Unit 3: Bioenergetics
Content Outline: Photosynthesis (3.1) – Part 1

I. **Autotrophs** – Organisms that can "*produce*" their own food. ("Auto" means "self"; "trophe" means "feeding")

II. **Heterotrophs** – Organisms that "*consume*" other organisms (living or dead). ("Hetero" means "other")

III. **Chlorophyll** – A *light-absorbing pigment* found in chloroplasts of plants, algae, and blue-green bacteria.

A. Found mainly in the *mesophyll layer* of ground tissue in plant leaves. ("meso" refers to "middle")
B. "phyll" means "pigment"; ""chloro" means "green" (They *reflect* green light.)

IV. Chloroplast structure ("plast" means "container") (These ore *organelles* remember in Eukaryotes.)

A. **Thylakoid** – Little green discs that *contain the pigment chlorophyll* found inside the chloroplast.
   1. Site of the *light reaction* of photosynthesis. (The thylakoid membrane contains the photosystems.)
      a. *Primary purpose is to make **ATP** and **NADPH**.* (Both are Energy molecules.)
      (Two different types of batteries, D and 9 volt, are good visuals. Students should know that batteries are need in devices to make them work. Make the batteries then…)

B. **Grana** – a stack of thylakoids.
C. **Stroma** – The *watery space* surrounding the thylakoids. (It holds the water needed for photosynthesis.)
   1. Site of the *light – independent reaction* (Dark or Calvin Cycle) of photosynthesis.
      a. *Primary purpose is to use **ATP** and **NADPH** to make sugars using CO_2*. (Use the batteries.)

V. Photosynthesis Chemical Reaction

A. Starts by taking *sunlight energy* and *converting* it into *chemical energy (ATP & NADPH).*
B. Then takes the chemical E (ATP and NADPH) and uses that chemical *energy to power* the production of sugar (Sugars are chemical E *storage* molecules.)
B. 6 CO_2 +6 H_2O (in the *presence* of sunlight) $C_6H_{12}O_6$ + 6O_2 + Heat (*Key Number* is 6 in balancing.)
C. Sugar is *stored chemical energy* for cellular respiration.
D. *H_20 splits*; *<u>not</u> CO_2*.
E. Two processes involved in the conversion of sunlight energy to sugar:
   1. **Light reaction** (light dependent) – It *changes* sunlight into ATP and NADPH. (*Usable* chemical energy.)
   2. **Calvin cycle** (A.K.A. **light independent reaction**) – Makes sugar using CO_2, ATP , and NADPH.
      a. Melvin Calvin discovered the working process.

F. NADP+ is *converted* to NADPH by picking up 2 negative electrons (The *first* cancels the charge; the *second* makes the NADP molecule negative which allows for H+ to attach and thus create NADPH.)
G. ADP is *phosphorylated* (Add a phosphate) to make ATP. This *requires the free E of electron transport chain*.

VI. Sunlight (It is *high quality* E. Remember, High quality means it *can perform work*.)

A. Sunlight travels in *waves* with different wavelengths. (The **Electromagnetic spectrum** shows all the Wavelengths/colors found in sunlight.)
   1. *Red Light*– Has the *longest* wavelength. (It also has the *least E* of "white light".)
   2. *Blue Light*- Has the *shortest* wavelength. (It has the *most E* of "white light".)
      (Good place to have students think about sunblock or sunscreen that contains UV protection.)
   3. **Spectrophotometer** – This *measures light wavelengths* not absorbed by a *specimen*.

B. *Visible "white" light* – ROY G. BIV (red, orange, yellow, green, blue, indigo, violet) are the colors within.
C. Light travels in *units of Energy* called **Photons**.

D. **Absorption** vs. **Reflection**

1. **Absorbed** –These colors are *usable* light E.
    a. *Plants use Reds and Blues*; *but* *not green.*
    b. **Chlorophyll A** – *Main pigment* found in all plants and algae.
    (It has a structure that looks like a Mg spider in carbon ring web.)
    c. **Chlorophyll B** – *Helps* Chlorophyll A receive sunlight E. (B *funnels* E to A.)
    d. **Carotenoids** – These are *accessory pigments* that help Chlorophyll A. (They *funnel* E to A too.) (These are red, orange, or yellow pigments.)
    (Good place to ask female students what accessories, in dress, are for? Help draw attention to one's self. The accessory pigment help draw in extra light energy.)
    e**. Photosystem** – *Group* of light absorbing pigments in thylakoid membrane. (Chlorophyll A would be in the reaction center.)("system" means "group of").
    (Compare them to solar panels.)
        i. Photosystem I (P700) – Responsible for *ATP and NADPH production*.
        ii. Photosystem II (P680) – Responsible for *ATP production only*.
3. **Reflection** – These colors are *not usable*. (They provide the *color* of an object in *your* vision.)
    a. *This is why plants appear green to you.* Green light is *reflected* back toward *your* eyes.

Photosynthesis – Part 2

VII. **Light Reaction** of Photosynthesis

A. This process is used for *converting* sunlight into *usable* chemical Energy molecules. (These molecules are: **ATP** and **NADPH**)

B. These two parts are occurring, *in the presence* of sunlight, *at the same time* on the **Thylakoid membranes**.

C. There are *thousands* of these Photosystems (I and II) on *each* Thylakoid membrane.

D. Good place to remind students about surface are. The more surface area… the more energy that can be converted… the more ATP and NADPH made… the more sugar that can be made by that cell.)

Step 1: Sunlight hits, and *splits*, the water in the stroma. It also hits the photosystems I (P700) and II (P680).

Step 2: *2 Excited electrons* travel down the electron transport chains. They came from the Mg in the Chlorophyll A molecule. (The 2 excited electrons were able to leave the Mg because the sunlight *heated them up* and made them move much faster. Fast enough to escape the pull from the nucleus' positive protons) As the *excited electrons* go down the electron transport chain, their *excited kinetic E (also called* ***Free E***) is *being used to power* the proteins called **Proton pumps**. (Remember, a proton is a Hydrogen ion and is shown as H^+) As the electrons go down their chain, their excited kinetic E *decreases.*

(Please remind students that the energy decreased because it was used to power the proteins. Like batteries going low (not dead) on energy.)

A. P680's *2 excited electrons*

1. ***Free E*** *of the electrons* is used to **actively transport** protons (H+) into the *confined* thylakoid space. (As the [H+] goes up inside the space. The [H+] goes down in the stroma. So a concentration gradient is *created*. This is a *source* of potential E now.) (It would be like blowing air into a balloon. The pressure builds as more air is blown in. This is also an example of potential E.)

(Good place to use a green balloon and the pinwheel to help make the concentration gradient visible. As remind students that as the [H^+} increases the pH is dropping too. Students should remember that pH can affect enzyme function. These are also enzyme driven processes.)

B. P700's *2 excited electrons* combine with NADP+, to make it negative so that NADPH can be generated.)(This is the ending point for *non-cyclic electron flow*.) (Help students "see" start and ending points are different.)

OR

Cyclic electron flow – P700 loses *2 excited electrons* to the electron transport chain, but they **return** to P700. (Remember this makes *extra* ATP.) (Students need to know more ATP than NADPH is needed.)

Step 3: The *trapped H+,* inside the Thylakoid, are *released through the* ***ATP Synthetase Complex***. This is the group of enzymes in the Thylakoid membrane that helps make ATP. Just look at its name. (This release of kinetic H+ *powers the phosphorylation* of ADP ATP.) (This would be like the air coming out of the blown up balloon and turning a pinwheel. (You will be setting up Cellular Respiration here.)

A. This Kinetic movement of H+ produces a *large amount of ATP***.**

B. This is an example of **Energy Coupling** (*Two* processes *working together* to make ATP. The *first* process was **Active transport** to pump the H+ into the Thylakoid to make the concentration gradient. The *second* process is a type of **diffusion**. The H+ going from high [ ] to low [ ]. The kinetic movement of the H+ fuels the production of ATP.) This is **Chemiosmosis** again.

Step 4: ATP and NADPH will now *be used to power* the fixing of CO2 into sugar in Calvin Cycle.

Photosynthesis – Part 3

I. **Calvin Cycle** (A.K.A **light independent reaction**)

A. This part *uses the ATP and NADPH* of light reaction to make sugar using CO_2.

B. There are 4 steps to *making* a single sugar molecule:

Step 1: 3 CO_2 molecules will be used, in the chloroplasts stroma, by the enzyme Rubisco to convert RuBPs into G3P molecules. (Remember, these were the 2 halves of a sugar molecule that were seen in Glycolysis.) The *energy to power the conversion* comes from ATP and NADPH.

Step 2: 1 G3P will be to *removed to put toward* making sugar.

Step 3: The remaining G3P will be reconverted back into RuBP using the extra ATP from the light reaction.

Step 4: Repeat steps 1 3 to make the *second half* of the sugar molecule.

C. These sugars will be needed to *feed* the whole plant or algae. The sugars will be *consumed* in the process of cellular respiration or *stored* to be used later or passed to consumers in a food chain.