Photosynthesis

Basic Properties of Molecules in Motion

- Diffusion: the random movement of molecules from a region of high concentration to a region of low concentration.
  - Concentration gradients
- Osmosis: the diffusion of water...
  - Osmotic pressure
  - Isotonic, hypotonic and hypertonic environments for plant and animal cells

Diffusion goes in all directions

Osmosis—passive transport of water across a membrane
Membrane Transport Mechanisms

- **Passive Diffusion**
  - Relies on concentration grad.
  - Through bilayer or memb. pores or channels

- **Facilitated Diffusion** (carrier mediated transport)
  - Relies on concentration gradient
  - Exhibits enzyme-like properties

- **Active transport** (ATP requiring carrier)
  - Can transport against the gradient
  - Important in maintaining osmotic equilibrium
  - Can be used to do work

- **Bulk Transport**: Exocytosis and Endocytosis

Active Transport

Proton pumps

The Importance of Active Ion pumping

- Many ions need to be kept in concentrations in the cells which are very different from the outside.
- $\text{K}^+, \text{Na}^+$, others.
- 30-70% of our cellular energy can be used keeping ions in the proper concentration!
- Differences in ion conc. can act like a battery, providing cell with energy

Plant Cell
The Chloroplast

- Most of the living world depends on chloroplasts for its energy!
- Two membranes on outside
- Complex membrane structure on inside

Photosynthesis: The synthesis of organic compounds (sugars) from simple inorganic compounds (CO₂ and H₂O) in the presence of chlorophyll using light energy from the sun.

\[
6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} = \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

Law of conservation of matter. Count the atoms on each side.

Parenchyma cell: Metabolic functions, including photosynthesis.

Figure 35.17 Leaf anatomy

Guard cells open and close stomata, regulating intake of CO₂, and loss of water and O₂ by the plant.

Stomata on the underside of a leaf

An open (left) and closed (right) stoma of a spider plant (Chlorophytum coloском) leaf. When guard cells are turgid, the stoma is open (left). Notice the chloroplasts in the guard cells, the only epidermal cells that photosynthesize.
6CO₂ + 6H₂O + light energy → C₆H₁₂O₆ + 6O₂
Plastoquinone is one of the electron acceptors associated with Photosystem II in photosynthesis. It accepts two electrons and is reduced to Plastoquinol and as such acts as an electron and energy carrier in the electron transport process.

Figure 10.17 The thylakoid membrane.

Figure 10.12 Excited electrons are the key to photosynthesis.

Figure 10.13 The light reactions of photosynthesis.
Figure 10.13 The light reactions of photosynthesis.

Via a proton pump

Figure 10.17 The thylakoid membrane.

The production of Sugar

The ATP and NADPH are used to make the sugar.

Three Phases
1. $\text{CO}_2$ fixation-Rubisco
2. Reduction of PGA via NADPH electrons to G3P
3. Regeneration of RuBP

For 1 G3P, used 9 ATP and 6 NADPH
RuBisCO  
- Ribulose-1,5-bisphosphate carboxylase oxygenase  
- The key enzyme in the Calvin Cycle or “C3 pathway”  
- 8 large and 8 small subunits  
- World’s most abundant enzyme!  
- Contains lots of Nitrogen  
- Catalyzes two competing and opposite reactions (photorespiration - we’ll get to this later)  
  - Somewhat inefficient…

Calvin Cycle  
- Begins with RuBisCO catalyzing reaction of 3 CO$_2$ and 3 RuBP to form 6 3-carbon compounds  
- Energy from ATP and NADPH is used to rearrange 3-carbon compound into higher energy G3P  
- G3P used to build glucose, other organic molecules  
- Cyclic process: one G3P (of 6) released each pass through cycle, rest (5) regenerate (3) RuBP  
- 3 CO$_2$, 9 ATP, 6 NADPH = 6 G3P (1 harvested)

Photorespiration  
Occurs under high O$_2$ and high heat  
O$_2$ replaces CO$_2$ in the Calvin cycle due to competition between O$_2$ and CO$_2$ around RuBisCO (high affinity for O$_2$).  
Wasteful and unproductive. Enhanced under high heat, and as oxygen levels increased over geologic time  
Plant response: C$_4$ photosynthesis. Create a (increased) ratio of CO$_2$ to O$_2$ in the cell around Rubisco  
**under high concentrations of CO$_2$ the benefits of C$_4$ are reduced!**

CAM photosynthesis:  
what to do when its hot outside and DRY?  
Water loss is the driving force – conserve water  
Open stomata at night when its cool and store CO$_2$ for the daytime.  
Similar mechanism as C$_4$, but driven by a different evolutionary pressure.
Other ways to get to the \( \text{CO}_2 \) C\(_4\) and CAM

\( \text{C}_4\) adaptation to hot environments
Carbon goes into 4-carbon molecule before Calvin.
Two different PLACES
Use 4-carbon as reservoir
Ex. Sugarcane, Corn, grass

CAM adaptation to hot and dry environments
Carbon goes into 4-carbon molecule before Calvin.
Two different TIMES, night and day
Use 4-carbon as reservoir
Ex. Pineapple, cacti, succulents