Unit 5 Notes

I. Photosynthetic Structures and Pathways

A. Photosynthesis consists of two groups of reactions in two separate regions of the chloroplast.

1. The light reactions occur on the thylakoid membranes – water is consumed and energy rich molecules are produced.

2. The Calvin cycle occurs in the stroma -- the energy rich molecules and CO_2. are consumed to make three carbon sugars.

3. The overall equation for photosynthesis is:

$$3\ CO_2 + 3\ H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_3H_6O_3 + 3\ O_2$$

B. The light reactions generate supplies for the Calvin cycle.

1. Light excites electrons in photosystem II (PSII), causing them to leave for the electron transport chain (e.t.c.).

2. An enzyme near the reaction center of PSII splits water, supplying e^- for the e^- "hole", H^+, and O_2 gas as a waste product ($2\ H_2O \rightarrow 4\ H^+ + 4\ e^- + O_2$).

3. As the excited e^- are passed down the e.t.c., much of their energy is used to actively transport H^+ into the thylakoid interior.

4. The e.t.c. passes the lower energy e^- to PSI where they get an energy boost from the light captured there.

5. These excited e^- are used to reduce $NADP^+$ into NADPH.

6. The other energy rich molecule, ATP, is produced using unequal concentrations of H^+.

   a. The combination of H^+ produced from splitting water, H^+ transported by the e.t.c., and H^+ removed by NADPH builds a H^+ gradient pointing out of the thylakoid.

   b. H^+ diffuses out of the thylakoid membrane through ATP synthetase, providing energy for ATP synthesis.

7. In summary, the light energy captured by PSII and PSI is used to create products (ATP and NADPH) for the Calvin cycle and O_2 gas as a waste product.

C. The Calvin cycle is a series of enzyme catalyzed steps (carried out in the stroma) that use the energy from ATP and NADPH to convert CO_2 into stable, easily transported sugars.

1. 3 CO_2 enter through stomates and are attached (carbon fixation) to 3 5-carbon compound (RuBP) producing 3 unstable, 6-carbon compounds. This step is catalyzed by the enzyme RuBisCO.

2. The 3 6-C compounds immediately split to form 6 3-C molecules of PGA.

3. In two enzymatic steps, 6 ATP and 6 NADPH are used to produce 6 3-C molecules of PGAL.

4. One of these PGAL (3-C) leaves the cycle to be used for maintenance and growth.

5. The remaining 5 3-C molecules of PGAL are converted back into 3 5-C molecules of RuBP (3 ATP are used for this) to begin the cycle again.

D. The 3-C PGAL molecules are used for various purposes.

1. Simple sugars such as sucrose can be made for respiration or transport to other regions of the plant.

2. Starches and lipids can be made for energy storage.

3. With the addition of NH_3, amino acids can be synthesized.

4. With the addition of NH_3 and phosphates, nucleic acids can be synthesized.

II. Photosynthesis and the Environment

A. Light intensity, temperature, O_2, and the availability of water, CO_2, and nutrients all affect the rate of photosynthesis.

1. Increasing light intensity promotes photosynthesis up to the point of photoinhibition (OH^- and H_2O_2 created).

2. The rate of photosyn. increases with temperature until protein shape, gas solubility, and stomate size are affected.

3. Increases in CO_2 conc. and water uptake increase the rate of photosyn. until other limiting factors are fully "taxed."

4. The factor(s) in shortest supply have the greatest effect on the rate of photosynthesis.

B. Photorespiration slows photosynthesis in many plants (C_3), but some have evolved ways around it.

1. In the Calvin cycle, RuBisCO can bind O_2 instead of CO_2 (similar shape) causing the loss of a previously fixed CO_2.

2. Two groups of plants (C_4 & CAM) have evolved ways to reduce photoresp. and aid survival in hot, dry climates.

a. C_4 plants (sugarcane, corn, crabgrass, etc.) fix CO_2 outside of the Calvin cycle, away from rubisco.

i. Mesophyll cells (exposed to gas pockets inside the leaf) use a different enzyme (PEP carboxylase) to fix CO_2. This step creates a 4-C acid.

ii. The 4-C acid delivers the CO_2 to RuBisCO in the bundle sheath cells surrounding leaf veins.

iii. The high conc. of CO_2 around RuBisCO inhibits photoresp., increasing photosyn. by up to 50%.

b. CAM plants (found in hot, arid regions) separate CO_2 fixation with time rather than location (seen in C_4).

i. Stomates are open at night (conserving water) allowing CO_2 to be fixed by organic acids.

ii. During the day, enzymes release the CO_2 from the acids, making it available for the Calvin cycle.

iii. This process is inefficient, causing slow growth.