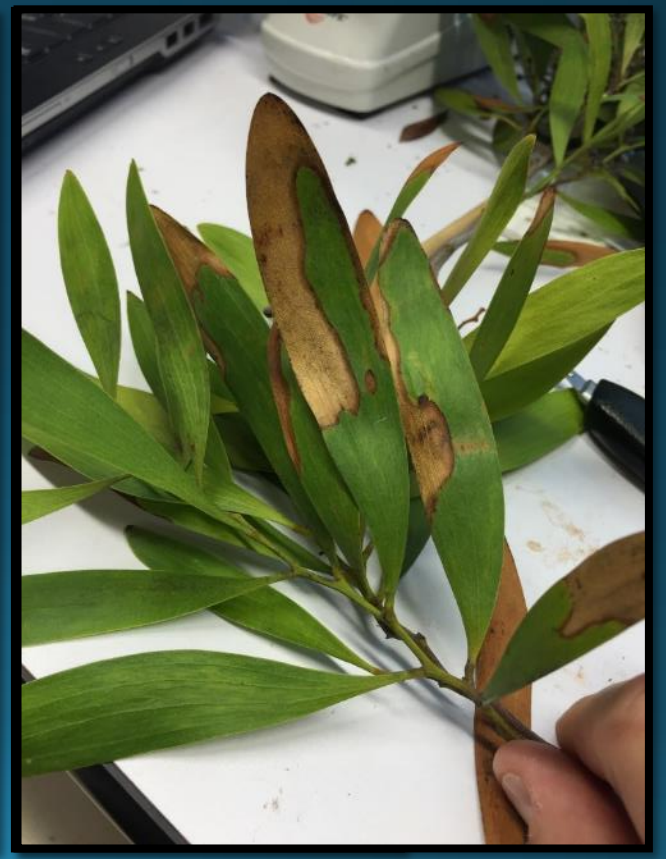
Dogwood 'flower petals' are actually leaves 'acting like' flowers

Other plant parts might 'act like' leaves…

Example of ‘other parts’ acting as leaves

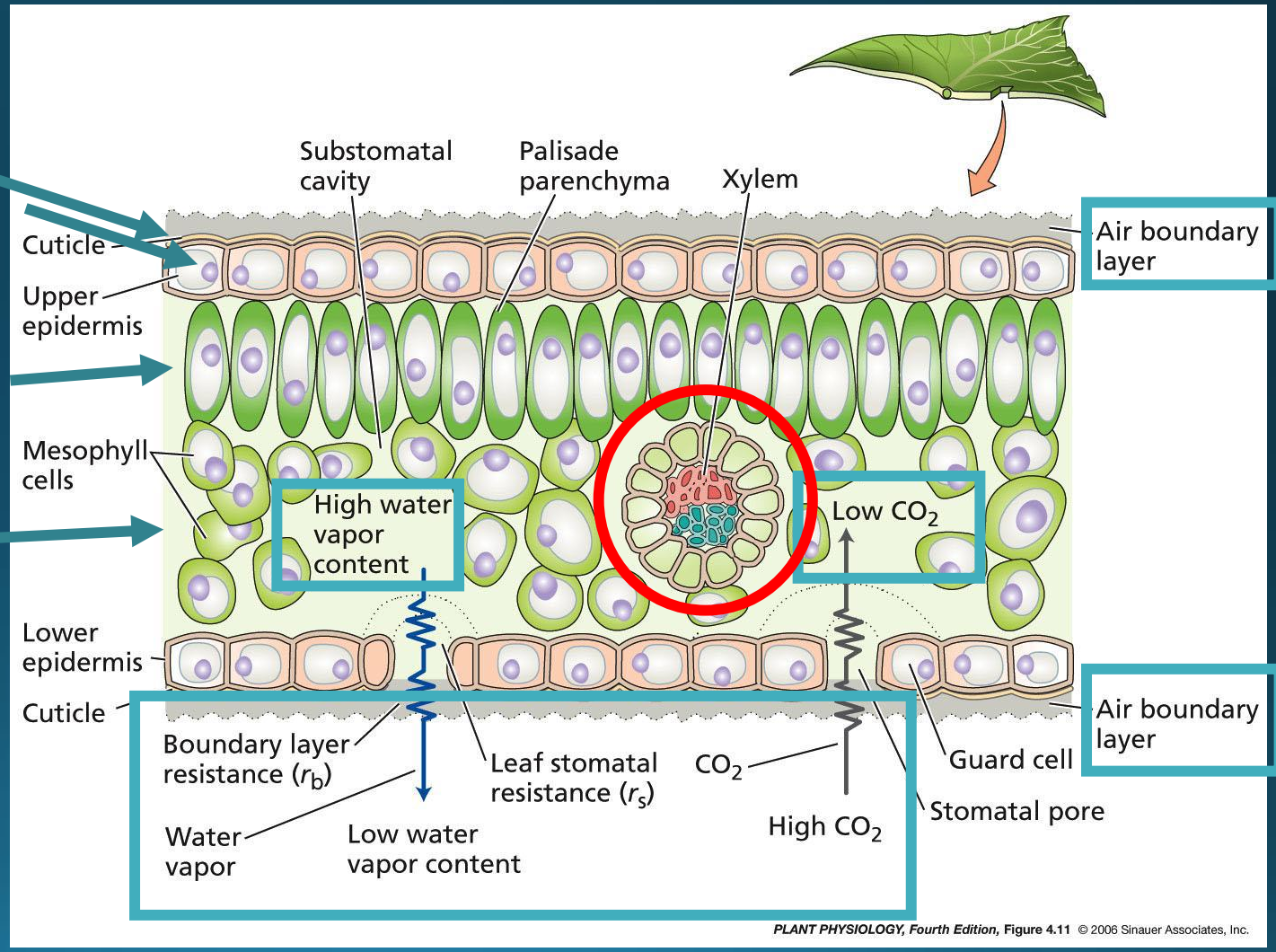
- Phyllode = winged leaf stalk (petiole) that acts as a leaf
  - *Acacia melanoxylon* (black acacia)



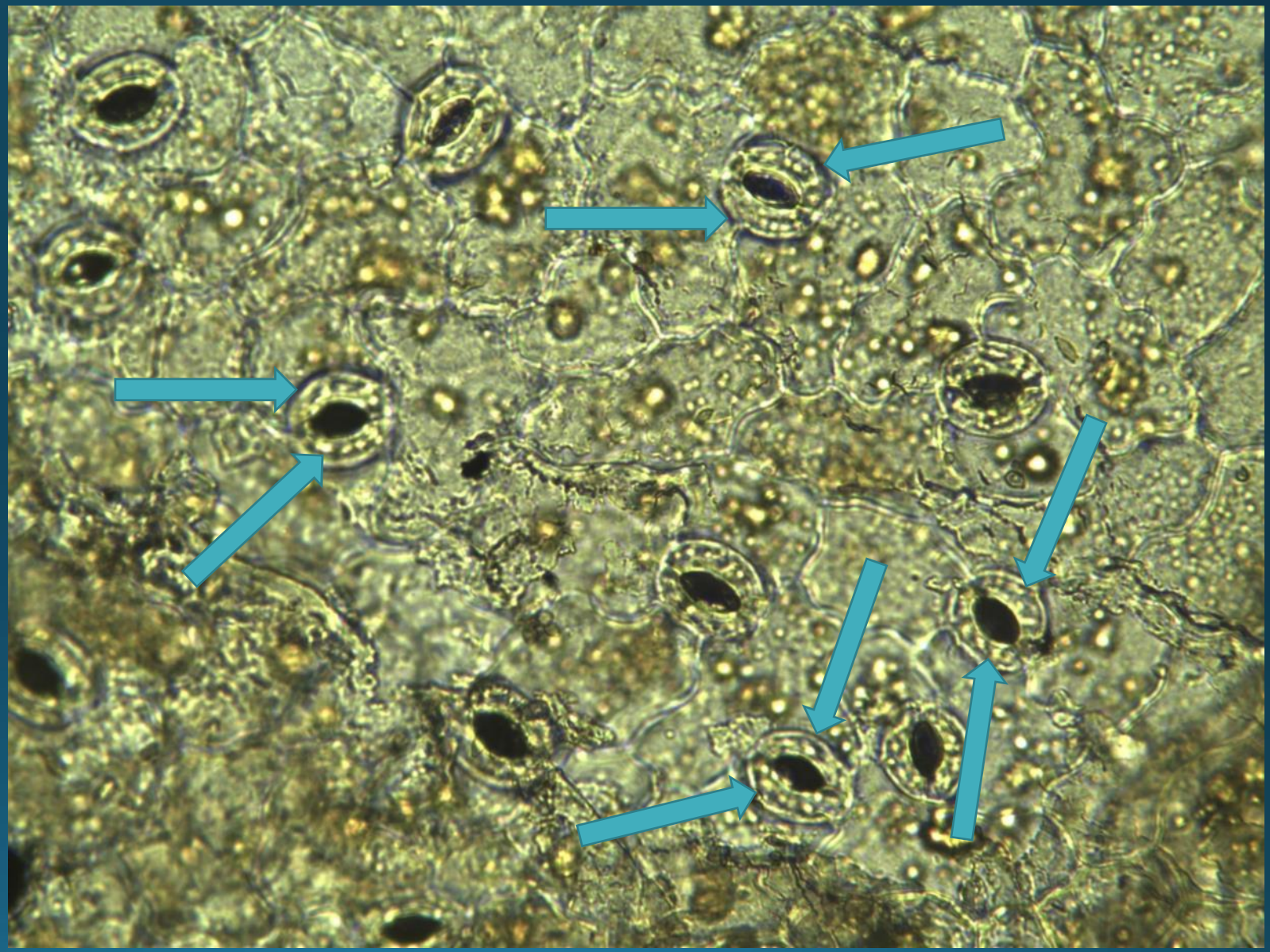



Internal morphology / anatomy

- Cuticle – wax layer
  - Prevents water loss
  - Physical protection
- Mesophyll cells
  - Contain bulk of chlorophyll
  - Palisade and Spongy
- Veins
  - Xylem and phloem
- Epidermis - upper and lower
  - Contains stomata (pores)
  - No chloroplasts

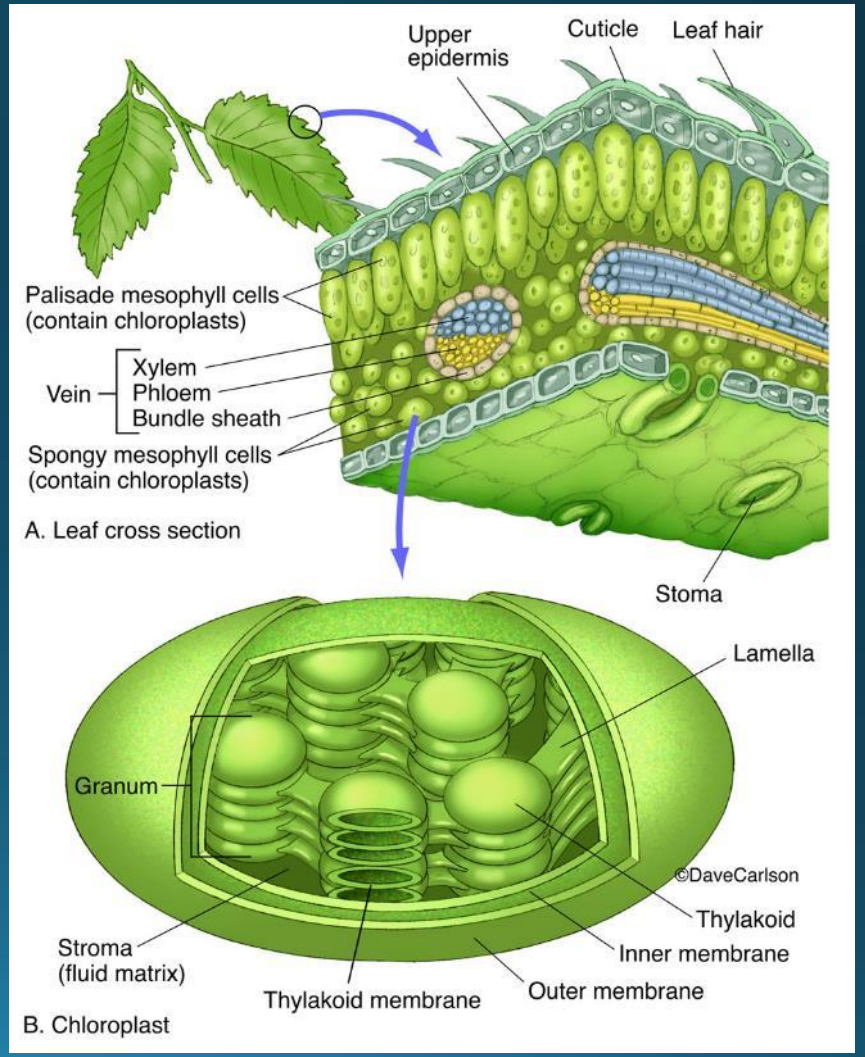


- Guard cells:
  - Control flow of CO_2 in and water vapor out.
  - Controlled by hydraulics or root-derived signals.
  - Calcium and Potassium are important in guard cell control.



Internal morphology / anatomy

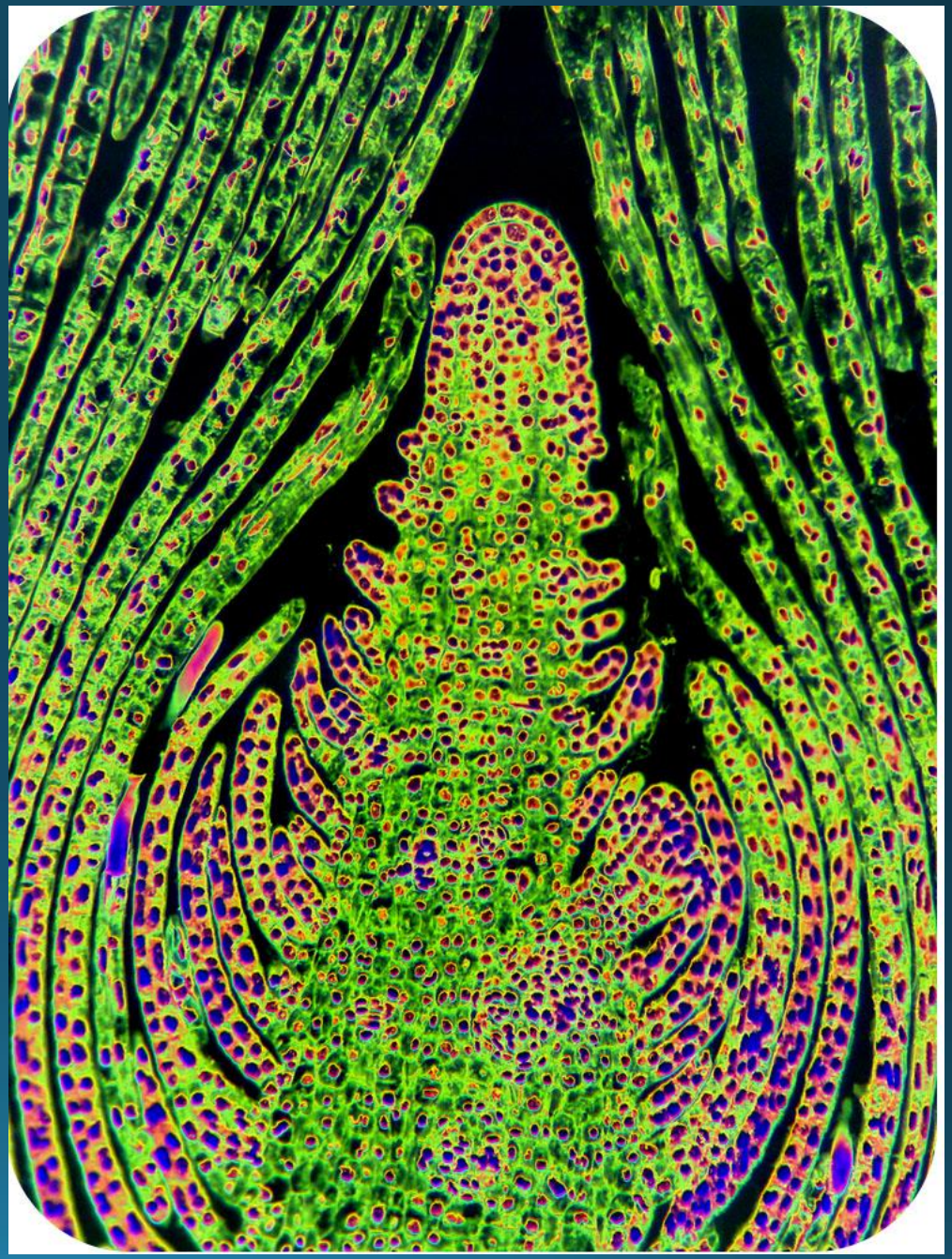
- Chloroplasts = complex system of membranes with embedded:
  - Chlorophyll and other pigments
    - Light energy receptors
  - 'Machinery' to use that energy to convert to chemical energy
    - Making sugars / carbohydrates



Anthocyanins and Carotenoids

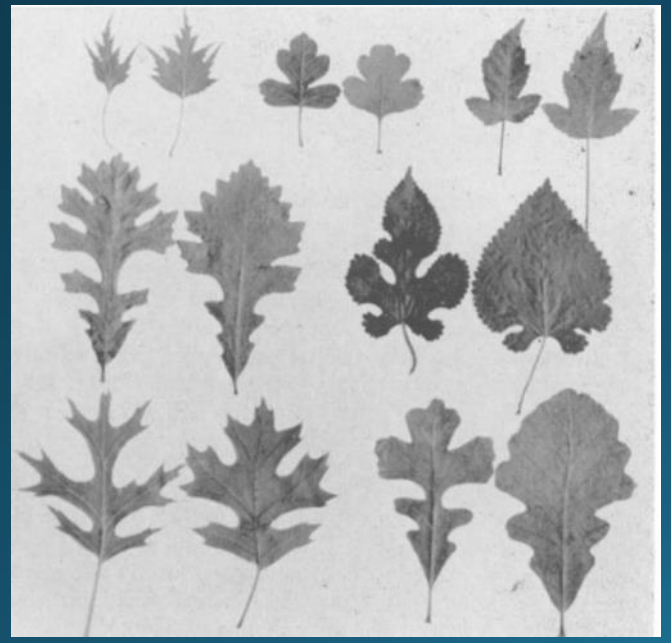
Leaf development

- Leaf cells start as undifferentiated cells produced in meristems.
- New cells expand and differentiate due to hormones (and turgor).
- Plants are incredibly 'plastic'
  - Genetically speaking
  - The same genes can lead to many different forms of growth



Leaf morphology

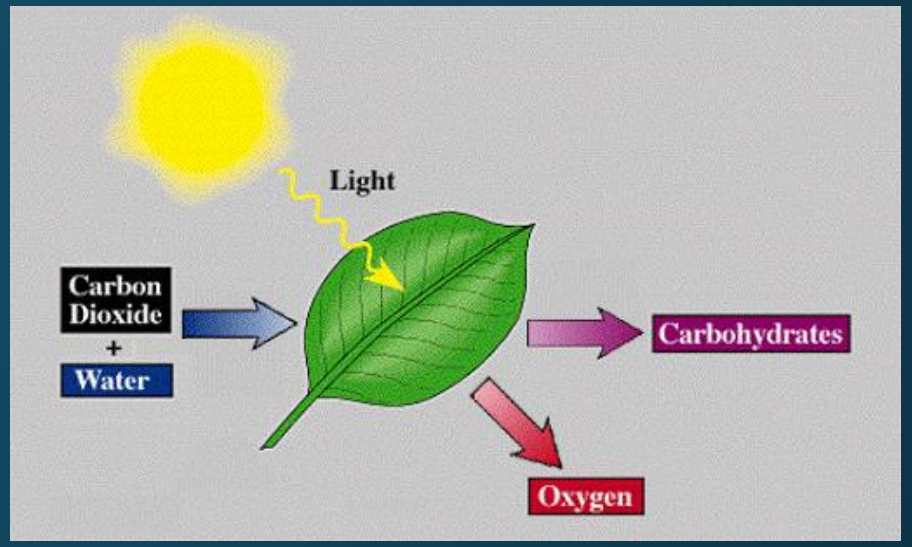
- Highly variable even on the same tree
  - Sun vs. Shade leaves
  - Upper / lower on very tall trees

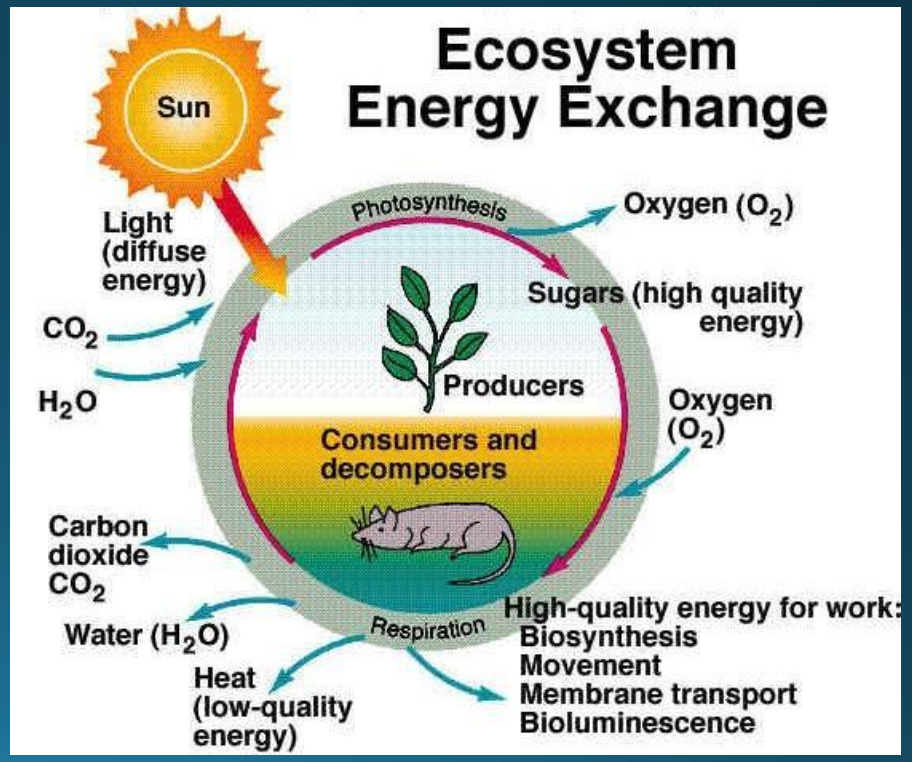


Energy in Plants

- All energy comes from **The Sun**
  - (photons = packets of energy)
- Photosynthesis
  - Turning sun's energy into chemical energy
  - Light + CO2 + water = Carbohydrates + oxygen
- Respiration
  - Using that chemical energy to live / grow / defend

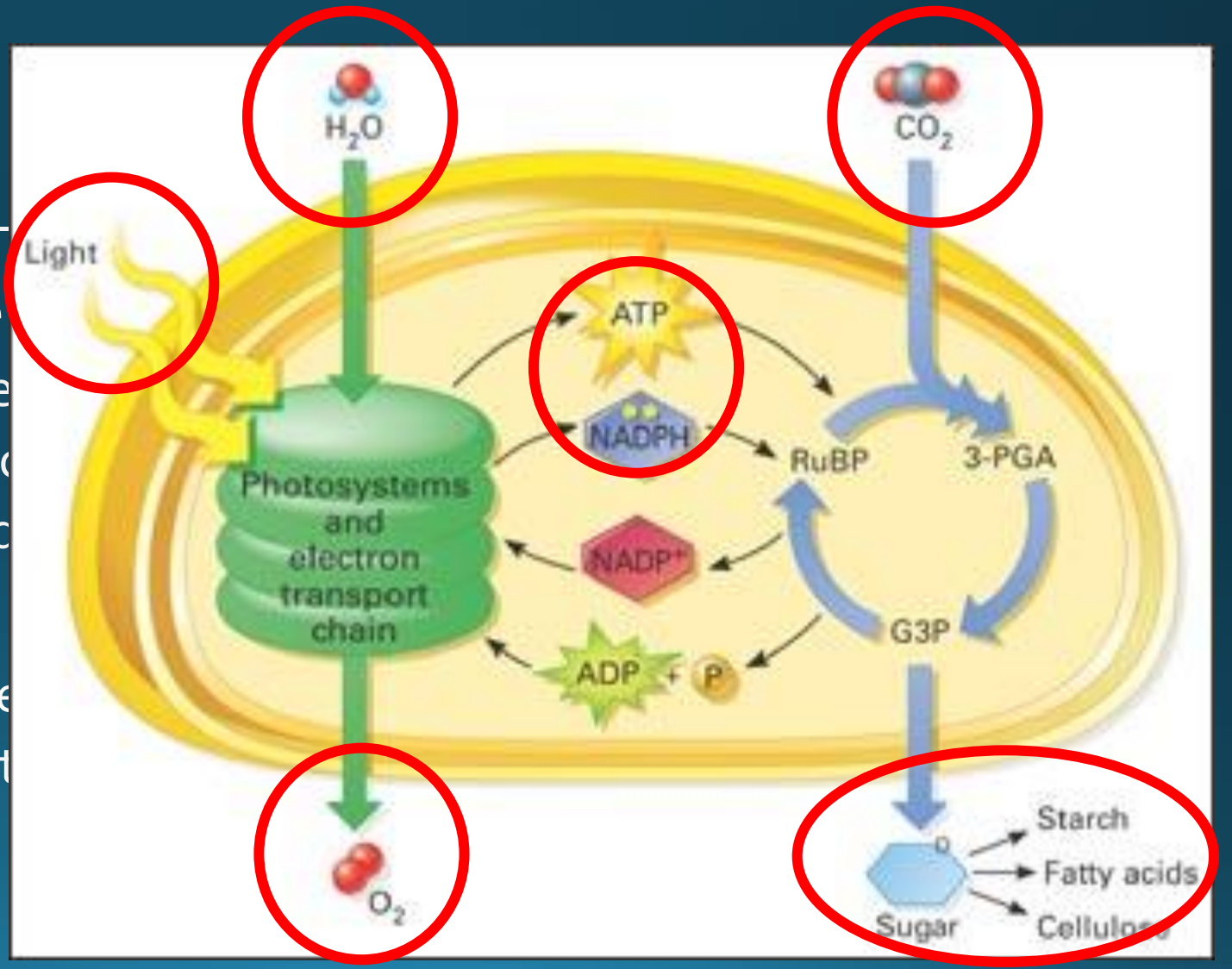
- Plants are 'producers' and 'users'





How does a leaf harvest the sun's energy?

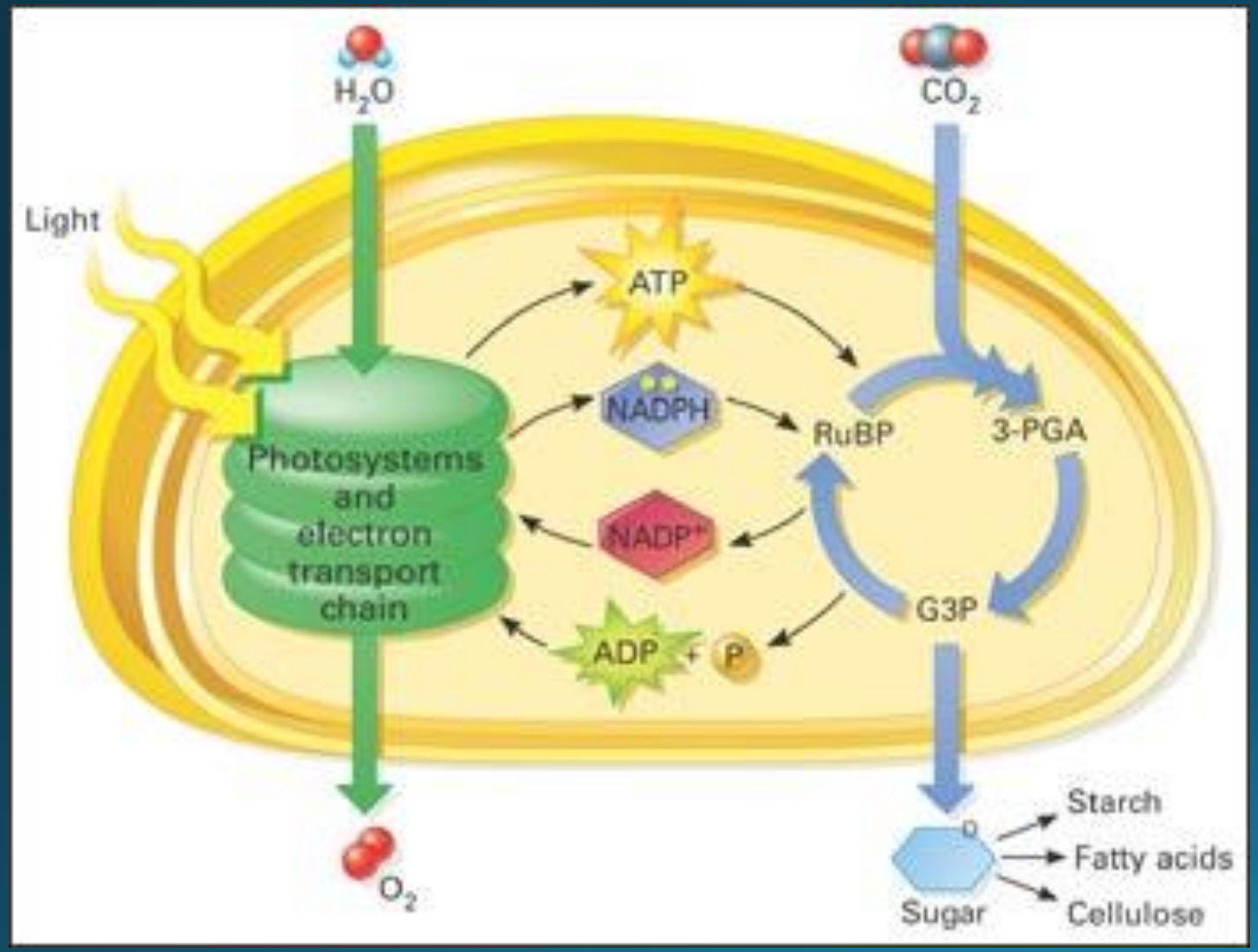
- Light reactions
  - Turn light energy into short-
- ~~Dark reactions~~ Calvin Cycle
  - Turns short-term chemical e
  - Sucrose (glucose, fructose) c
  - Or used to build (cellulose, c
- RuBisCO
  - Most abundant enzyme on e
  - Takes CO_2 and 'sticks' it on t



Photosynthesis at its simplest…

- Sun energy converted to chemical energy in bonds
  - P added to ADP to create ATP, energy locked in that bond
  - Breaking that bond releases energy
- Energy from breaking P from ATP used to attach C to 5C
  - C is from CO_2, 5-C comes from 'Calvin cycle'
  - 6C Sugars are how 'trapped energy' is moved around plant.
- The 'C-supply' is CO_2, enters through stomata
  - Water must be available to leave while CO_2 enters or stomata will shut.

The start of energy deficits



Trees ‘eat’ carbon dioxide, not fertilizer

…and the occasional sign, bench, fence, bicycle, etc.

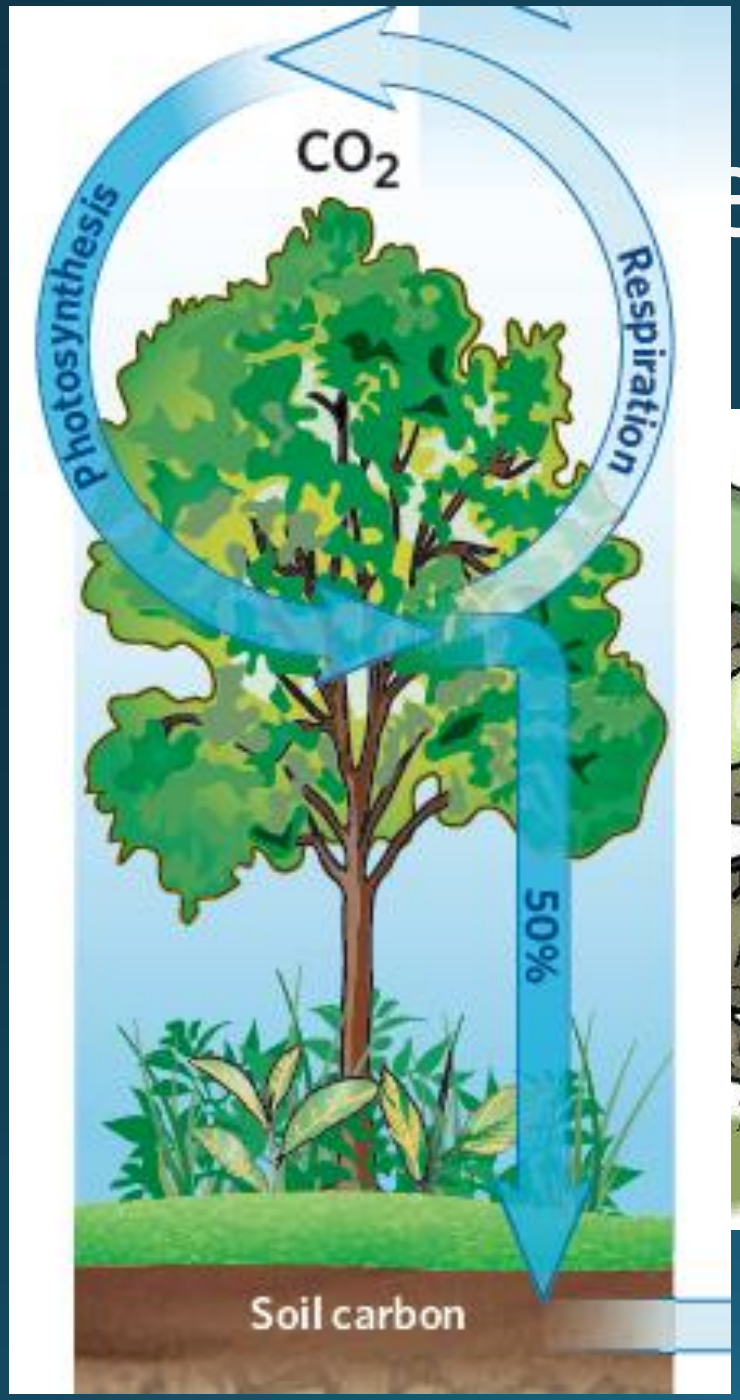
We **DO NOT** feed trees!!!!!!

- *Please* don't refer to fertilization as 'feeding trees', **it's wrong**!
- In a 'food' analogy, trees feed themselves
  - Carbon is the food, comes from the atmosphere
  - What is a better way to apply food analogy to fertilization?
- Fertilization would be more like:
  - Providing the tree with more mouths, or a bigger mouth to eat with
  - Giving the tree more teeth or installing dentures
  - Giving the tree a bigger plate, fork, or spoon
- Trees 'feed' themselves (acquire their own energy), fertilization makes it easier for them to acquire that energy, or 'food'.

Money is a better analogy for the Energy Budget

- Photosynthesis = doing work, earning money
  - ATP = cash, dollars
  - Sugars / Carbohydrates = checking account
  - Starch = investments, assets
  - **Fertilization = giving the tree 'tools' to do the work**
- Respiration = spending money
  - Growth / Defense / Repair / Reproduction
    - all spend the same money
  - When money is tight, plant 'chooses' what to spend on
- When respiration outpaces photosynthesis, savings are spent, and deficit spending starts the decline process.

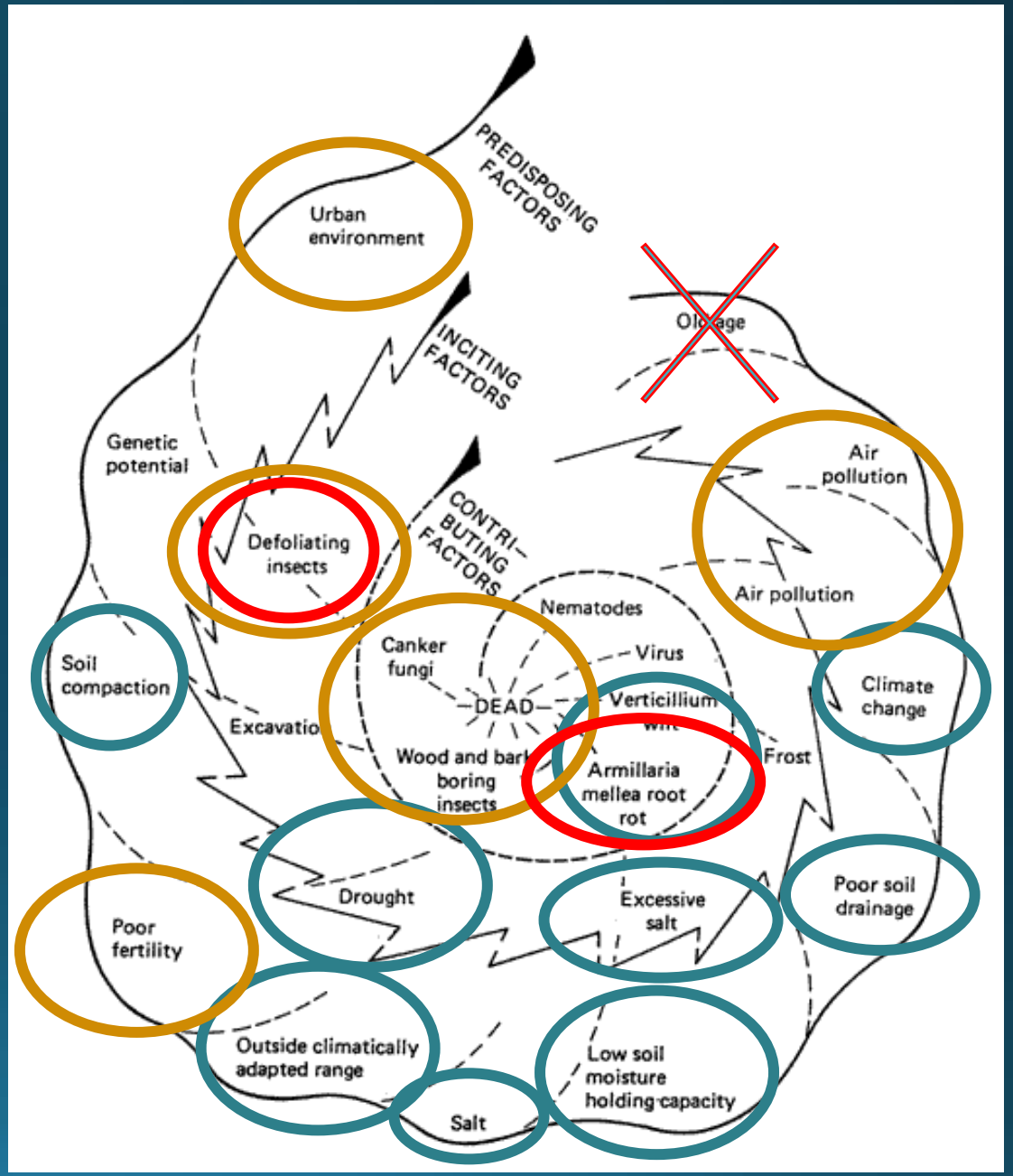
ergy use:



- **Building, Growing, and Repairing** cells and cell components
- **Defense** – building defense compounds, reinforcing plant parts
- **Payment to symbionts** – direct or indirect transfer to microorganisms
- **Reproduction** – flowers / nectar / pollen / seeds / fruit / nuts / etc.
- **Transport** – movement across membranes, against gradients

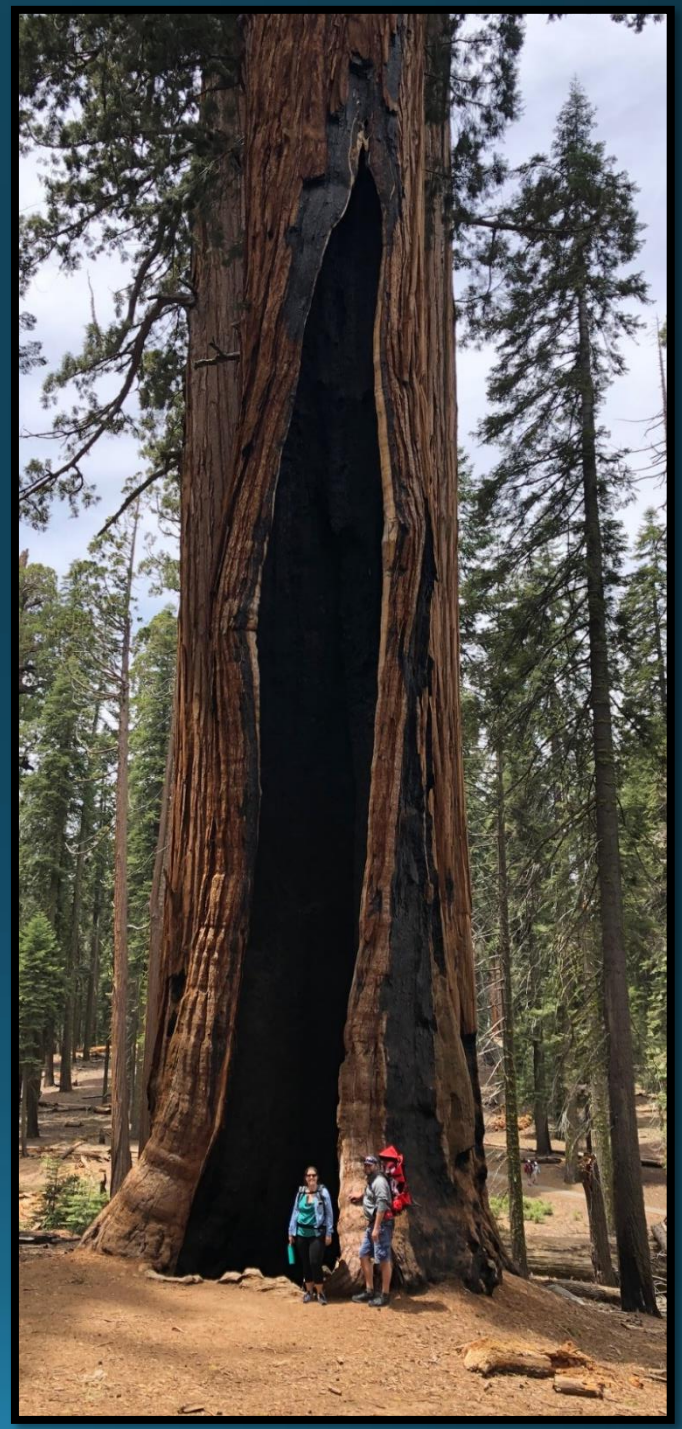
Most factors in ‘decline spiral’ fall into 3 categories:

- Prevent adequate water from reaching leaves
  - leading to closed stomata, less energy gain
- Cause stress – increase energy use while decreasing energy gain.
- Directly ‘steal’ energy, leading to more use than gain.



Trees don’t die of old age

- This is an area of heated debate in academics.
- The living components of trees are never more than a few years old.
- Trees might fail because non-living components failed (decayed) over long periods of time…
- Or they die because accumulated stress (time related) have caused carbon deficits.



Palms and Tropical Trees

- Growth habit may be different to extended or constant growing season
- May not ever go dormant experiencing prolonged growth
- Can develop large buttress roots and aerial roots
- Often have large foliage, leaves and fruit

Palms

- No cambium, growth rings, secondary growth, or CODIT
- Defense to decay comes from the nature of its fibrous tissue
- Instead of a root collar they have a root initiation area from which roots are formed
- Single apical meristem from which all fronds and flowers develop

Tree Biology Wrap-up

- Water:
  - Most important factor for plant health and growth
  - Moves through plant based on gradients of solutes or humidity
  - Moves up and distributes in xylem – as do systemic PHC materials
- Roots:
  - Stability, uptake, storage, signaling, symbioses
  - Must have water, oxygen, non-compacted soil
  - Highest density of fine roots near trunk, not very deep
  - Water, nutrients, and some PHC materials taken up by roots
  - Others must be injected (larger and less soluble molecules)

Tree Biology Wrap-up

- Root collar:
  - Important to inspect for structure and health reasons – must be exposed
  - Best injection site: better distribution through tree and wound closure
  - Injections should be made into the xylem tissue
- Trunks / Branches:
  - Form is dictated by genetics, light, water, space, arboricultural practices
    - Ultimately all these factors affect hormones
  - CODIT walls offer some insight into wound response
    - Trees seal, they don't heal
  - Trunks and branches store important reserves of water and carbohydrates

Tree Biology Wrap-up

- Leaves:
  - Morphology can change depending on location on plant and environment
  - Primary producers of food
  - Contain chloroplasts that contain chlorophyll
  - Transpiration through the stomata produce gradients that pull water, nutrients, etc. up from the roots
- Photosynthesis and Respiration:
  - Photosynthesis converts light energy into chemical energy stored in sugar
  - Stored energy is “spent” in Respiration to grow/defend/repair/reproduce

Questions?

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