Why Do Trees Die?

Rex Bastian, Ph.D.
The Davey Tree Expert Co./The Care of Trees
Wheeling, IL

To Understand How Trees Decline and Die, We Must:

- Understand stress and how it affects trees
  - » To do this, we must also understand:
    - – Tree anatomy and how trees grow
    - – The processes of respiration, photosynthesis transpiration, and translocation
- Understand how trees allocate resources

-Merker and Hopper, 2005

What is "Stress?"

- Any condition, or complex of conditions, that limits the tree's ability to obtain essential resources from the environment
- This can occur because of:
  - » Actual shortage of resources in the environment
  - » Inability of the tree to obtain/move/process resources that exist in adequate supply in the environment

Tree Physiology

- The study of processes that take place inside at tree
  - » Photosynthesis
  - » Respiration
  - » Transpiration
  - » Absorption
  - » Translocation
  - » Growth and Development
  - » Defense

Photosynthesis

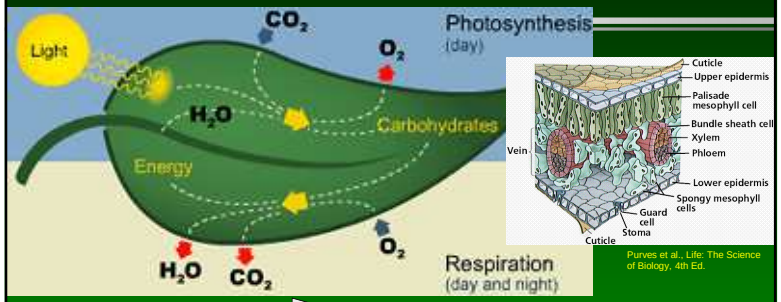
Water + Carbon Dioxide —(Light Energy, Chlorophyll)→ Sugar + Oxygen

- This process allows us to live on this planet
- Sugar can function as both a potential and kinetic energy for the tree

What Happens to the Sugar?

- Much is used as a kinetic energy source for respiration
  - » fuels day to day processes (makes things happen)
- Chained together to make "Cellulose"
  - » more leaves, roots, wood, etc.
- Chained together to make "Starch"
  - » stored for future energy needs as carbohydrate reserves (Potential Energy)
- Used for fuel to make protective chemicals

Respiration

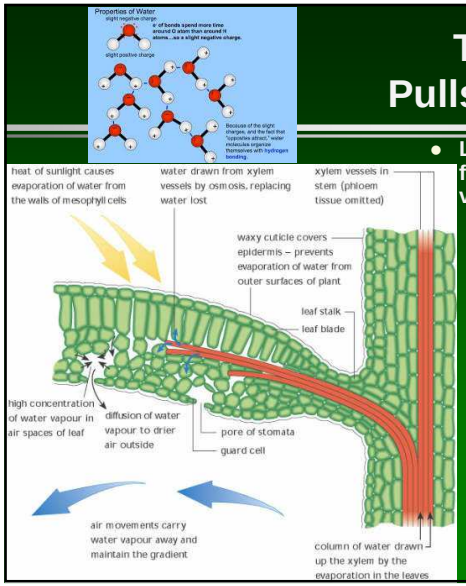


Purves et al., Life: The Science of Biology, 4th Ed.

Sugar + Oxygen → Energy + Water + Carbon Dioxide

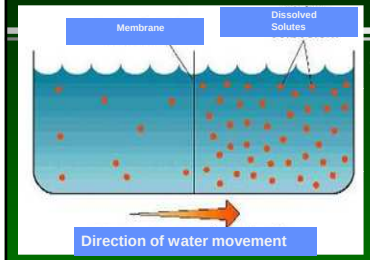
- Reverse of photosynthesis
- Sugars are burned to produce kinetic energy for use
- Occurs both day and night (even when trees are dormant)
- Ultimately, this becomes the key process

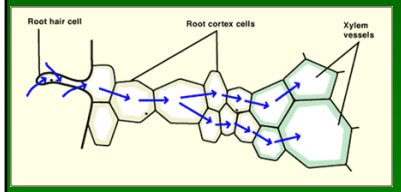
Transpiration Pulls Water Up Stem



- Loss of water through the foliage in the form of water vapor
  - » As water vapor is lost, water molecules "pull" each other up the plant
  - » Direct connections exist from root hairs to leaves
  - » Rate of water loss is regulated by stomates
    - Usually open during day and close at night
  - » Temperature, humidity, light and other factors all influence transpiration

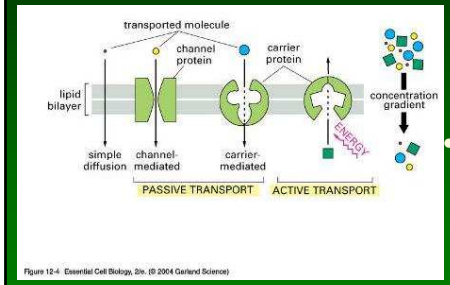
Absorption/Translocation
Water Moves into Root By Osmosis





- Plant cells have more solutes in their interior than does water in the soil
  - » Water moves from low solutes to high solutes
    - – Same principle as used in pickles or salted meats
  - » Requires no or little energy
  - » Once water reaches xylem tissues in root, transpiration pulls water molecules up the tree

Absorption/Translocation
Passive and Active Uptake of Nutrients

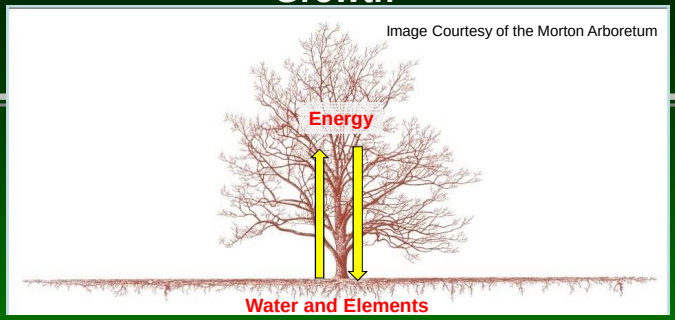


- Passive Transport - movement of nutrients from higher to lower concentration (Diffusion)
- Active Transport - root selectively transports nutrients across plasma membrane and into the root against concentration gradient
  - » Requires Energy

Translocation

- Food (sugars and other compounds) are moved in phloem tissues
  - » Sources (where made)
    - – Leaves/green twigs
  - » Sinks (where needed)
    - – Fruit
    - – Seeds
    - – Young foliage
    - – Root tissues
- This movement can be up, down, or sideways in the tree
  - » Loading the phloem requires energy
- The phloem, like the cambium, is very thin and easily damaged

Growth



- Tree Growth depends on two “pumps”
  - » One produces water and elements
  - » The other produces energy
- Each depends on the other
  - » If one begins to fail, the other will soon follow
- Growth and health depend on how well both pumps can function as the tree grows larger

Trees are Generating Systems

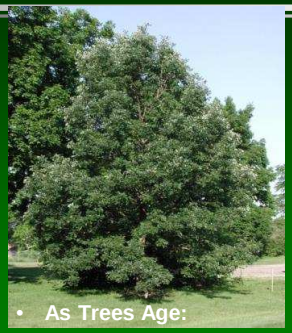
- They must grow to survive
- They can grow fast or slow, a lot or a little, but they must grow
  - » They have no choice
- If trees stop growing, they die!

Trees Allocate Resources

- » Metabolism
- » Growth
- » Reproduction
- » Defense
- Tree must finance all of these
- Maintaining a high level of potential energy is key to long term health

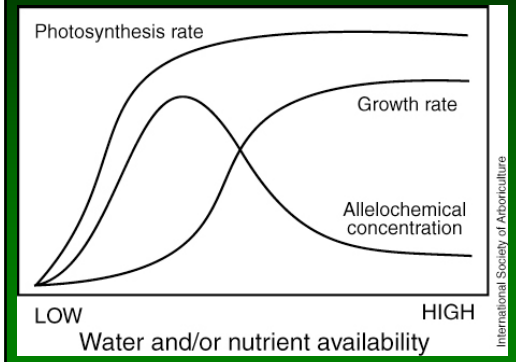
Dynamic vs Static Mass

Dynamic Mass: Tissues that are alive and functioning
Static Mass: Tissues that are dead or not actively functioning



- As Trees Age:
  - Static mass increases relative to dynamic mass
  - Potential/Kinetic energy ratio decreases
  - Demand for carbohydrates increases
    - Volume of respiring tissues increases while photosynthetic volume remains fairly constant

Photosynthesis Vs Growth Vs Defense

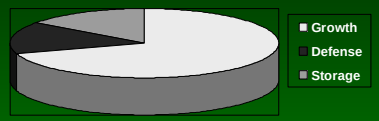


- Can there be too much of a good thing?
- What about the low/moderate range?

How Does Nature Handle the Situation?

Growth Strategy and Life Expectancy

Fast Growth Tree Species

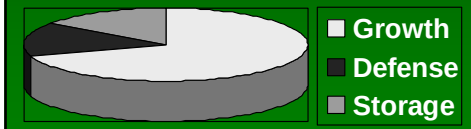


Slow Growth Tree Species

- Trees allocate energy to growth and defenses differently
- Resulting life expectancy vary based on growth strategy
  - » Poplars → 60 years
    - – "Live Fast, Die Young"
  - » Oaks → 200-300 years
    - – "Slow and Steady Wins the Race"

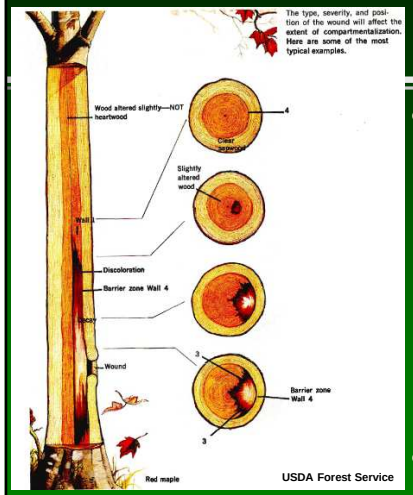
Quandary--Which is More Desirable?

Resource Allocation Unequal Incomes



- The tree with the greater income can allocate more to each use, but maintain the balance

Tree Defense Systems CODIT



- CODIT can be hard to visualize
  - » Key points
    - – It's a survival mechanism
    - – Wood that forms after wounding is more resistant to decay
    - – Trees may become hollow as a result of CODIT
    - – Decay spreads vertically faster than sideways and outward
- Requires Energy, but is funded at low priority

Prioritization of Resources

1. Maintenance of living tissues (Respiration)
2. Production of fine roots
3. Flower and seed production
4. Primary growth (elongation of shoots and roots)

5a. Secondary/Diameter growth

5b. Defensive chemicals

Oliver and Larson, 1996

Trees Are Fighting A Losing Battle As They Age

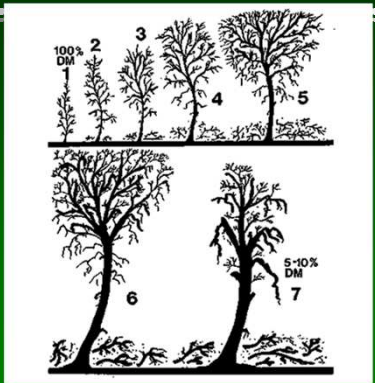
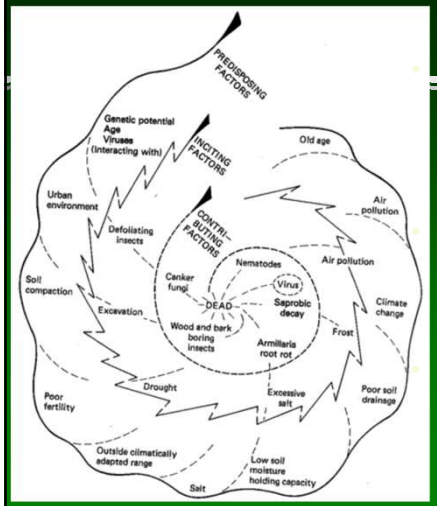


Image from Shigo, Modern Arboriculture

- The tree is committed to increasing its mass
- With limiting resources, the tree regulates its dynamic/static ratio so that kinetic energy demands do not exceed potential energy reserves
- It can't keep doing this forever!

The Decline Spiral



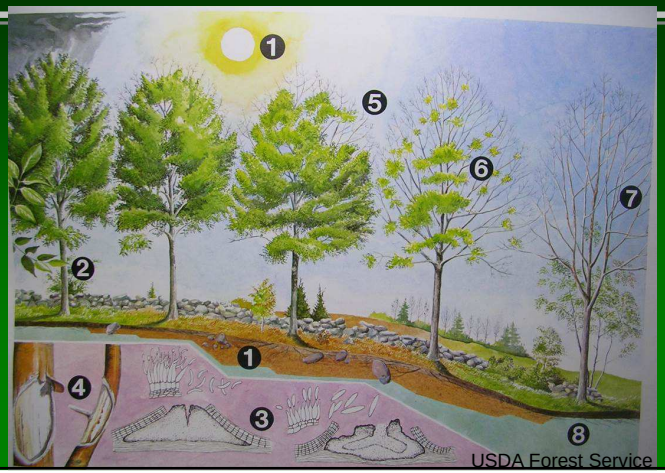
Image/Text from Manion, Tree Disease Concepts

Predisposing Factor
- » Diminishes vitality from optimum
- » May not be noticeable
- » Long term
- » Character of tree or physical environment

Inciting Factor
- » Especially damaging to Predisposed tree
- » Short term
- » Often very noticeable
- » Physical or biotic

Contributing Factor
- » Perpetuates decline of already altered tree
- » Long term
- » Effect often very noticeable
- » Often opportunistic insect/pathogen

The Decline Spiral



USDA Forest Service

Patterns of Death in Landscape Trees

- Structural Failure
  - Branch, crown and stem failure, uprooting, decay, girdling
- Environmental Degradation
  - » Acute
    - Flooding, fire, vandalism, construction injury, drought, high/low temperature
  - » Chronic
    - Soil toxicity, soil compaction, air pollution, restricted growing space, low fertility, severe pruning
- Parasitic Invasion
  - Insects, fungi, bacteria, viruses, mycoplasma-like organisms, parasitic plants

So, Why Do Trees Die?

- **And finally, Respiration Terminates**
  - » Which leads to carbohydrate production ceasing and/or carbohydrate stores being exhausted
    - – Then, photosynthesis slows or discontinues
      - Factors necessary for photosynthesis are unavailable, interrupted, or obstructed
        - » Because of physical, biological, environmental or human factors

Summary

- Each part of a tree's anatomy contributes to its survival
- Photosynthesis produces energy, respiration uses that energy, and transpiration keeps trees hydrated
- A tree's vascular system is responsible for moving water, nutrients, and foods to where they are needed
- Trees defend themselves from insects and diseases, but ultimately, run out of energy