More Photosynthesis

Leaf Anatomy - The leaf is the primary photosynthetic organ of the plant

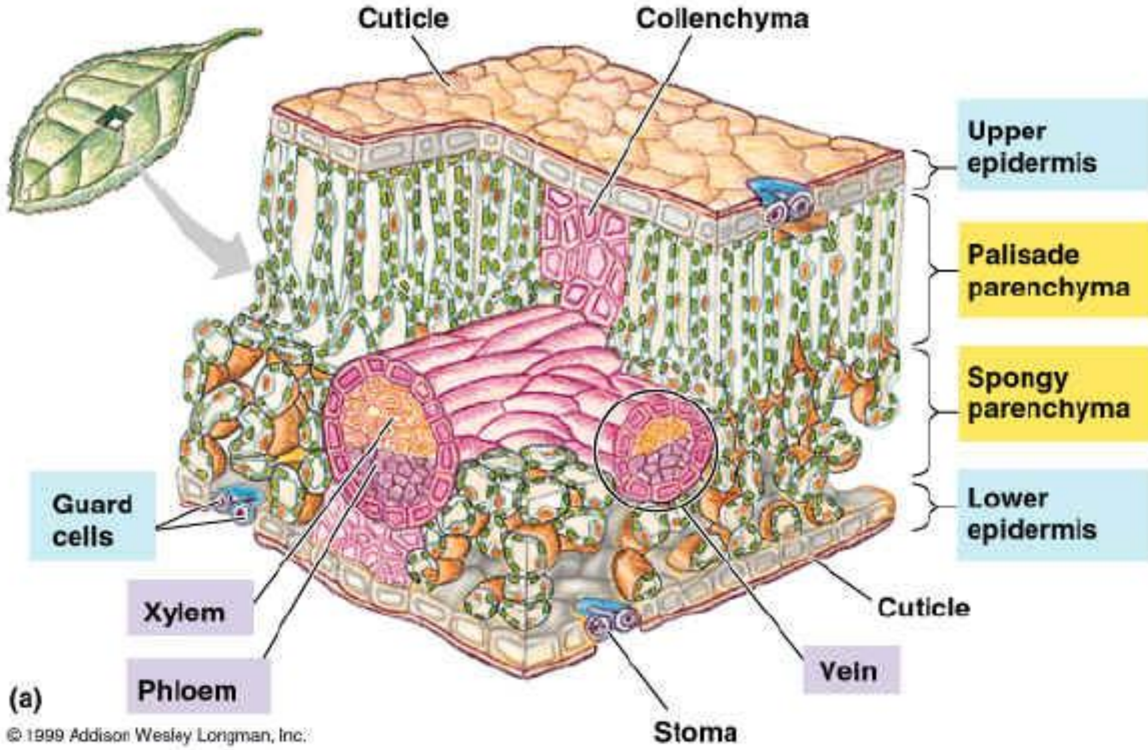
- It is has a large surface area to maximize light harvesting
- They are thin so that light will penetrate through to the bottom cells
- Composed of the lamina (blade) and the petiole (stalk)
    - Leaf shape is highly variable - there are literally 1000's of different shapes of leaves
- **Simple leaf** - developmentally it has one lamina per leaf
    - Look where the petiole meets the stem - you should see a bud
- **Compound leaf** - developmentally it has many distinct lamina per leaf
    - Look where each leaflet meets the rachis, there is no bud.
    - Look where the rachis meets the stem, there is a bud
    - Therefore, the entire structure is a leaf

Leaf Epidermal Anatomy

- The outer epidermis is covered with a waxy cuticle to prevent water loss
    - This also prevents gas exchange :(
- Stomata (sing = stoma) are pores in the surface of leaves which allow for gas exchange
    - Pore surrounded by two guard cells
    - Guard cells open and close to allow gas exchange
    - The density of stomates is dependent upon ecological conditions like humidity and CO_2 concentration
- The underside of leaves is usually covered with hairs (trichomes).
    - Many functions: catch water, reduce airflow, produce wax, etc.

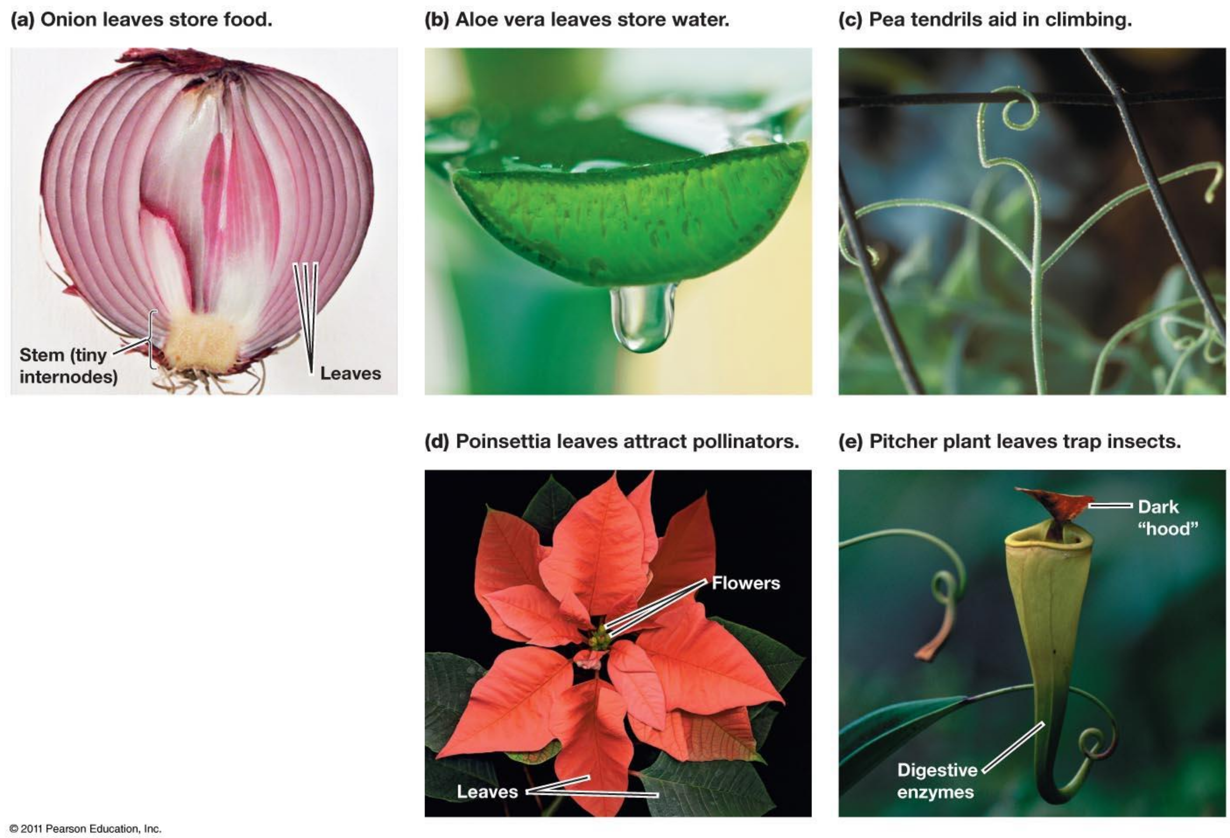
Leaf Internal Anatomy

- A "typical" leaf cross section



- **Upper and Lower Epidermis** - protective function
  - Lower epidermis generally contains more stomates than upper epidermis (in dicots)
  - Epidermal cells lack chloroplasts
- **Palisade Mesophyll** - tightly packed cells on the upper surface
  - Contain three to five times as many chloroplasts as those of the spongy parenchyma.
  - Chloroplasts remain usually near the cell wall, since this adjustment guarantees optimal use of light
- **Spongy Mesophyll** - loosely arranged cells
  - Creates air spaces to facilitate gas exchange

Leaves can have other uses besides photosynthesis



C_3 Photosynthesis

The photosynthetic pathway we discussed in the previous lecture is known as the C_3 pathway

- The first stable molecule formed after CO_2 fixation is a 3-Carbon molecule
- Most (>90%) of all angiosperms are C_3 plants
- Possess "typical" mesophyll arrangement
- Rubisco is exposed to O_2 and the plant loses energy due to photorespiration

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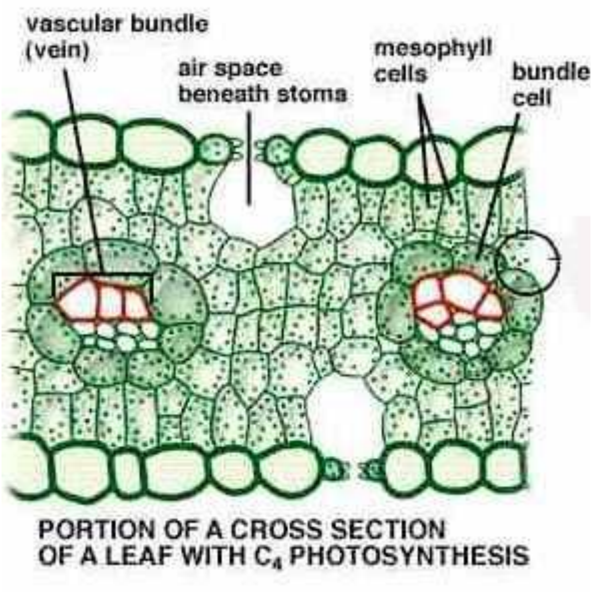
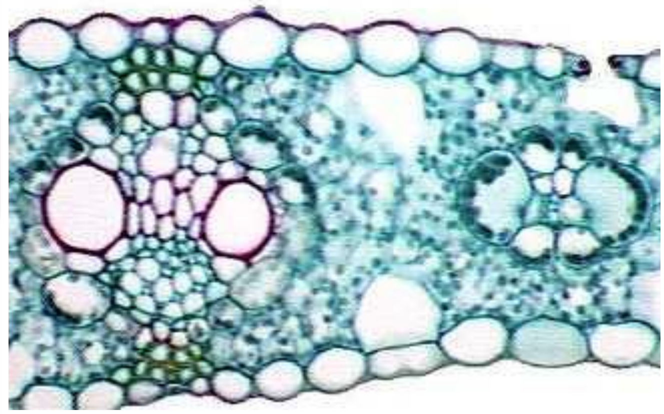
C4 Photosynthesis - a Mechanism to Reduce the Effects of Photorespiration

Some plants have been observed to fix CO_2 and initially form a 4-Carbon molecule. What is up with that?
These same plants have an odd cross-sectional anatomy, called **kranz anatomy** (kranz is German for "wreath")





Cross Section of *Zea mays* displaying Kranz anatomy

- The vascular bundles are surrounded by a special type of mesophyll cell which are collectively called the **bundle sheath**
  - The mesophyll cells do not have Rubisco
  - The bundle sheath cells have Rubisco and fix CO_2 just like in C_3 plants
  - But where do they get the CO_2 ?
- The mesophyll cells have another CO_2-fixing enzyme, PEP carboxylase
  - CO2 + PEP (phosphoenol pyruvate) >>> OAA (Oxaloacetate), a 4-Carbon compound
  - PEP Carboxylase has NO affinity for O_2
  - OAA >>> Malate
  - Malate is shuttled into the bundle sheath cell
  - The CO_2 is removed, forming Pyruvate, a 3-Carbon compound
  - Pyruvate is shuttled back to the mesophyll cell where it is converted to PEP (requires ATP)
  - CO_2 enters the Calvin-Benson cycle (exactly the same as in a C_3 plant)

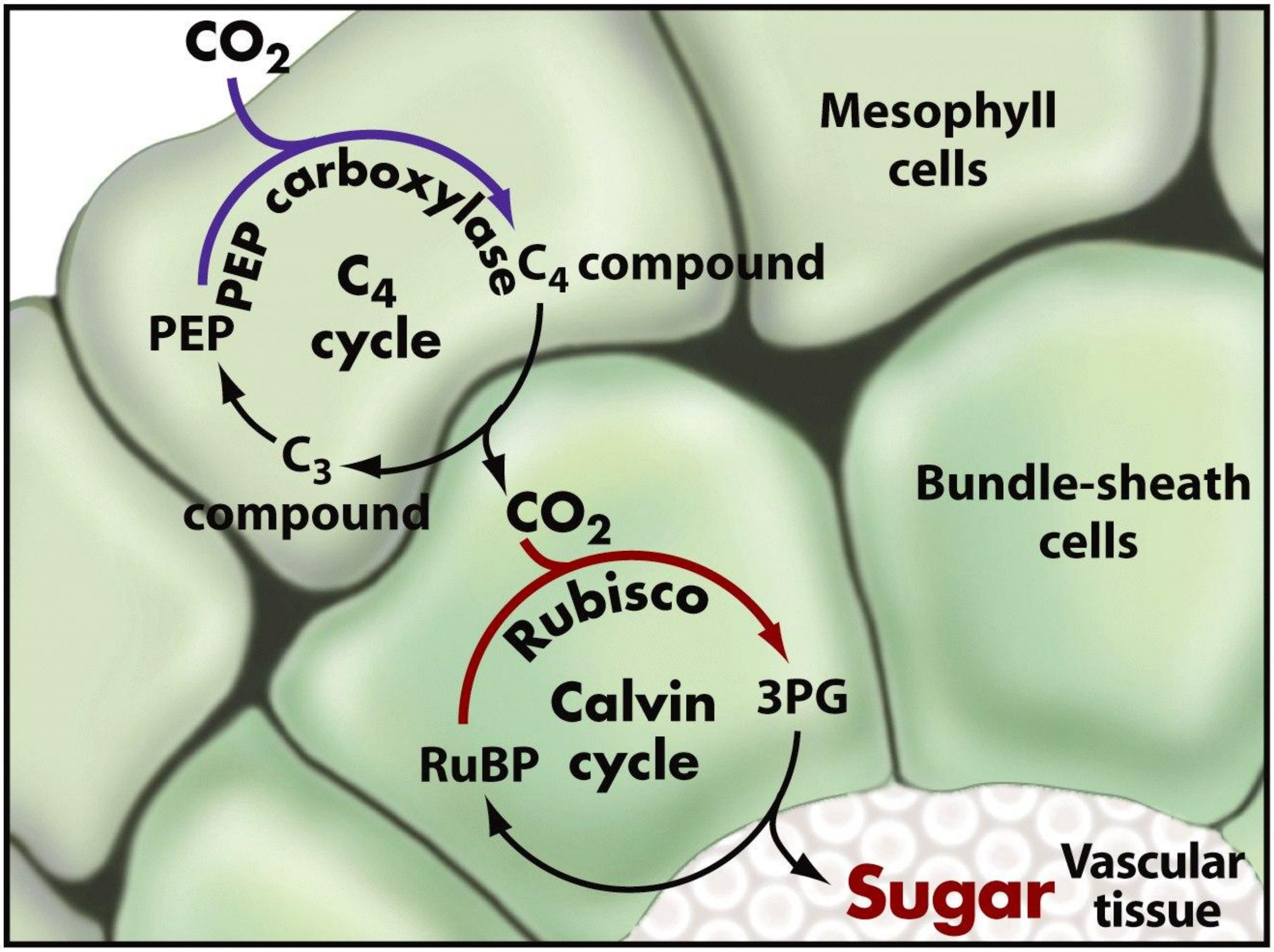


Figure 10-25b Biological Science, 2/e

C_4 Photosynthesis

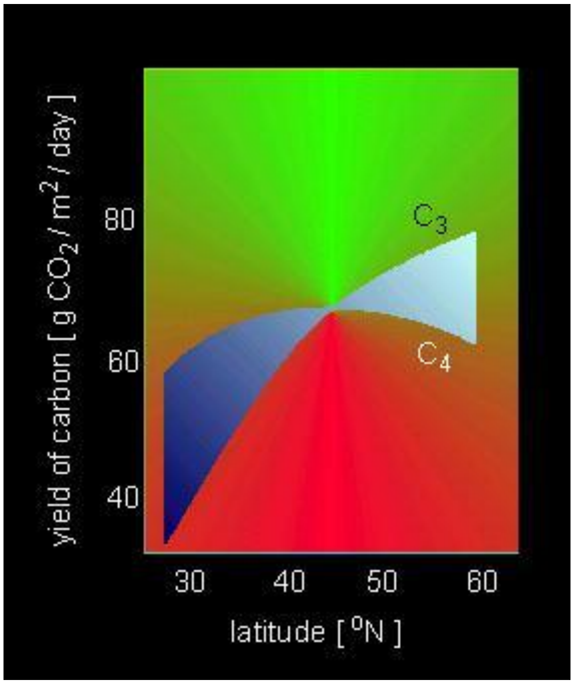
C_4 Photosynthesis is found in many plants, mostly in drier climates

- C_4 photosynthesis has evolved independently many times
- All of the enzymes involved in C_4 photosynthesis were already present in the plant, so nothing new needed to evolve, just the sequence of operation
- Corn and sugar cane, two of the 10 most important crops worldwide, C_4 plants

C_4 plants are more efficient than C_3 plants in hot, dry environments, but in moist or cold environments, C_3 plants can be more efficient

- PEP carboxylase has a much greater affinity for CO_2 at high temps than does Rubisco, so it can assimilate carbon much more efficiently
- However, the CO_2 shuttling costs energy, so this efficiency is lost in cooler temperatures

- Also, the CO_2 shuttling becomes saturated at a much lower CO_2 concentration than does Rubisco, so when CO_2 levels are high (such as when the stomates are wide open in moist tropical plants) C_3 is more efficient
- **C_4 Photosynthesis and CAM [animation]**



Carbon dioxide yield of C_4 and C_3 plants of open grasslands in different parts of the world

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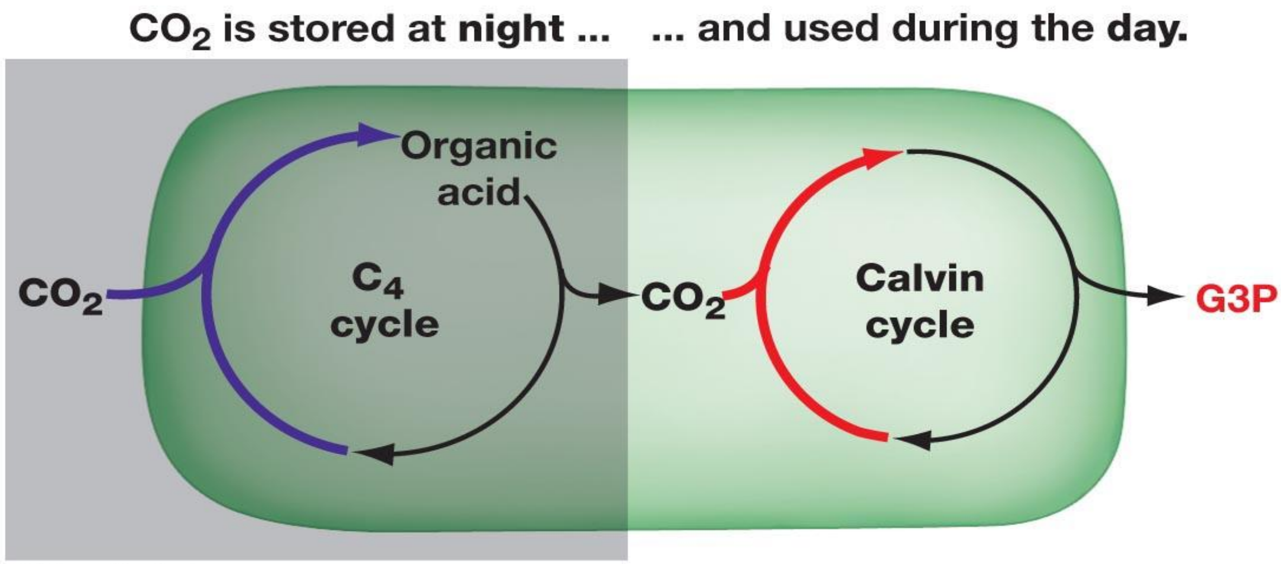
CAM Photosynthesis

As if C4 wasn't enough, there is yet another addition/modification to the typical C3 photosynthetic pathway, called Crassulacean Acid Metabolism (CAM)

- Found almost exclusively in plants in xeric (dry) environments
    - mainly in succlents, cacti, etc.
- Plants open stomates during the night - they are kept closed during the day to conserve water
- The light-dependent reactions occur during the day, creating ATP and NADPH as expected
- During the night, the stomates of a CAM plant open, CO_2 is taken up into the plant and incorporated into a variety of organic acids
- During the day, the light-dependent reactions proceed, making more ATP and NADPH - this promotes the release of CO_2 from the organic acids and Rubisco operates as normal (but in a greatly CO_2-enriched environment)

- This is more of an adaptation to conserve water than to reduce the effects of photorespiration



Food For Thought:

- What type of plant, C_3 or C_4 , would you expect to show the greatest improvement if it were grown in an artificial environment with no O_2?
- Global CO_2 levels are on the rise (don't believe anything to the contrary, this is just big business trying to protect their interests. CO2 levels are steadily on the rise and have been since the industrial revolution!) Sorry, off my soapbox. Global CO_2 levels are on the rise - will this help or hinder plant growth on the earth? What about agricultural plants?