Plant
Form & Function
(Freeman Ch 36 & 37)
**Lecture Schedule (middle third)**

18 Feb KB - **Fungi, Ch31**

23 Feb KB - **Prokaryotes & Protists, Ch28&29**
25 Feb KB - **Plant Diversity, Form, Function, Ch30&40**

2 Mar KB - **Plant Form and Function, Ch36&37**
4 Mar KB - **Plant Function, Ch38&39**

9 Mar KB - **Plant Ecology, Ch50,52,53**
11 Mar KB - **Ecology, Ch50,52,53**

13-21 Mar Spring Break

23 Mar KB - **Biology of the Galapagos**
                 Wikelski 2000 and http://livinggalapagos.org/
25 Mar KB - Part 2. Discussion and Review.

30 Mar KB - **EXAM 2**
Extant Plants

Common ancestor of land plants
Protected embryos

Seedless

See Fig 30.12
Unique among eukaryotes because have:
1. Chloroplasts
2. Vacuoles
3. Cell walls with cellulose (structure!)

Cell types:
1. Parenchyma
2. Sclerenchyma (rigid support, lignin)
3. Vessel Elements
   - xylem
4. Sieve Tube Elements
   - phloem
Focus on Angiosperms

Most (97%) angiosperms are in two clades:

- **Monocots**: one cotyledon
- **Eudicots**: two cotyledons

• Other clades include star anise and relatives, water lilies, and magnoliids.
Developing embryos consists of an embryonic axis and one or two cotyledons (seed leaves), which metabolize endosperm and may become photosynthetic.
Angiosperm Diversification

More than 250,000 species

Common ancestor of angiosperms

Carpels; triploid endosperm; seeds in fruit

Vessel elements

Carpels fused by tissue connection

Only one cotyledon

Pollen with three grooves

Amborella

Water lilies

Star anise

Magnoliids

Monocots

Eudicots
Angiosperms

Non-angiosperms

Oldest living angiosperm lineages

Several lineages related to magnolias Monocots Eudicots

Lineages in orange were traditionally called dicots, but this tree shows that dicots are not a natural grouping
Monocots

(A) *Phoenix dactylifera*

(B) *Triticum* sp.

(C) *Lilium* sp.

Palms
Lilies
Grasses
Eudicots

(A) *Opuntia* sp.

(B) *Cornus florida*

(C) *Rosa rugosa*

*LIFE 8e, Figure 29.19*
Angiosperm Structure

- **Shoot System**
  - Leaves (petiole & blade),
  - Stems, elevate and support

- **Root System**
  - Anchor
  - Root, take up and Minerals
Morphological Adaptations

- Modified Leaves $\rightarrow$ Spines
- Thick bark
- Waxy cuticle to retard water loss
- Tall stem to avoid herbivory
Prickly Pear in Galapagos

Tall; Waxy Cuticle
Leaf Types
simple vs. compound

Simple
Compound
Doubly compound
Modified Leaves!

(a) Onion leaves store food.
(b) Aloe vera leaves store water.
(c) Pea tendrils aid in climbing.
(d) Poinsettia leaves attract pollinators.
(e) Pitcher plant leaves trap insects.
(f) Flowerpot plant leaves collect soil.
Modified Stems!

(a) Cactus stems store water.
(b) Stolons produce new individuals at nodes aboveground.
(c) Rhizomes produce new individuals at nodes belowground.

(d) Tubers store carbohydrates.
(e) Thorns provide protection.
Modified Stems/Leaves

Stems:
- Tuber
- Runner
- “Barrel”

Leaves:
- Spines
Root Types
(w/ Lateral roots)

1. (w/ Lateral roots)

2. Fibrous Roots

3. Adventitious Roots - from above ground stem
Mesquite

Roots to 50m!
Saguaro Roots?
Mangroves

• Live in **salty** habitat
• Roots in water with **low oxygen** content

Pneumatophoroes

Pneumatophores are root extensions that grow out of the water, under which the rest of the roots are submerged.

Salt Excretion
Adaptive Radiation

Morphological Diversity

(a) Tree-sized silversword

(b) Mat-forming silversword

(c) Rosette-forming silversword
Phenotypic Plasticity

Grown in shade

Grown in sun
Phenotypic Plasticity

Shoot is short and broad

Shoot is tall and narrow
Where does the carbon we eat in a salad come from?

A. The Earth
B. The Air
C. The Water
D. Fossil Fuels
E. None of the above
During dry periods, the thorny, leafless stems of an ocotillo appear almost dead.

When water is available, leaves develop rapidly and provide the plant with photosynthetic products.

A cool local plant!
Octotillo

Boojum

same family
more about leaves...

**Epidermis** is important outer layer of leaves and stems:
- may contain *waxy cuticle* layer
  - retard water loss
- specialized cells to allow for *gas exchange* (and water loss)
  - guard cells of stomata
guard cells of stomata
guard cells of stomata

Ingredients

Sunlight +
H₂O + CO₂ + Nutrients

Product

“CH₂O” + O₂

Water  Carbon
dioxide  Nitrate NO₃  “Organic
Phosphate PO₄  matter”
Iron  Silica  Oxygen
$C_3$ vs $C_4$ & CAM (see Ch 10)

- Photosynthesis slightly different among different groups.
- Acted on by natural selection.
- $C_3$ do better in temperate climates.
- $C_4$ do better in hotter climates
  - even with stomata closed can fix carbon.
  - CAM is a form of $C_4$ wherein the initial carbon is incorporated at night and the light reaction takes place the next day.

and help reduce during
C₃ vs C₄ & CAM

If you placed these plants side-by-side at noon in March and then took the temperature of the leaf surface...

A. they would be same temp
B. rose would be cooler
C. cactus would be cooler
D. need more information

Why?
Because with CAM photosynthesis, stomata closed during day and therefore much less evaporation to cool the leaf.
Monocot vs. Eudicot

The shoot system consists of stems and leaves, in which photosynthesis takes place.

The root system anchors and provides nutrients for the shoot system.
Monocot vs. Eudicot

<table>
<thead>
<tr>
<th></th>
<th>Monocots</th>
<th>Eudicots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotyledons</td>
<td>One</td>
<td>Two</td>
</tr>
<tr>
<td>Veins in leaves</td>
<td>Usually parallel</td>
<td>Usually netlike</td>
</tr>
<tr>
<td>Flower parts</td>
<td>Usually in multiples of three</td>
<td>Usually in fours or fives</td>
</tr>
<tr>
<td>Arrangement of primary vascular bundles in stem</td>
<td>Scattered</td>
<td>In a ring</td>
</tr>
</tbody>
</table>
Vascular Tissues

- Distributes water and minerals from roots to rest of plant

- Transports carbohydrates (product of photosynthesis) from leaves to rest of plant

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunlight +</td>
<td>“CH₂O” + O₂</td>
</tr>
<tr>
<td>H₂O + CO₂ + Nutrients</td>
<td></td>
</tr>
</tbody>
</table>

Water  Carbon dioxide  Nitrate NO₃ Phosphate PO₄ Iron Silica  “Organic matter”  Oxygen
Vascular Bundles
xylem, phloem, (& vascular cambium in eudicots)

(A) Eudicot
(B) Monocot

The vascular tissues in stems are organized into bundles.
Meristems

• Apical Meristems
  - Sites of ________ growth
  - Found in tips of roots and stems
  - Found in leaf buds

• Lateral Meristems
  - Generate secondary growth
    at vascular cambium
    - Including wood (2° xylem)
    and bark (2° phloem)
Apical meristem

Leaf primordia

The apical bud contains a shoot apical meristem.

Axillary bud primordium

In woody plants, the vascular cambium and cork cambium thicken the stem and root.

Lateral meristems:
- Cork cambium
- Vascular cambium

Root apical meristem

Root cap

Shoot apical meristem

100 μm

50 μm

LIFE 8e, Figure 34.11

Secondary Growth
Secondary Growth

that arises annually from
Vascular Cambium (for )

• **Meristem Cells Become...**
  - 2º Phloem to the outside
  - 2º Xylem to the inside

Cork Cambium

• Mostly produces cells to the outside, comprises most of the BARK
(b) Lateral meristems (cork cambium and vascular cambium) produce bark and wood.
Cork Cambium

- Outer bark
- Inner bark
- Cambium
- Sapwood
- Heartwood
What is a knot in wood?

Why does girdling kill?
Plants:
Transport of Water & Sugar+
Video 35.2

Recovery in a wilted plant
Pressure Potential ($\Psi_p$) aka Pressure

Physical force of water either because of gravity or some other push...

In plants, water into cells meets resistance of cell wall, leading to turgor pressure
Osmotic Potential

Isotonic (same solutes)

Hypotonic (fewer solutes)

Hypertonic (more solutes)
Solution B has more dissolved solutes
If you put a cell in a hypertonic solution it will

A. Remain unchanged
B. Tend to shrink
C. Tend to swell
D. Depends on the solution
Solute Potential ($\Psi$)
aka Osmotic Potential

Dissolved solutes (salts, proteins, sugars – anything in solution) will attract water

Water flows toward solution with more dissolved solutes
How do plants get water >300’ in the air?

from left to right
Sequoia Redwood (oldest trees), Coast Redwood (tallest trees), Douglas Fir, Port Orford Cedar, Sitka Spruce
Xylem and Phloem

Moving Water and Solutes
Water moves from high potential to low potential

Low water potential
Atmosphere $\psi$: $-95.2$ MPa
(Changes with humidity; usually very low)

Leaf $\psi$: $-0.8$ MPa
(Depends on transpiration rate; low when stomata are open)

Root $\psi$: $-0.6$ MPa
(Medium–high)

Soil $\psi$: $-0.3$ MPa
(High if moist; low if extremely dry)

High water potential
Tension, Cohesion, Adhesion

Result in Capillary Action
The water only *continues to move* if being pulled by

1. Root pressure can move water short distance
2. Capillary action can move water short distance
3. ____________________ can pull water from ground to top of Coast Redwood (>300’)


Water is a polar molecule and _____ bonds link water molecules.
Transpiration (water evaporating from leaf surface) Rates will be highest when

Stomates are open/closed

Humidity in atmosphere is high/low

Temperature around tree is high/low

Tree is in shade/sun

What does this tell you about trees living in the desert?
Why is water transpiring?

1. **Stomata open to get CO₂**

   ![Diagram showing photosynthesis process]

   **Ingredients**
   - Sunlight
   - H₂O
   - CO₂
   - Nutrients

   **Product**
   - “CH₂O”
   - O₂

2. **Stomata open for leaf cooling**
THE COHESION-TENSION THEORY

1. Inside a leaf, the area not occupied by cells is filled with moist air. Water diffuses from the inside of the leaf to the atmosphere.

2. As water exits the leaf, the humidity of the spaces inside the leaf drops, causing water to evaporate from the menisci that exist at the air-water interfaces.

3. The resulting tension created at the menisci pulls water from the surrounding mesophyll cells, which in turn pulls water out of the xylem.

4. Tension is transmitted from water in leaf xylem through stem all the way to root xylem by cohesion (continuous hydrogen bonding).

5. Tension pulls water from root cortex cells into root xylem.

6. Tension pulls water from soil into roots.
Cohesion-Tension relies on a

from soil to atmosphere at
leaf surface

Theory only really accepted in
1990s! Relies on very strong
surface tension that results
from transpiration.
Based on your understanding of cohesion-tension theory, why does a tree trunk become slightly narrower during each day?

37.13
Adaptations to Desert Living

a. Small or no leaves
b. Thick waxy cuticle
c. Thick epidermis
d. Stomata on underside of leaves
e. Trichomes to increase humidity at leaf surface
f. C4 or CAM photosynthesis
Temperature sensitivity of drought-induced tree mortality portends increased regional die-off under global-change-type drought

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“starve to death”
Getting & moving water is “free”.

Getting nutrients and moving sugars around
Energy to get nutrients etc.

- Plants have a proton pump (instead of a NaK-ATPase pump) that creates electrochemical gradient to do work.
During middle of growing season, mature leaves provide sugars to rest of plant.
What happens differently to movements of sugars in early spring, before there are any leaves?

Source vs. Sink
Proton Pump (ATP) needed to move sugars from photosynthesizing leaf (source) into phloem and then also from phloem into storage cells or growing tissues (sinks).

Move sucrose into cell AGAINST its concentration gradient.
Why does ‘girdling’ kill a tree?

Remove a ring of bark to girdle the tree.

Organic solutes accumulate in the phloem above the girdle, causing swelling.

Active xylem and phloem are just under the bark. If tree can’t transport water and carbohydrates then it will die.

Was this tree girdled in March or in July?