Tree Physiology and Growth

Dr. Gary Chastagner

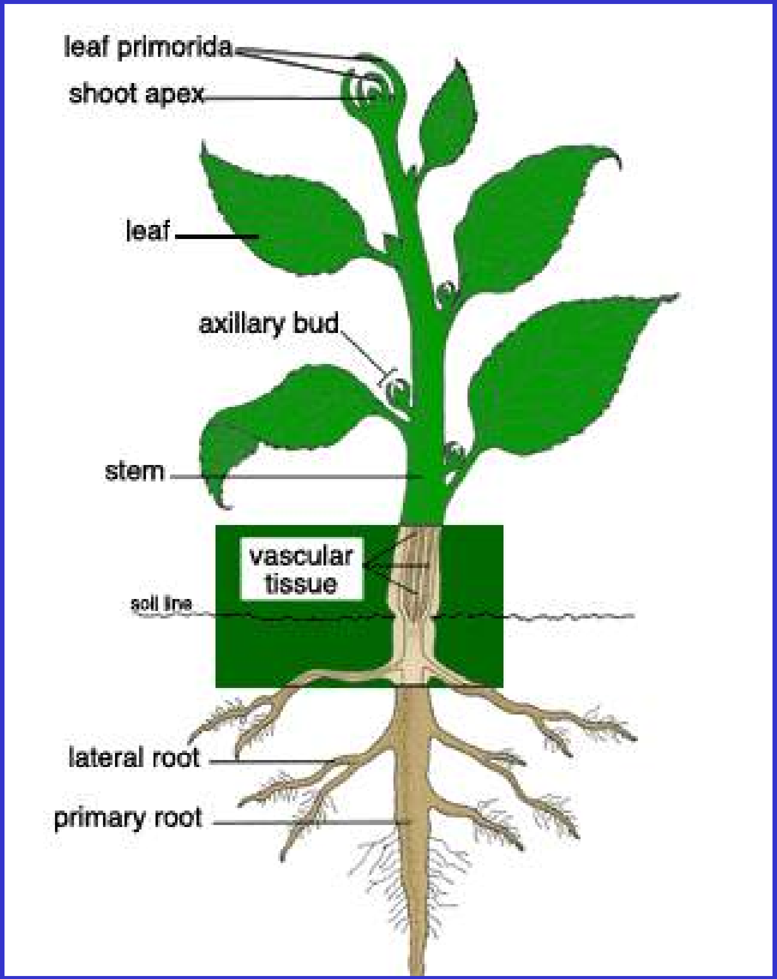
Washington State University

Puyallup, WA 98371

chastag@wsu.edu

March 2008

Principal Parts of a Vascular Plant



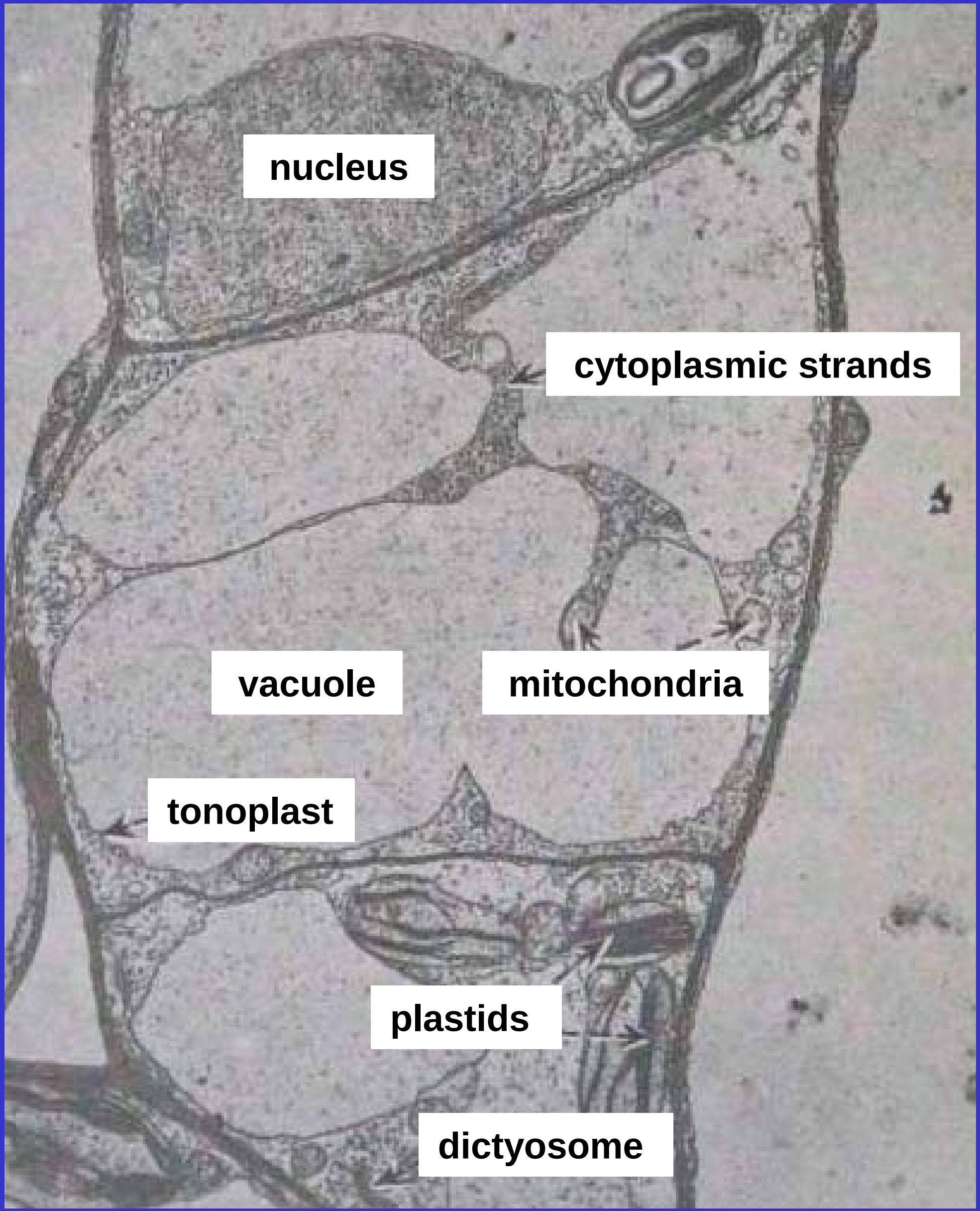
Vegetative structures
– leaves, stems, roots

Reproductive structures –
flowers, fruits/cones, seeds

Growth is a cellular process that results in the increase in size and number of leaves, stems, and roots and the production of reproductive structures

http://extension.oregonstate.edu/mg/botany/external.html

Cells



- Basic structural and physiological units of plants
- Most plant reactions (growth, photosynthesis, respiration, etc) occur at the cellular level

Robins, Weier, & Stocking. 1966. Botany. Wiley

Plant Tissues – Large organized groups of similar cells that work together to perform a specific function

i.e. Meristems, xylem, phloem, etc.

Plant Growth

- Growth occurs via meristematic tissues – cell division, elongation and differentiation
- Is influenced by genetics
- Is influenced by environment (water, light, temperature, nutrients, pests)
- Is influenced by plant hormones
- Growth activity can be manipulated by cultural practices (shearing, etc.)

Plant Growth and Development

Three major physiological functions drive growth and development

- Photosynthesis
- Respiration
- Transpiration

Function of Vegetative Structures

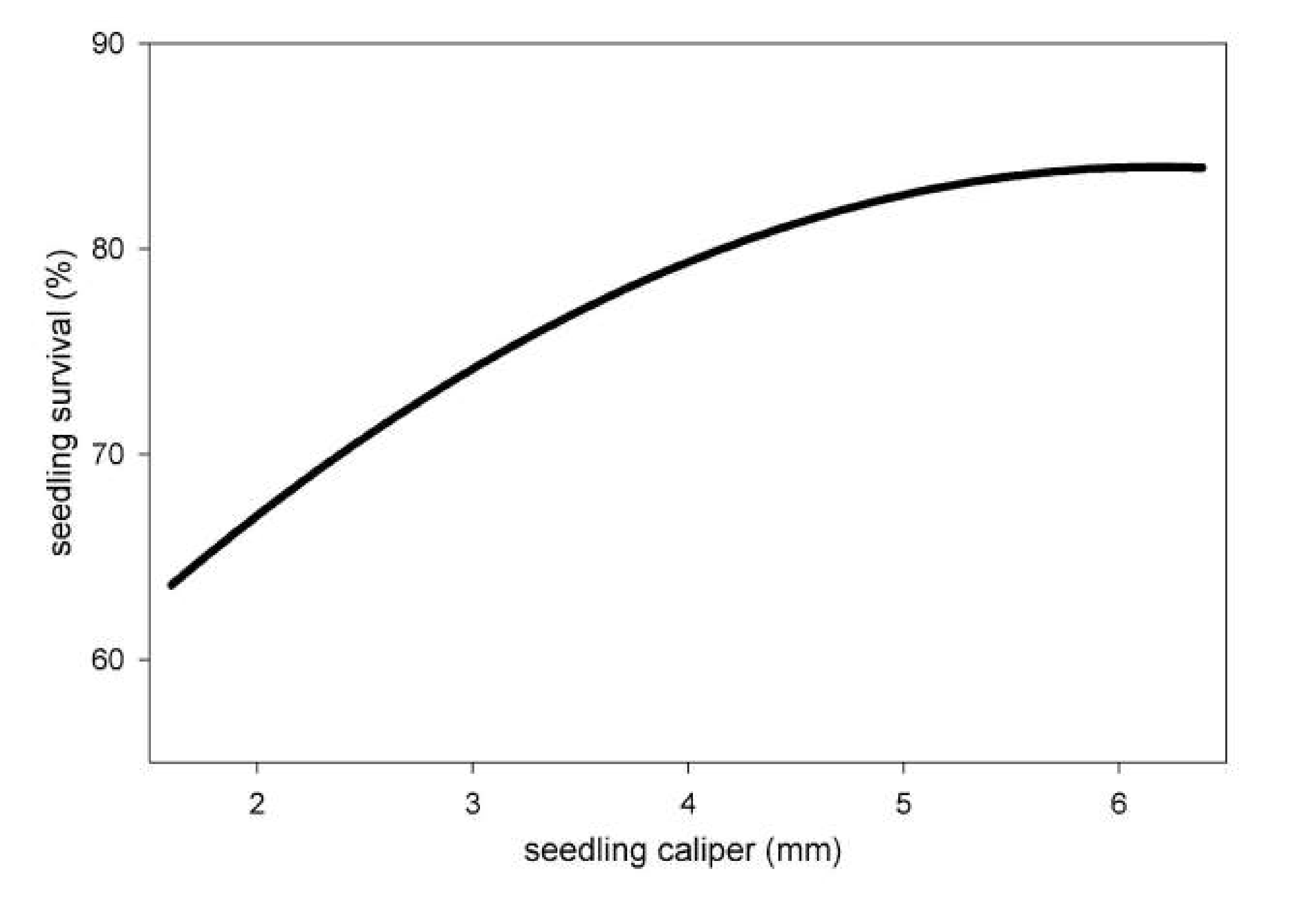
Leaves - absorb sunlight to manufacture plant sugars (photosynthesis) and provide energy (respiration) to produce proteins, etc. needed for cell growth

Stems – support, transport of materials (food, minerals, hormones, water, etc,) and storage of carbohydrates

Roots - absorb nutrients and water, anchor plant in soil, support stem, storage of carbohydrates, and produce hormones



Seedling Survival is Closely Related to Seedling Stem Caliper

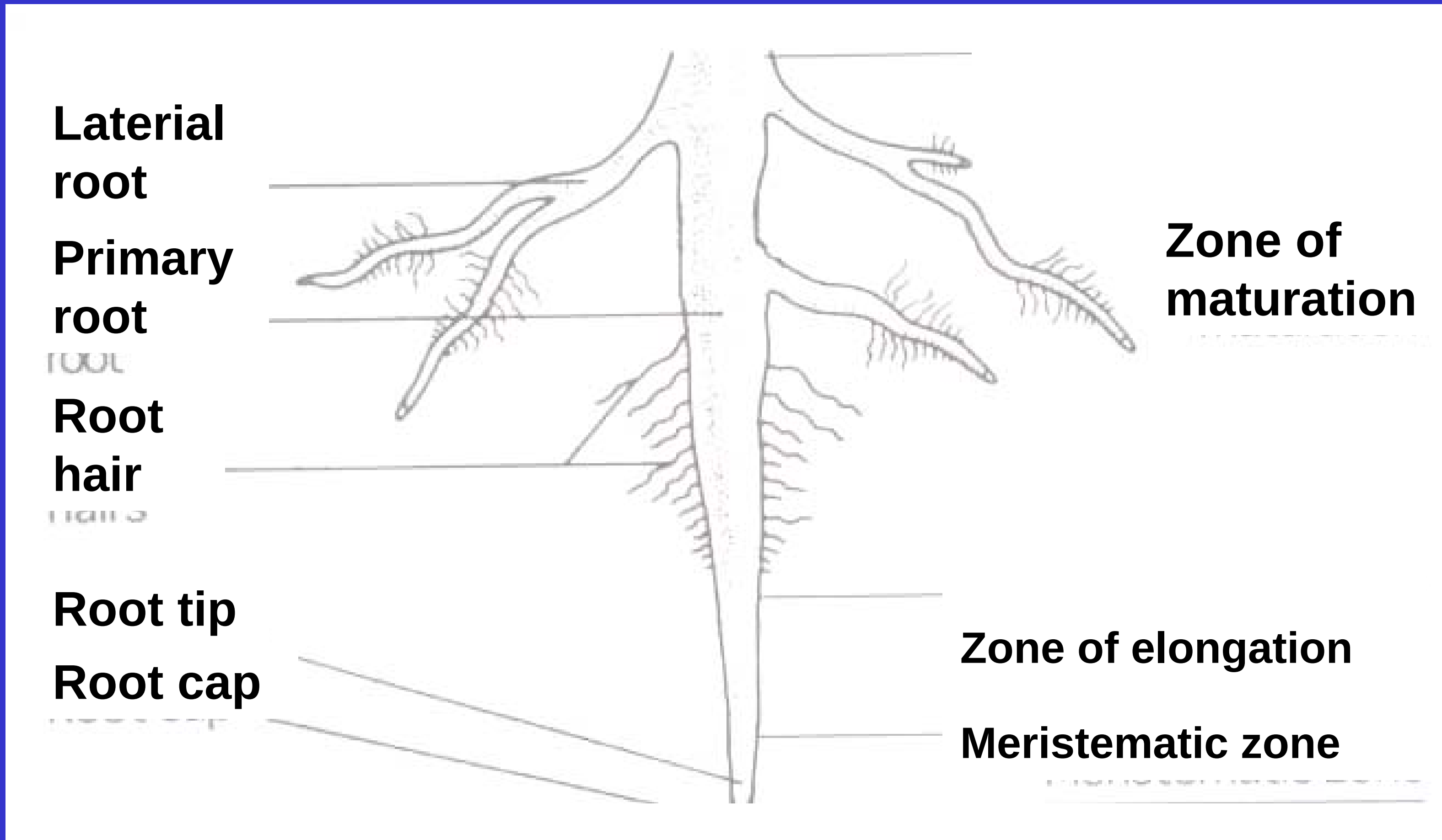


Source: Bert Cregg, MSU; Adapted from South and Mexal (1984).

Root to Shoot Ratio and Height

Douglas-fir seedlings with a shoot/root ratio (S/R) of 0.8 had 25% greater survival than seedlings with a S/R greater than 1 on dry sites in the PNW

Root Structure – 3 major zones



Uptake of Water and Nutrients by Roots

Epidermis – outermost layer where water and nutrient absorption occurs

Root hairs – increase surface area and absorption (short lived)

Cortex – movement of water from epidermis to vascular tissue

Vascular tissue – movement of water, nutrients, and carbohydrates throughout plant

Mycorrhizae – increase nutrient absorption

Mutualism

Ectomycorrhizal Root Tips

http://www.ffp.csiro.au/research/mycorrhiza/ecm.htm

Plant Root

Fungus

Fixed Carbon →

← Increased Nutrients
Increased Water Uptake
Protection from Pathogens

Distribution of Root Systems

Generally limited to top 12” of soil

Affected by host, soil type, saturation and compaction

Roots Require Oxygen to Survive and Grow

Oxygen Requirements

- Root survival – need 3% O_2 in soil
- Apical meristem region requires 5 to 10% O_2
- New root formation $\geq$ 12% O_2

Soils and Oxygen Levels

- Undisturbed loam soil – 0 to 6” depth ~ 20%
- Sandy soil – 15% at 5 feet
- Clay loam soil does not have enough oxygen to support root growth at 3 feet
- Compacted loam soil - 5% at 15 inches, roots will survive, but new roots would be stressed

Effect of Soil Compaction on Monterey Pine Shoot and Root Growth

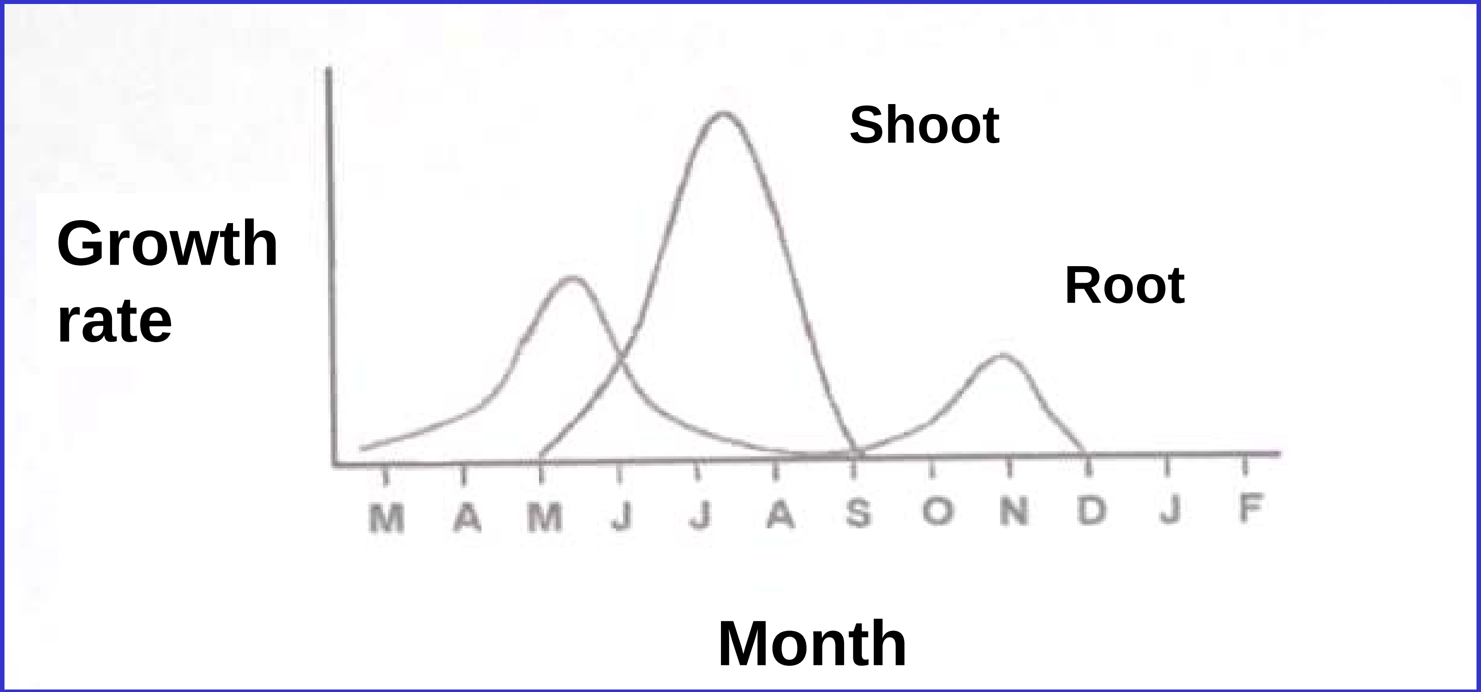
Soil bulk density (g/cm3)	Dry volume		Root volume (cm3)	Height (cm)
	Shoots	Roots		
1.60	3.6	3.0	24.7	20.5
1.48	5.9	4.9	39.3	29.2
1.35	7.0	5.6	47.3	32.8

>bulk density = > compaction

Source: Sands and Bowen 1978. Aust. For. Res. 8:163-170

Annual Shoot and Root Growth Patterns

(Conifers in PNW)



Roots Require Oxygen to Survive and Grow

Oxygen Requirements

- Root survival – need 3% O_2 in soil
- Apical meristem region requires 5 to 10% O_2
- New root formation $\geq$ 12% O_2

Soils and Oxygen Levels

- Undisturbed loam soil – 0 to 6” depth ~ 20%
- Sandy soil – 15% at 5 feet
- Clay loam soil does not have enough oxygen to support root growth at 3 feet
- Compacted loam soil - 5% at 15 inches, roots will survive, but new roots would be stressed

Effect of Soil Compaction on Monterey Pine Shoot and Root Growth

Soil bulk density (g/cm3)	Dry volume Shoots	Roots	Root volume (cm3)	Height (cm)
1.60	3.6	3.0	24.7	20.5
1.48	5.9	4.9	39.3	29.2
1.35	7.0	5.6	47.3	32.8

>bulb density = > compaction

Source: Sands and Bowen 1978. Aust. For. Res. 8:163-170

Planting Stock Types

- Seedlings – bare root and plugs
- Transplants – bare root, plug + bare root, and plug + plug
- Rooted cuttings
- Grafted

Planting Stock Type

Container (plug) vs bare root

Planting Stock Type

Container (plug) vs bare root

- Out planting performance differences have been variable!
- In general, container seedlings tend to:
  - be less prone to stress during shipping and storage
  - be better on droughty or stressful sites
  - provide a wider window for planting
  - be more expensive for a given size
  - have more root problems
  - take longer for roots to come in contact with soil
  - increase the time for water movement from soil to seedling roots

Container Stock Root Structure

Plug Transplants are Becoming Increasingly Popular

Advantages include:

- **rapid turnaround**
- **maximum control of growing environment during early stages of growth**
- **advantages of bare root production for the end customer – hardy seedlings that establish rapidly at the out planting site**

Vascular System = plumbing

Xylem – conducts water and dissolved nutrients

Phloem – movement of carbohydrates, hormones, etc

Cambium – meristematic tissue

Balsam Fir Christmas Tree Stem

Cambium

Bark

Xylem
tracheids
fibers
parachama cells

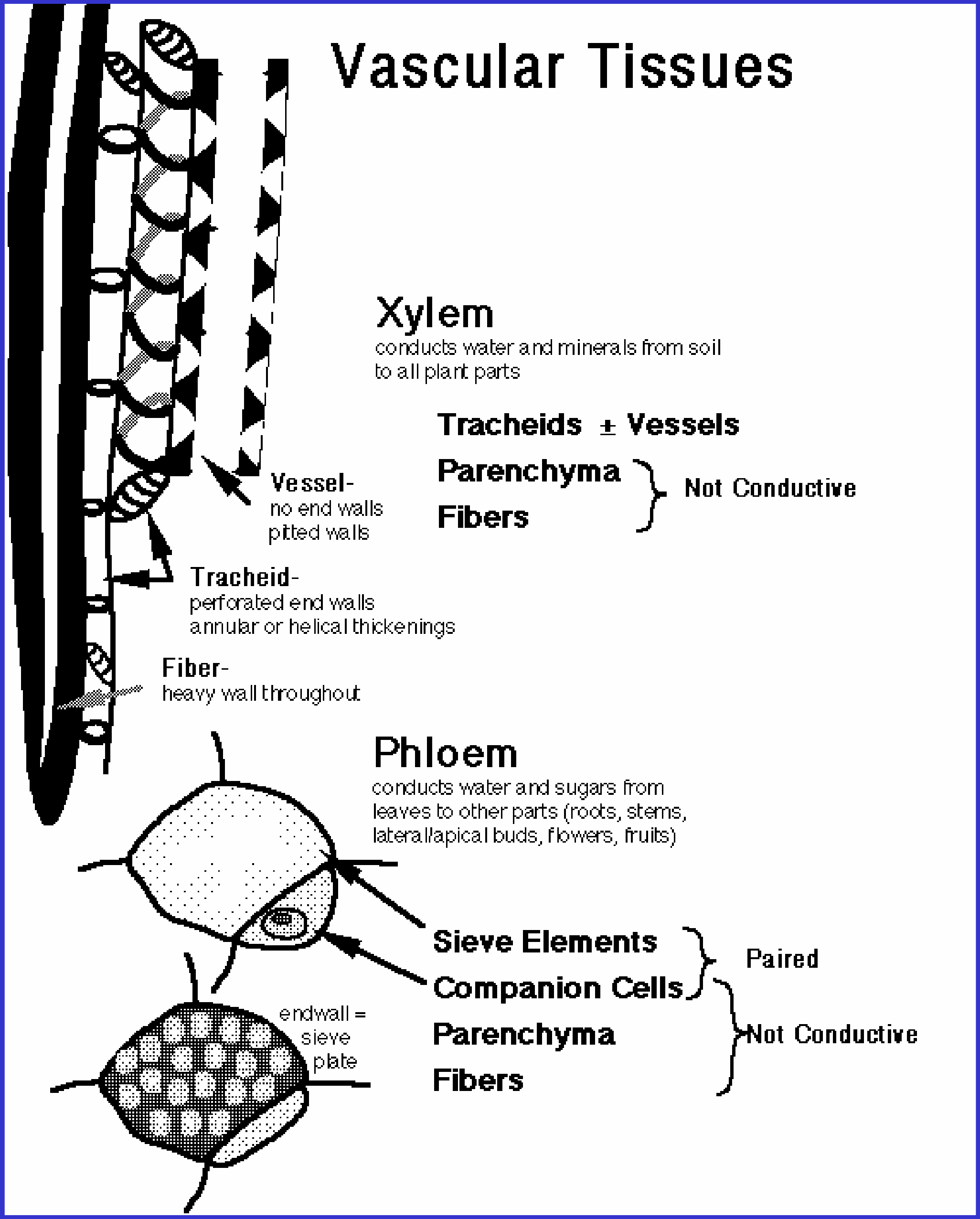
Annual growth ring

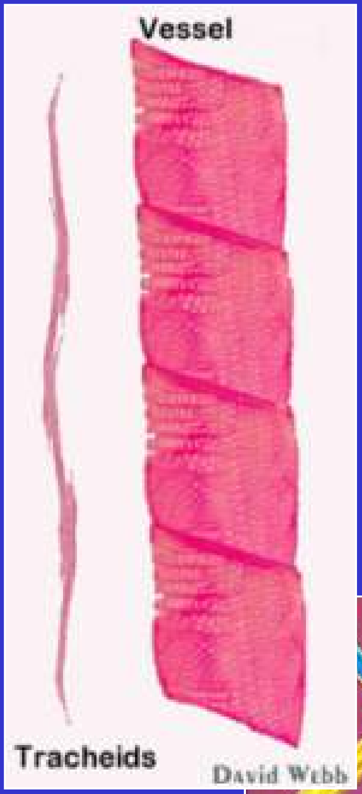
Photo H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings

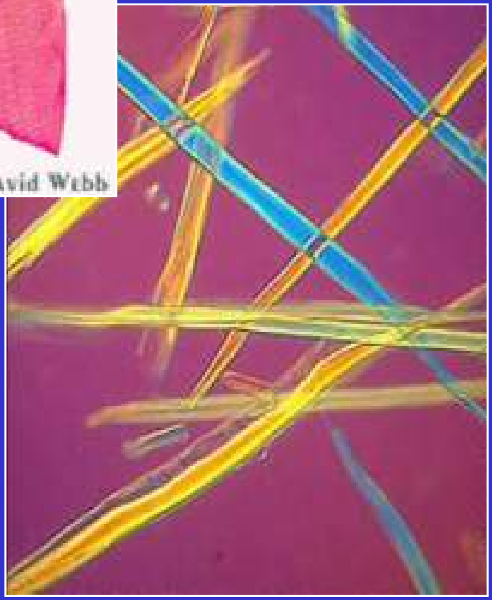
Conifer Xylem

- Have “nonporus” wood consisting of tracheids, fibers and parenchyma cells
- Tracheids - hollow primitive cells (1 mm long) that have pits
- Fibers - thick walled, structural strength
- Parenchyma cells - produce vascular rays that provide for lateral movement of material across the stem and respond to wounds

Xylem and Phloem Tissues



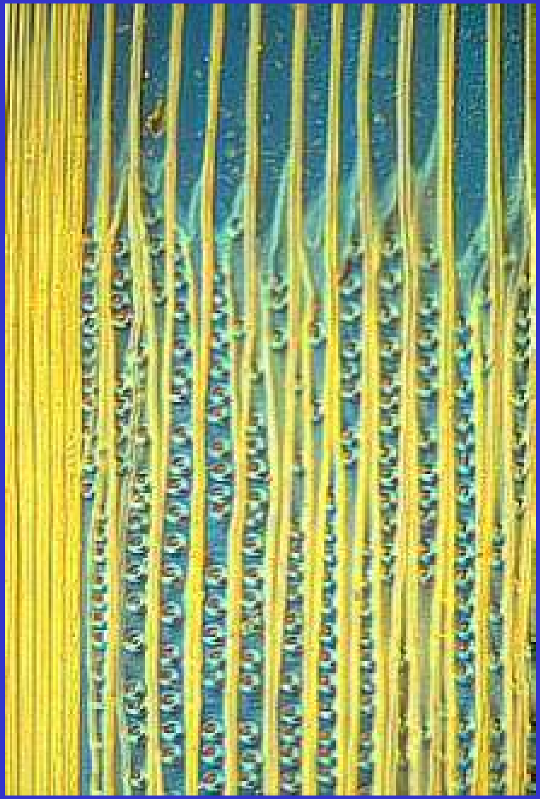




http://koning.ecsu.ctstateu.edu

http://www.biologie.uni-hamburg.de/b-online/e06/06b.htm

Radial sections of *Abies pectinata* wood showing bordered pits on tracheids



← **Pith ray**

↗

Annual growth ring

Photo Peter v. Sengbusch *http://www.biologie.uni-hamburg.de/b-online/e06/abieshof.htm*

Tree ring showing springwood (larger) and summerwood (smaller) cells

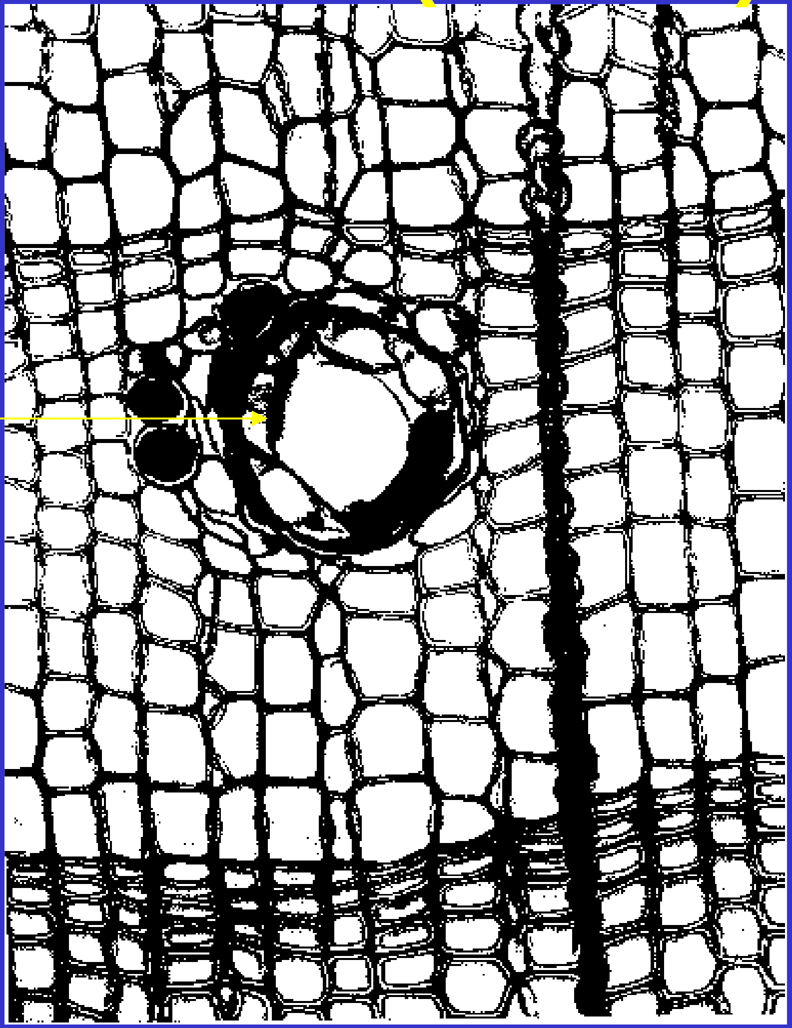


Photo Laboratory of Tree-Ring Research http://web.utk.edu/~grissino/gallery.htm#Rings

Douglas-fir Tree Rings

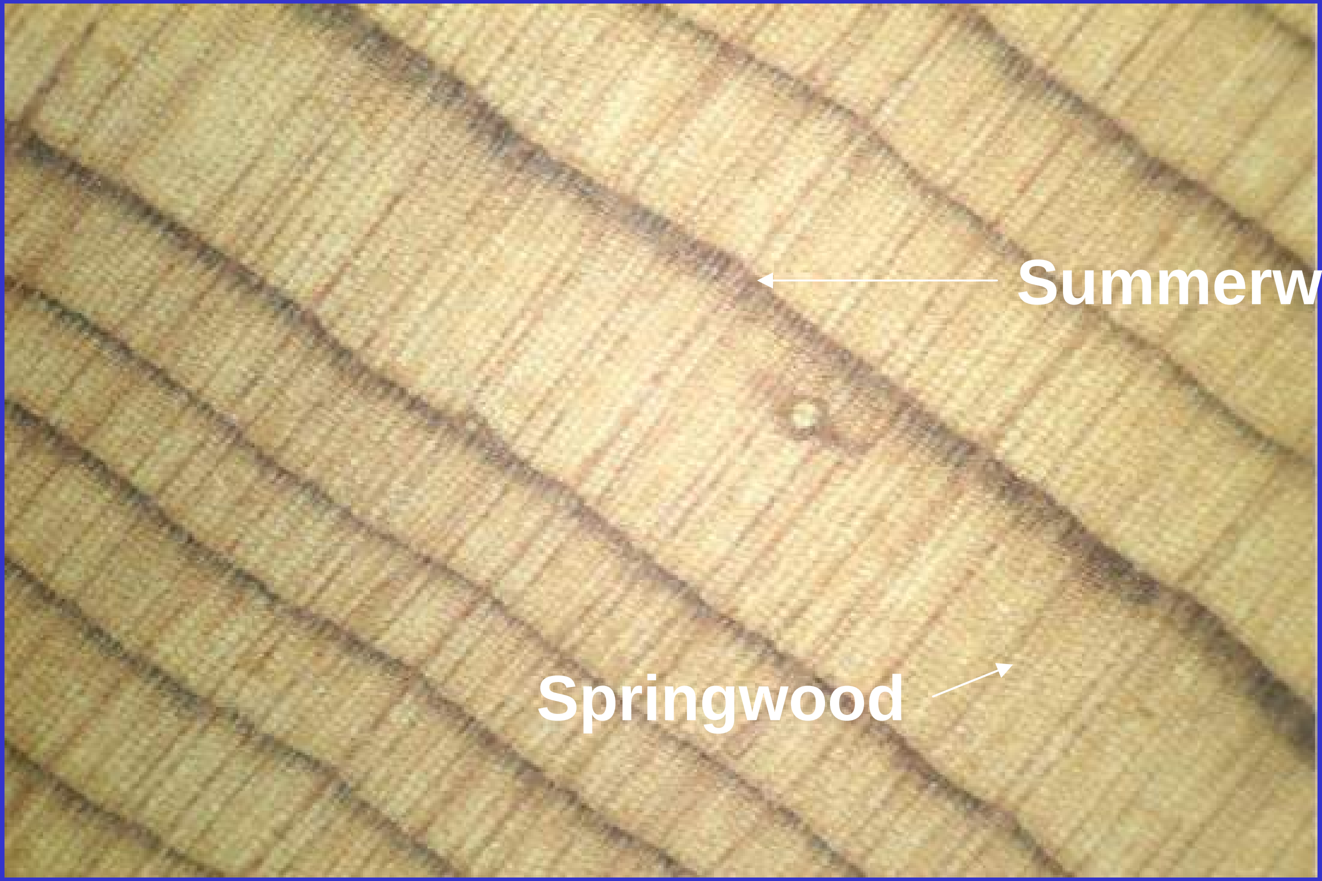
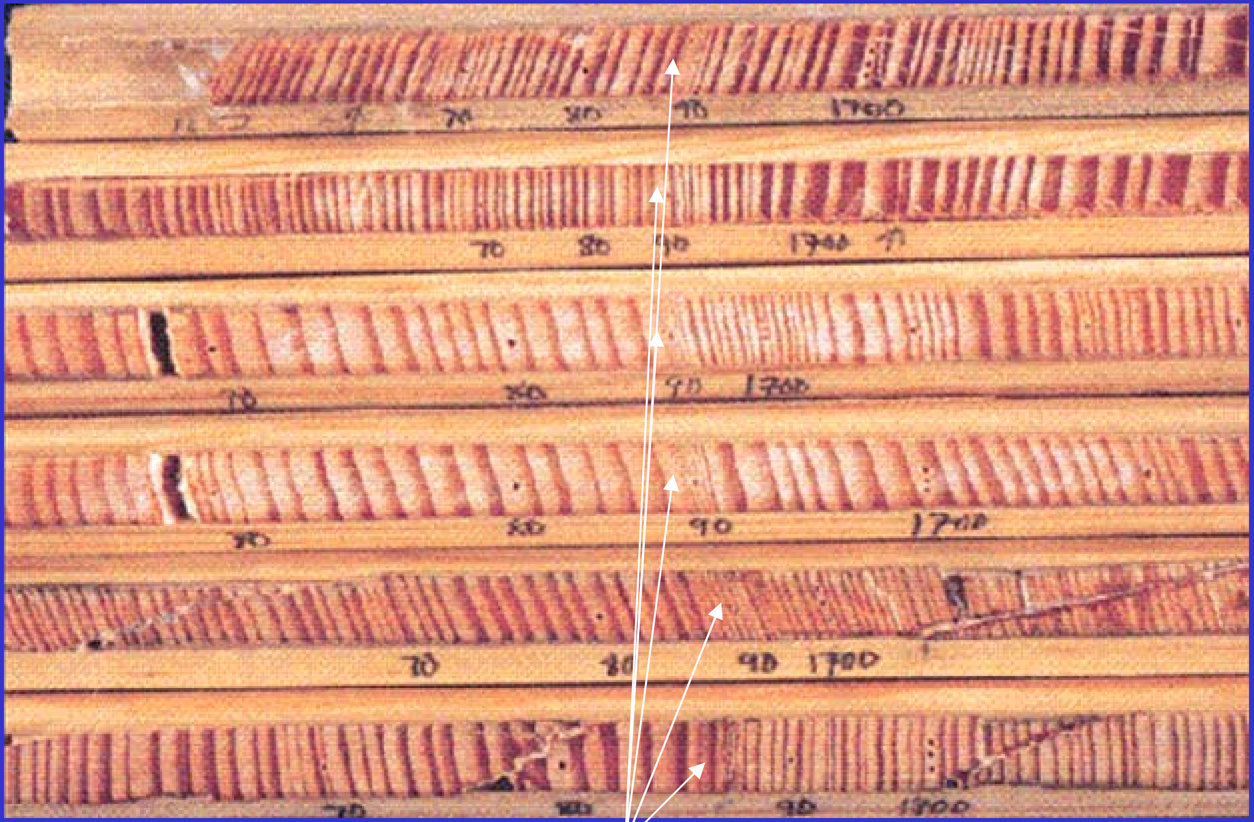


Photo © H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings

Douglas-fir Increment Cores From Trees Growing in Southeastern Arizona



Suppressed growth due to a forest fire that damaged the trees in 1685

Phloem – transport of food and hormones, does not accumulate in rings

Material is moved under positive pressure

5 types of cells

- Sieve cells (pits) – conifers
- Sieve tubes (hardwoods)
- Fibers
- Parenchyma
- Scierids or stone cells – small fiber like cells

Vascular cambium produces xylem and phloem

Cork cambium – located outside functional phloem and produces bark and succulent tissues

Cross Section of a Douglas-fir Stem

Sapwood

- physiologically active, water and nutrient movement, carbohydrate storage

- Water flow is driven by transpiration

Bark

Cambium

Xylem

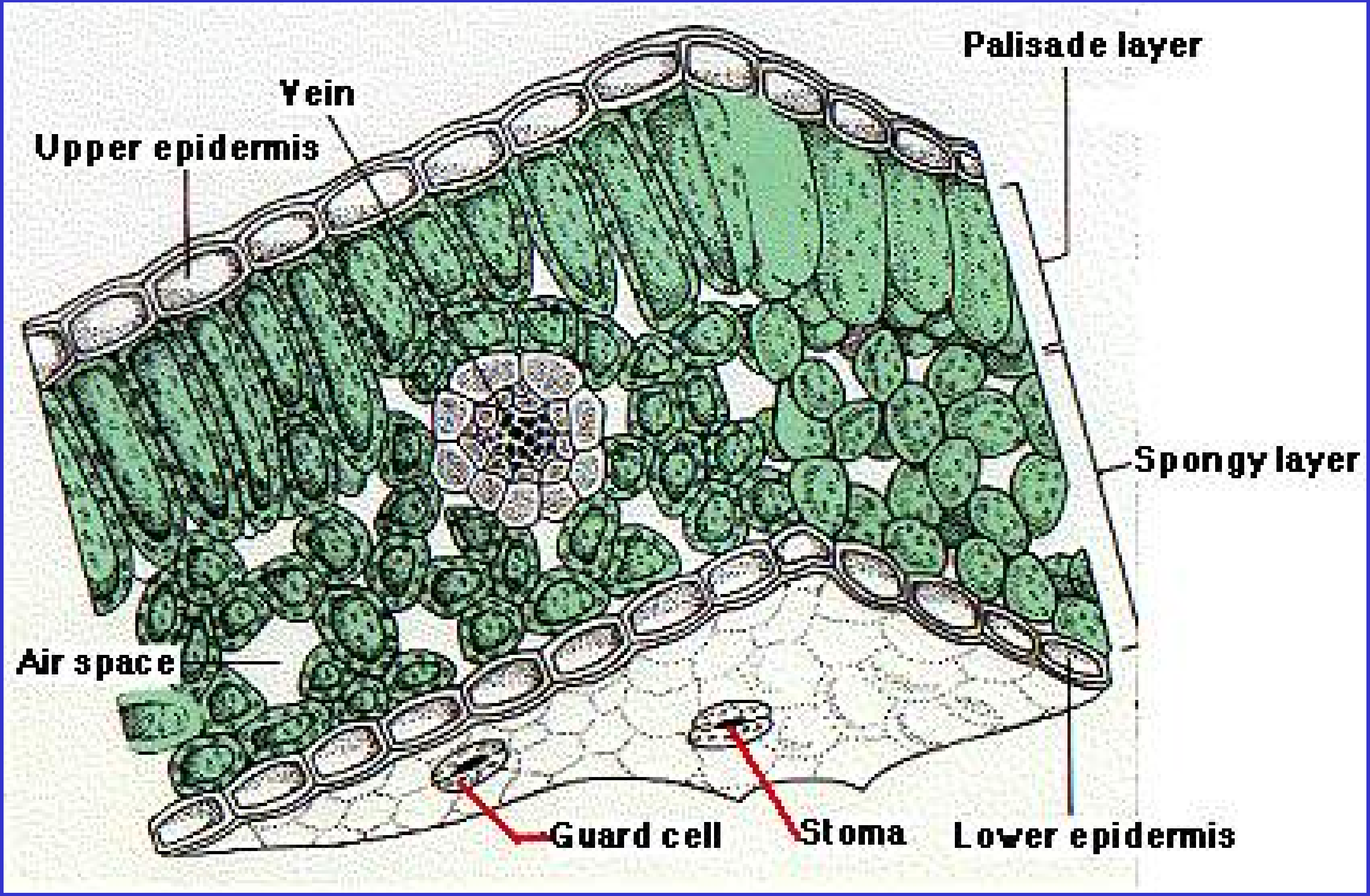
- **Sapwood**
- **Heartwood**

Heartwood

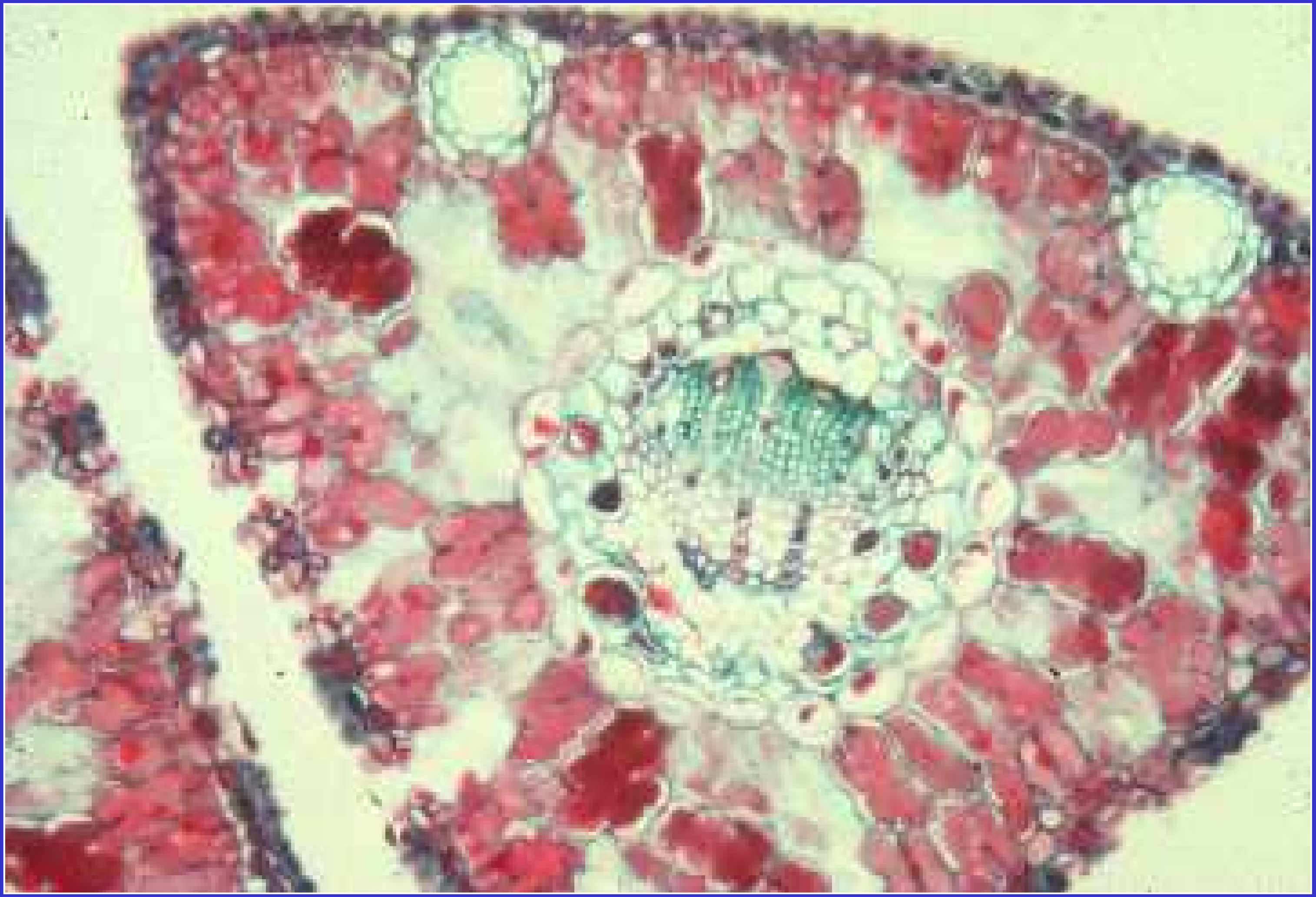
- dead, contains higher levels of tannins & phenols, provides for structural support

Photo © H.D. Grissino-Mayer http://web.utk.edu/~grissino/gallery.htm#Rings

Leaf Structure



Cross Section of a Pine Needle

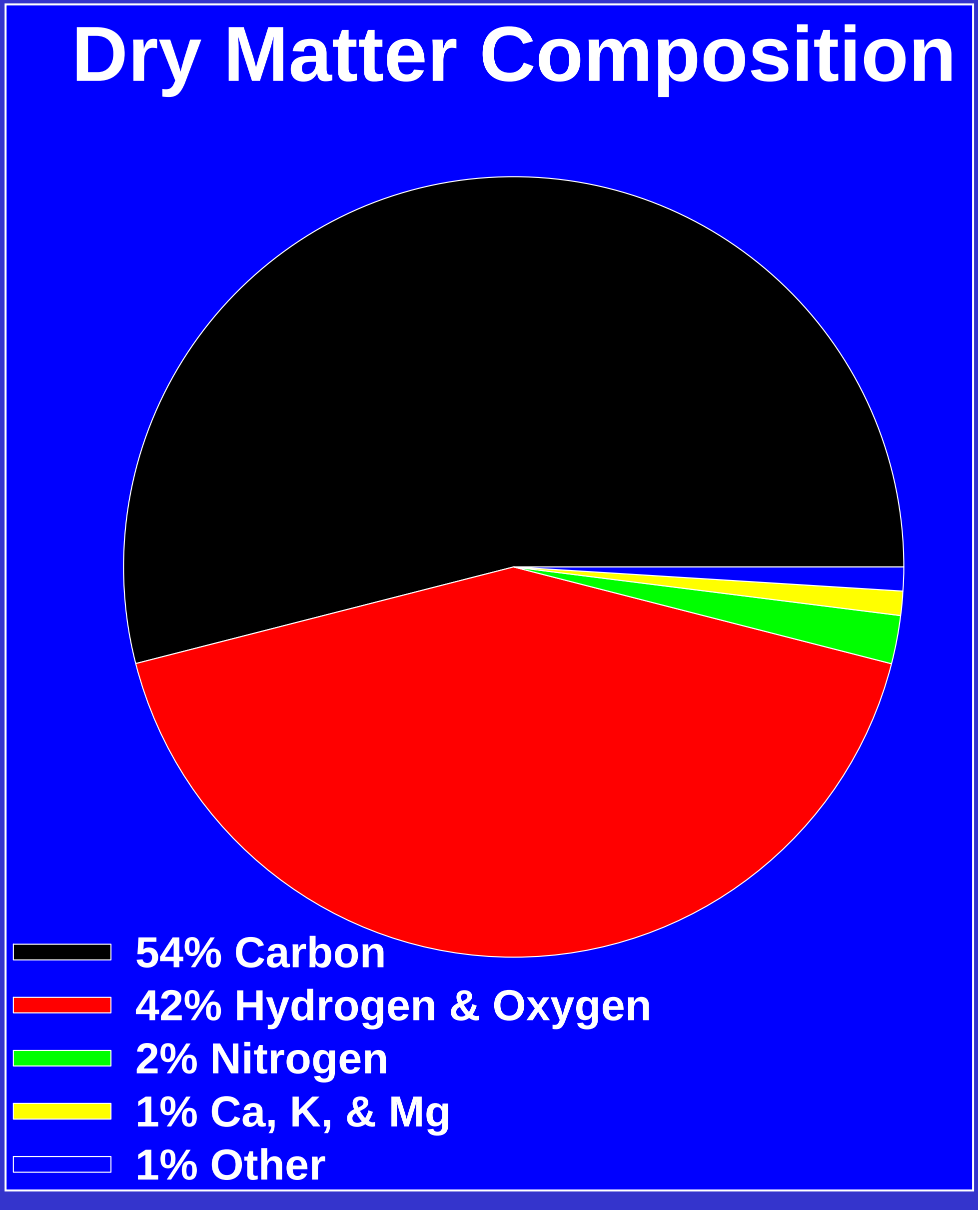


http://biology.uwsp.edu/courses/botlab/Lab08a.htm

Typical Composition of Needles

85-90% water

10-15% dry matter



Photosynthesis – The physiological process plants use to manufacture their own food

Sunlight + carbon dioxide + water is used to produce sugars and oxygen

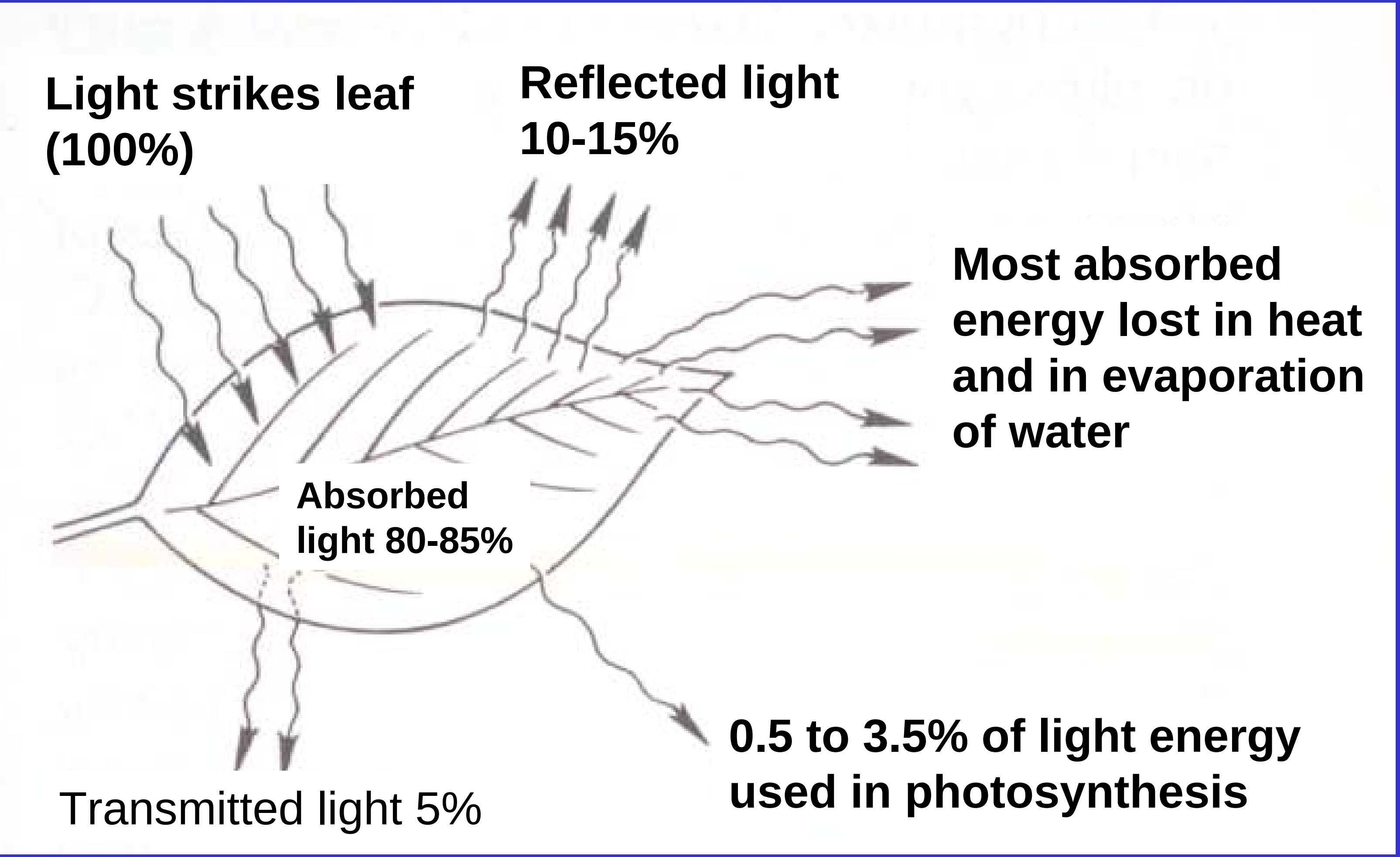
$$6CO_2 + 6H_2O > C_6H_{12}O_6 + 6O_2$$

http://biology.uwsp.edu/courses/botlab/Lab08a.htm

Chloroplasts – a type of plastid that contains chlorophyll and is the site of photosynthesis

Chloroplasts are very small - 400,000/mm^2

Fate of Light That Strikes a Leaf



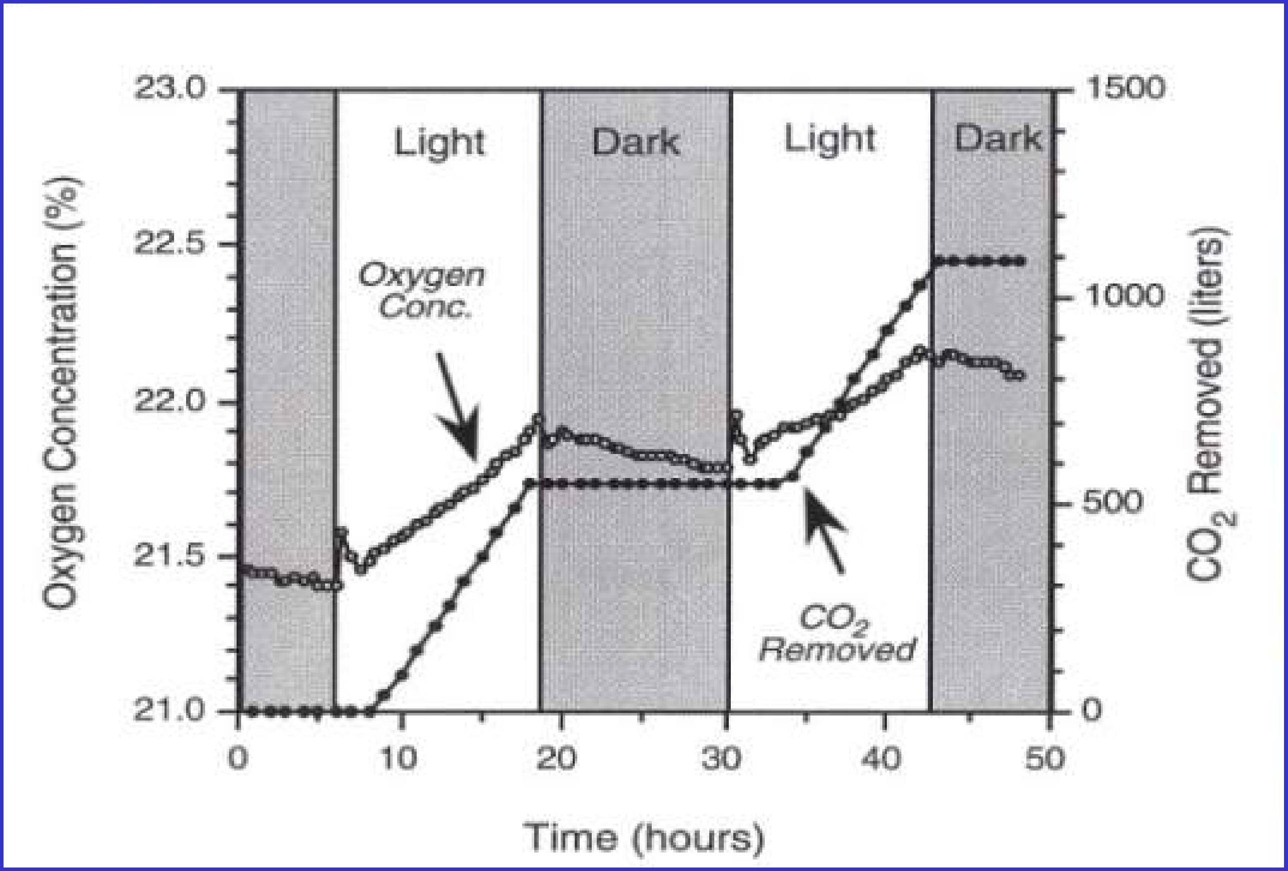
Respiration

- The process (oxidation) of converting carbohydrates (sugars and starches) to energy that is needed for cell growth and production of new tissue

$$C_6H_{12}O_6 + 6O_2 > 6CO_2 + 6H_2O + \text{energy}$$

- Does not require light

Production and Utilization of Oxygen and Carbon Dioxide by Plants

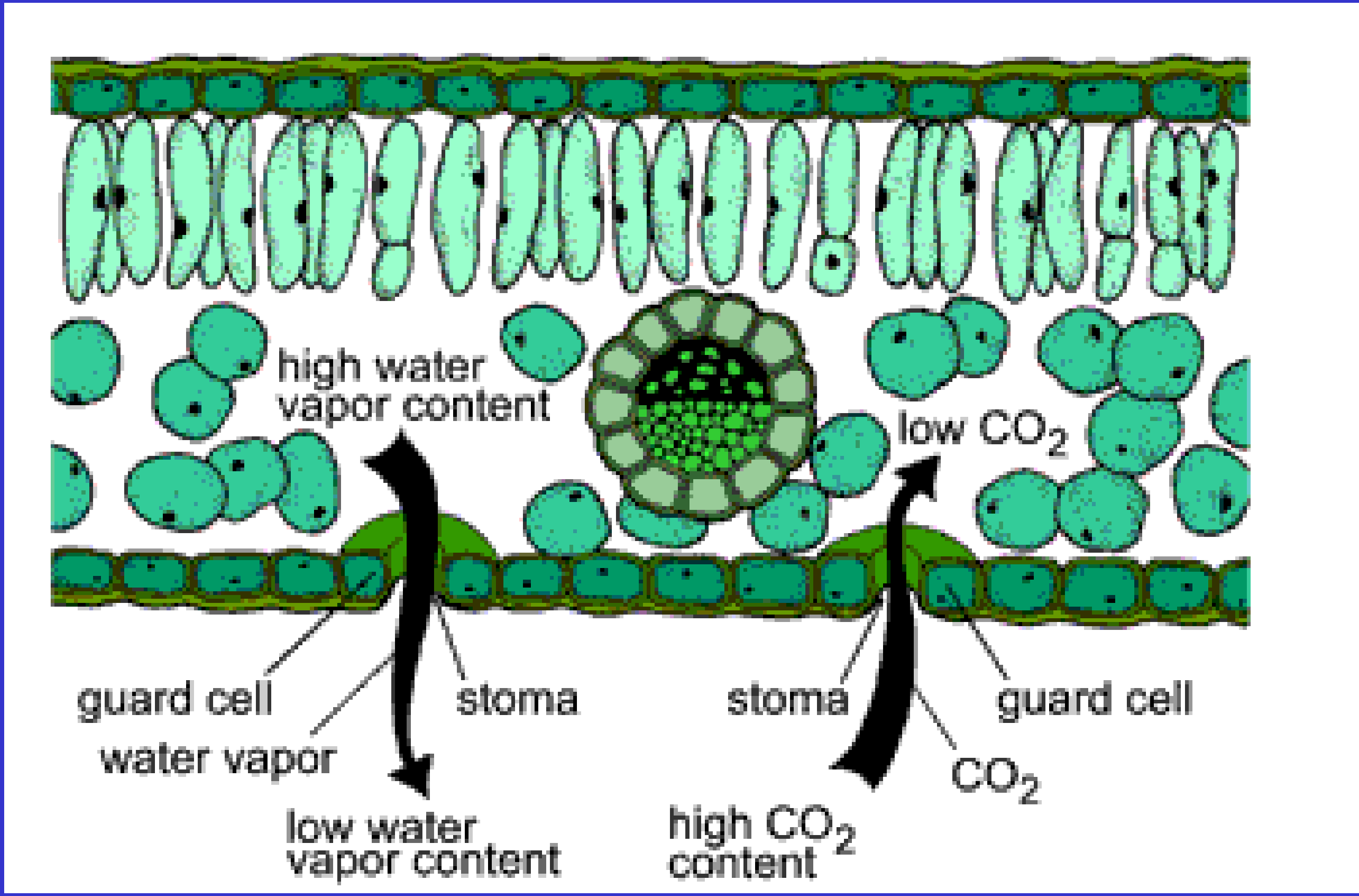


http://www.spacebio.net/modules/pb_resource/bioregen_lecture/sld027.htm

Photosynthesis and Respiration

Photosynthesis	Respiration
Produces food	Uses food
Stores energy	Releases energy
Uses water	Produces water
Uses CO_2	Produces CO_2
Releases O_2	Uses O_2
Occurs in sunlight	Occurs in dark as well as light

Movement of Gases and Water Through Stomata



http://extension.oregonstate.edu/mg/botany/photo2.html#figure25

Plant Growth and Development

Three major physiological functions drive growth and development

- **Photosynthesis**
- **Respiration**
- **Transpiration**

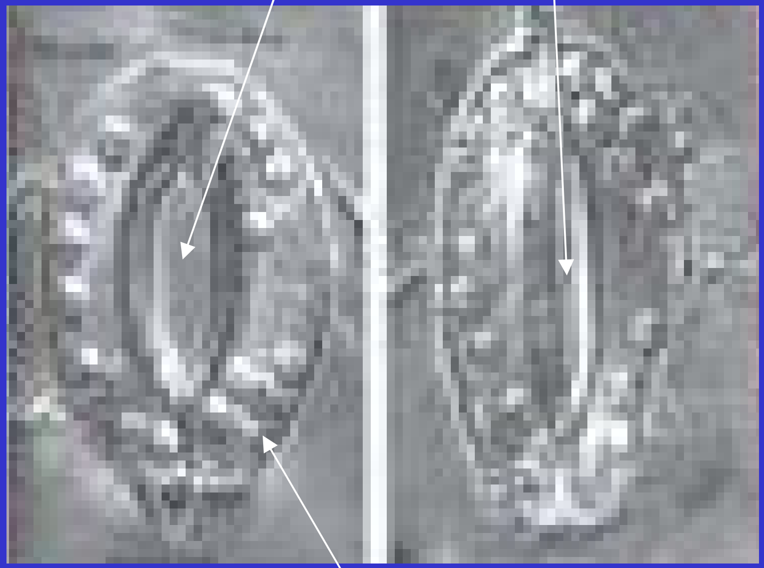
Transpiration – loss of water vapor from leaf surfaces via stomata and is affected by soil moisture, temperature, humidity, wind (vapor pressure deficit)

Stomata

Stomata account for 1% of leaf surface area and 90% of transpired water

90% of water taken up by roots is transpired

Open **Closed**



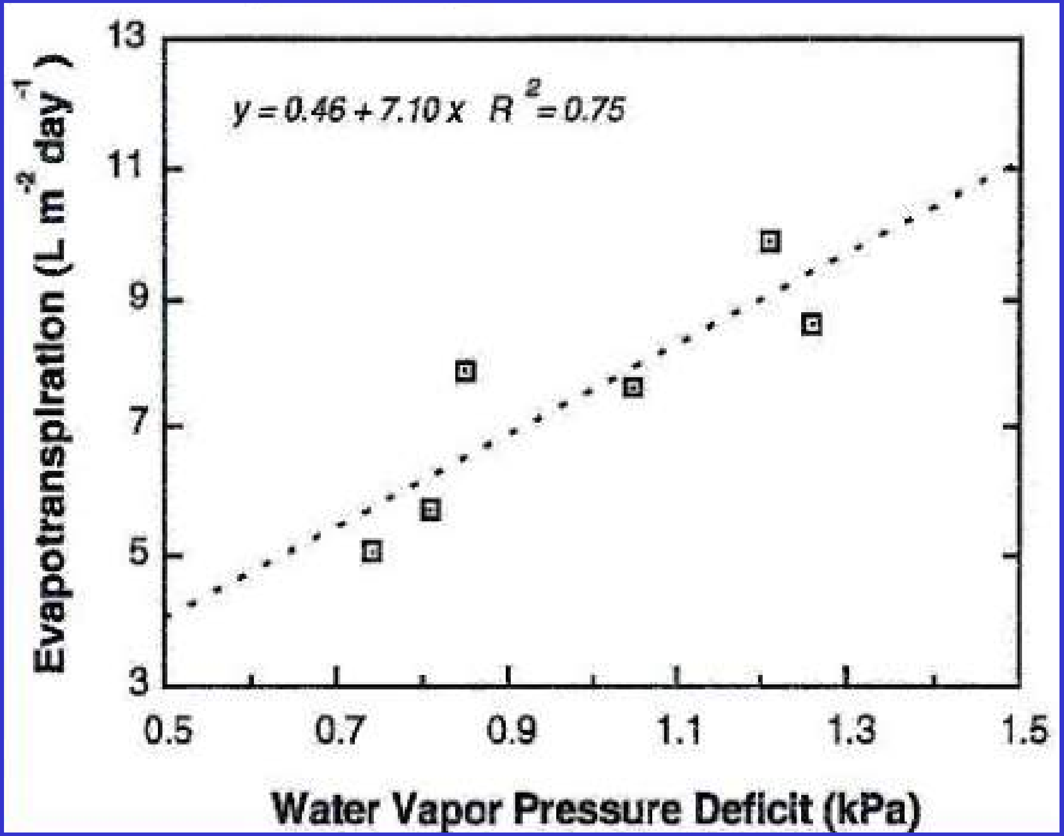
Guard Cell

Stomatal Opening

- Photosynthesis
- Temperature
- Moisture stress
- Increased ABA

http://complabs.nevada.edu/%7Ejbn/bio191lab.htm

Plant Transpiration Is Related to Vapor Pressure Deficit

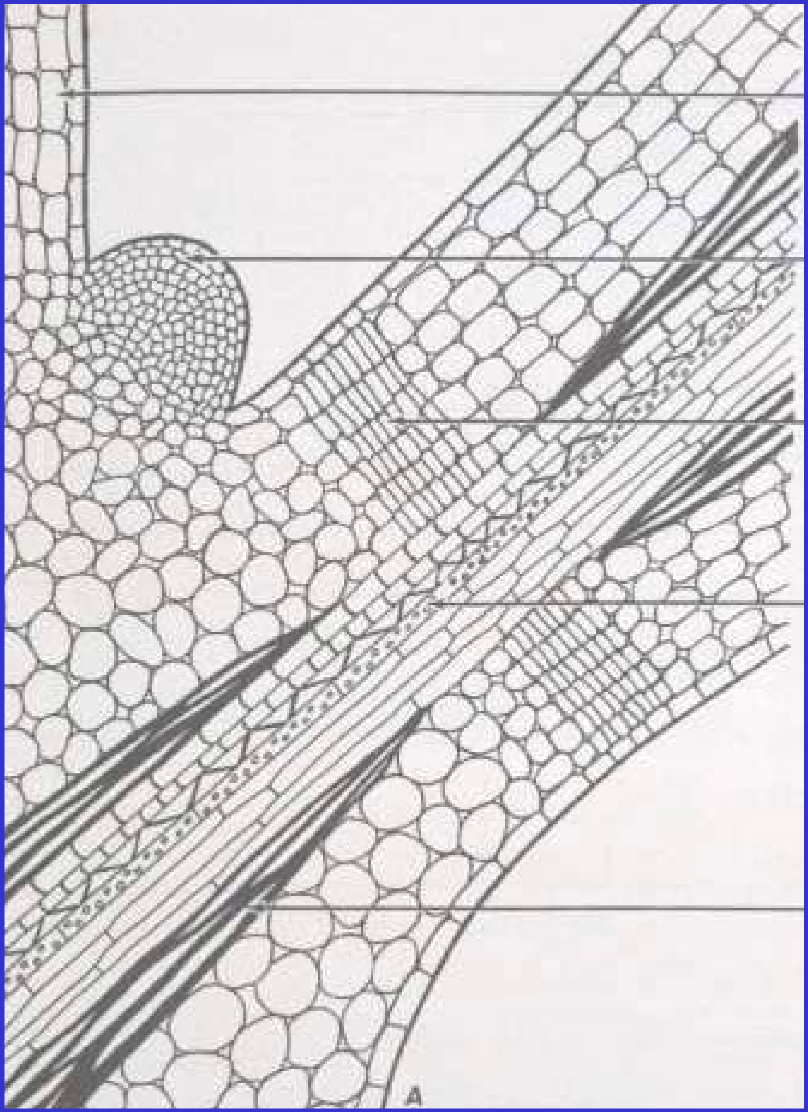


http://www.spacebio.net/modules/pb_resource/bioregen_lecture/sld030.htm

Water

- 90% of plant
- Photosynthesis and respiration
- Turgor pressure and cell growth
- Solvent for minerals and carbohydrates
- Cooling
- Regulation of stomatal opening
- Pressure to move roots through soil
- Chemical reactions

Abscission of Leaves



Stem

Axillary bud

Abscission zone

Vascular bundle

Sclerenchyma

For More Information

Capon, B. 1990. Botany for Gardeners: An introduction and guide. Timber Press, Portland, OR

Kozlowski, T. Wisconsin Woodlands: How Forest Trees Grow. http://cecommerce.uwex.edu/pdfs/G3277.PDF

Chaney, W. How Trees Grow. www.fnr.purdue.edu/inwood/past%20issues/how%20trees%20grow.htm

Duryea and Malavsi. How trees grow in the urban environment. http://edis.ifas.ufl.edu/BODY_FRoo2

Botany Basics http://extension.oregonstate.edu/mg/botany/