STUDY GUIDE - *Ch. 10.3 - The Light Reactions convert solar energy to the chemical energy of ATP & NADPH*

NAME: ________________________

- **PHYSICALLY PRINT OUT this PDF and HANDWRITE (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **not** accepted. Do **not** answer questions on separate paper.*
- **Importantly, study guides are NOT GROUP PROJECTS!!!** *You, and you alone, are to answer the questions as you **read** your assigned textbook. You are **not** to share answers with other students. You are **not** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing LEGIBLY, neatly, and in a medium-sized font.** *AP essay readers and I will skip grading anything that cannot be easily read so start perfecting your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **SCAN physical documents in color and with good resolution. Then, upload your final work as PDFs to Archie.** *Avoid uploading dark, shaded, washed-out, sideways, or upside-down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **READ FOR UNDERSTANDING and not merely to complete an assignment.** ***First**, read a section quickly to get an overview of the topic covered. Then, read it a **second** time slowly, paraphrasing each paragraph **out loud** and analyzing every figure. Finally, read it a **third** time as you answer the study guide questions if assigned and start building your memory. Try to write answers out in your own words, when possible, and try to purposefully and accurately use all new terminology introduced.*

How the Light Reactions occur is a long and challenging concept. Don't be intimidated. Try to picture the process, making sure to paraphrase each of the paragraphs out loud to yourself as you read them to try to force yourself to extract the key information from each paragraph as you read.

1. As a warm up, describe the following terms and concepts.

   a. **Light =**

   b. **Wavelength =**

   c. **Electromagnetic Spectrum =**

   d. **Visible Light =**

   e. **Photons =**

2. Our eyes are able to detect light energy waves of certain wavelengths and frequencies, which our brain assigns a color to in our mind. The electromagnetic **energy** we are thus able to "see" range from what we refer to as violet to red light **energy** (violet, blue, green, yellow, orange, red electromagnetic energy). Notice the wavelengths of waves that make up the electromagnetic spectrum in Figure 10.6. Explain the **relationship between wavelength and energy.**

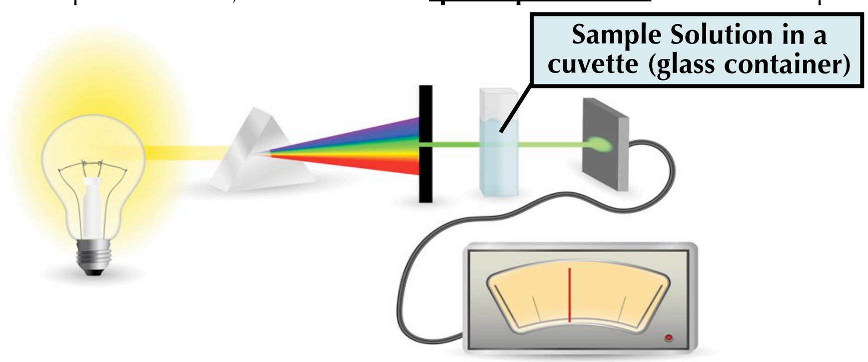
3. Why does it make sense that the light *(or energy)* from the **visible light spectrum powers photosynthesis** on Earth instead of other types of electromagnetic radiation?

4. a. What is a **pigment**?

b. What determines the color of a given pigment?

c. Why then are plant leaves colored green to our eyes?

5. a. Read your text and then review the information in **Figure 10.8 Research Methods: Determining an Absorption Spectrum**. Note that, even though the example diagrammed in your book shows a solution of chlorophyll pigment molecules from the chloroplast of the plant suspended in liquid, the relative amount of absorption of light energy of different wavelengths can be measures for any solution to find out what types of visible light energy the molecules in the solution absorb or fail to absorb. **Label** all remaining parts of the figure below highlighting the spectrophotometer's components. Then, describe how a **spectrophotometer** works in the space below.



How a Spectrophotometer Works =

b. With the help of a Spectrophotometer, one can create an Absorption Spectrum. What is an **Absorption Spectrum**?

6. a. Read your text and then Figure 10.9 carefully. How is an **Action Spectrum** different from an **Absorption Spectrum**?

b. How would you create an **Action Spectrum for a particular type of photosynthetic bacteria**?

7. a. Describe **Engelmann's experimental set up**.

b. How did **Engelmann's experiment first elucidate which wavelengths of light are most effective in driving photosynthesis** before technology was available to measure O_2 concentrations.

c. Based on the Action Spectrum Graph shown in Figure 10.9.b., which wavelengths of light drive the **highest** rates of photosynthesis? (Check your answer to 7.c. by going to the Ch.10 **Figure Questions** for **Figure 10.9** in Appendix A of your book)

d. Based on the Action Spectrum Graph shown in Figure 10.9.b., which wavelengths of light drive are largely **ineffective** in powering photosynthesis?

8. a. What is **chlorophyll a**?

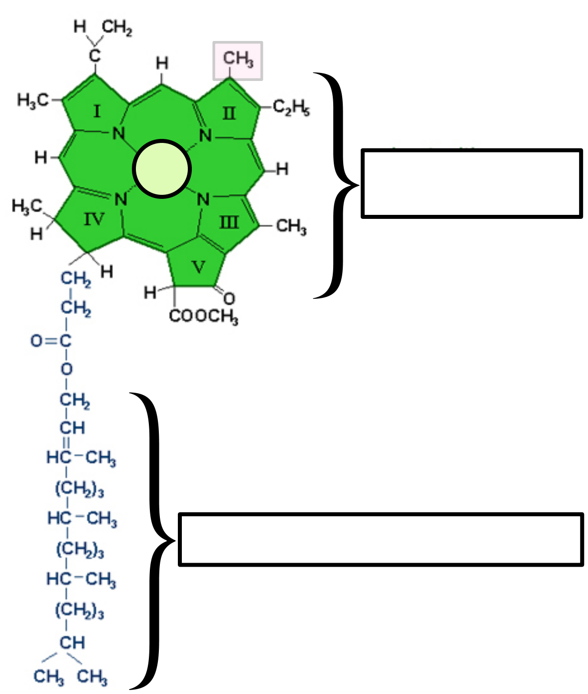
b. What is **chlorophyll b**?

c. What are the **carotenoids**?

d. Identify the two parts of the **structure of chlorophyll a** in the figure to the right. Note that **chlorophyll b is nearly identical**, the only difference being the presence of CHO in place of the CH_3 methyl group highlighted in the pink box.

e. Which part of the structure of chlorophyll is **responsible for absorbing light (light energy)**?

f. What is the use of the **hydrocarbon tail**?



9. **Chlorophyll b** molecules, along with the **carotenoids**, are considered an **accessory pigment.**

a. Explain why it is **beneficial to the plant to use the accessory pigment chlorophyll b**?

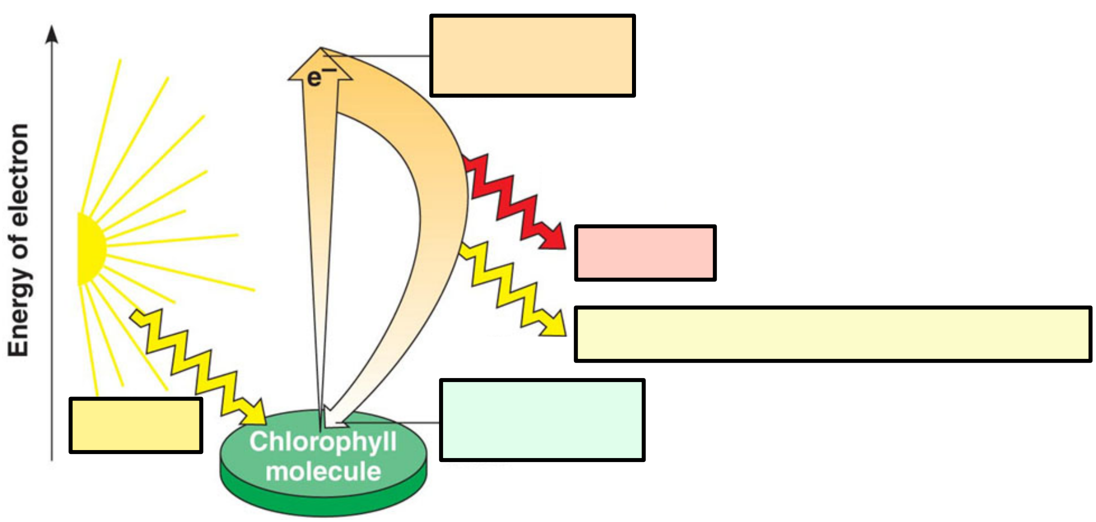
b. Explain two reasons why it is also **beneficial for the plant to use the accessory pigments** referred to as **carotenoids**?

1.

2.

10. a. In terms of the initial conversion of energy from **radiant energy into potential energy,** explain step-by-step the events that occur inside a **chlorophyll** (or any pigment) **molecule when it is hit by light**?

b. In isolation (outside of the chloroplast in a photosynthetic eukaryote or outside of the plasma membrane in a prokaryote), an **excited electron nearly immediately drops back to its ground level state, emitting excess energy as heat and light** *(fluorescence)*. Label this figure that shows the behavior of an electron in an excited chlorophyll molecule.



11. Of course, the pigments, when in photosynthetic cells, do not release back into the environment all the radiant (light) energy they initially absorb as heat (thermal energy) and light. The energy absorb will instead be used to eventually build carbohydrates. As it turns out, the pigments then are not found alone in cell membranes, but are organized, along with multiple other small organic molecules proteins, into functional complexes called **Photosystems** that help plants not only capture **radiant energy**, but store it as a usable form of **chemical energy** that the cell can then use to build high-energy carbohydrates with from low-energy CO_2 molecules.

a. What is a **Photosystem** composed of?

b. Describe the structure of the **Reaction-Center Complex of a Photosystem**.

c. What does the **Primary Electron Acceptor in the Reaction-Center Complex** do.

d. Describe the structure of the **Light Harvesting** (or Antennae) **Complex of a Photosystem**.

e. **How and through which regions does energy move in a Photosystem** that is struck by photons of light energy?

12. *Think* = In a leaf containing a similar concentration of chlorophyll as the fluorescing solution shown in Figure. 10.11 was exposed to the same light, no fluorescence would be seen. Explain the reason for the difference in fluorescence emission between this solution and the leaf. (Check your answer to 12 by going to the Ch.10 **Figure Questions** for **Figure 10.11** in Appendix A of your book)

When chlorophyll is in solution =

When chlorophyll is in leaf cells =

13. a. Turns out, there are two slightly different Photosystems in photosynthetic eukaryotes like plants (and in some types of prokaryotes like cyanobacteria), **Photosystem II (PS II**) and **Photosystem I (PS I)**. Where in the plant's **chloroplasts** are the two **Photosystems located**?

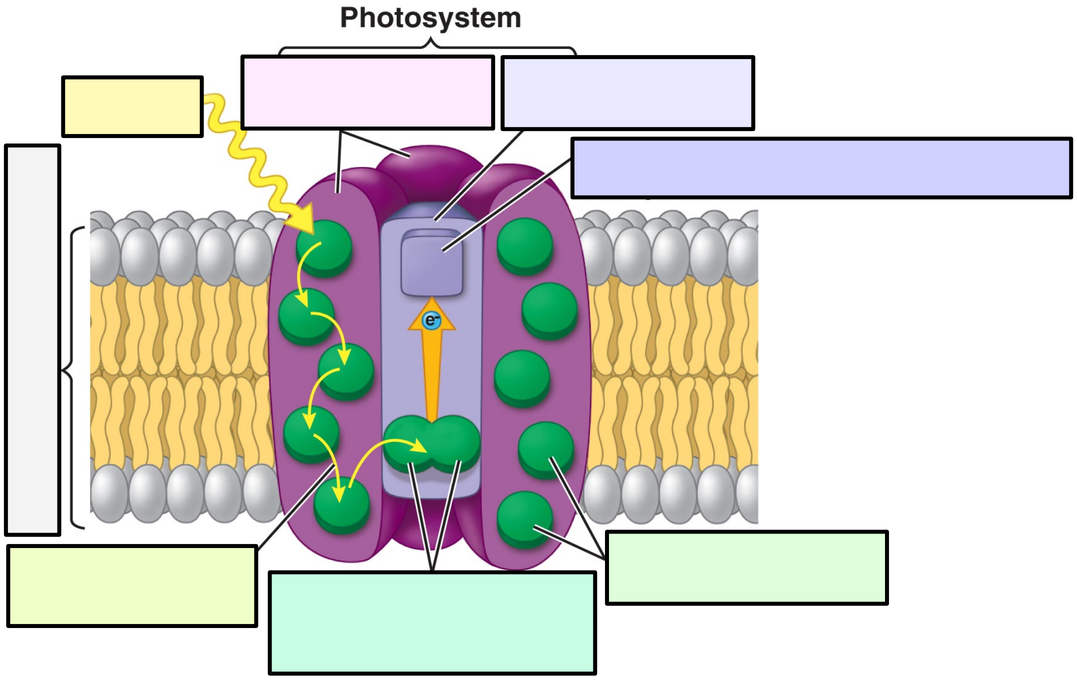
b. What are the 'nicknames' of the **two chlorophyll a** molecules located **in the Reaction Center Complex of Photosystem II**? Why is this their nickname?

c. What are the 'nicknames' of the **two chlorophyll a** molecules located **in the Reaction Center Complex of Photosystem I**? Why is this their nickname?

d. What do these two photosystems together help produce as the **two main product of the Light Reactions**?

Products of the Light Reactions of Photosynthesis = 1. _________________ + 2. _________________

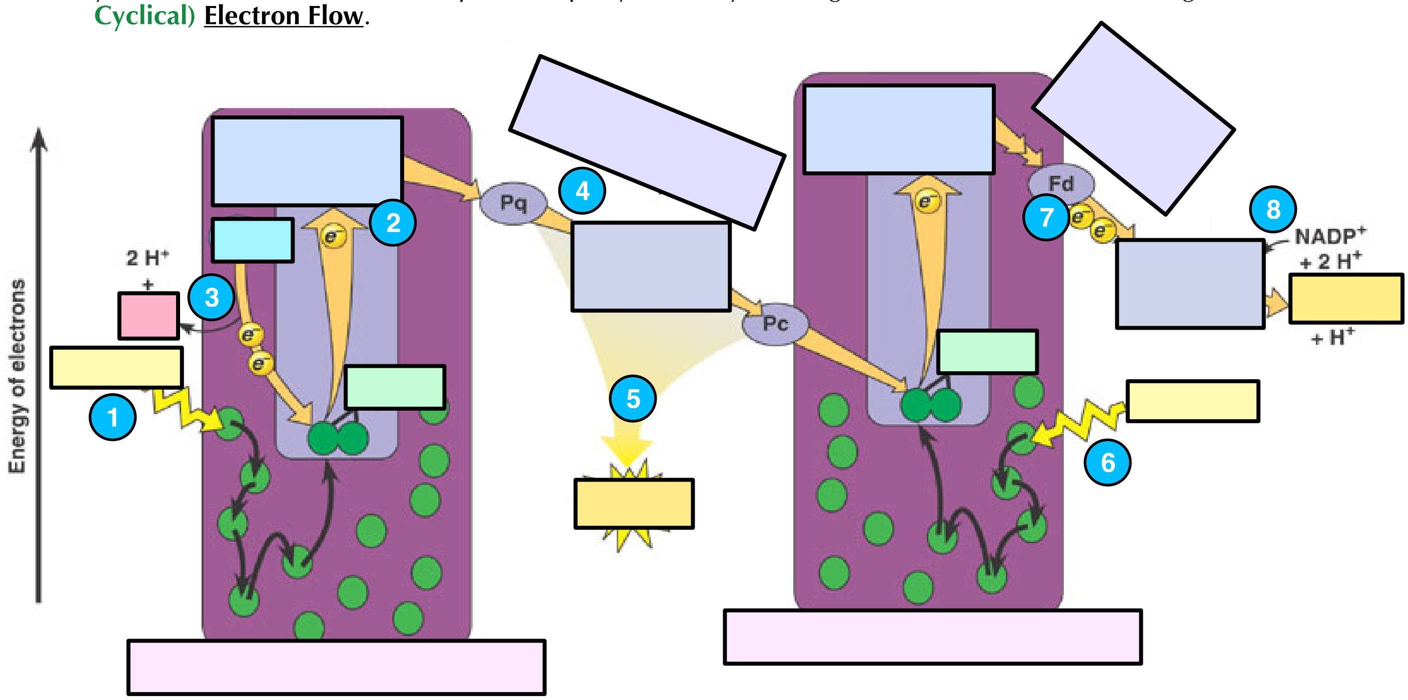
14. Let's make sure we understand the parts of a photosystem. Label the figure below showing how **<u>Photosystems harvest light energy, converting it into the potential energy stored in electrons</u>** *(the electrons going from being **low**-energy to being **high**-energy electrons in the process).*



15. Photosystem II and Photosystem I are found as multiple pairs embedded in the thylakoid membrane in chloroplasts of photosynthetic eukaryotic cells *(and in plasma membranes or regions of infolding of the plasma membrane, sometimes also called thylakoid membranes, of certain photosynthetic prokaryotic cells).* **Energy is transferred from light into the energy stored on ATP and the high-energy electrons stored on NADPH through the <u>flow of electrons</u> through these <u>two photosystems</u> and some other <u>associated proteins</u> in the <u>thylakoid membrane</u>.**

    a. What do we **<u>call this movement of electrons from H_2O to PS II to PS I to $NADP^+$</u>** *(a coenzyme electron carrier akin to NAD^+ used during cellular respiration in the cytoplasm of cells and also in mitochondria of cells that posses this organelle)*?

    b. Now, **<u>study Figure 10.13 carefully</u>** as you <u>read</u> about the eight steps of this linear electron flow. When you feel you have <u>memorized</u> the entire process, quiz yourself by labeling the illustration below showing **<u>Linear</u> (NON-Cyclical) <u>Electron Flow</u>**.



c. Now, try to explain from memory steps 1 through 8 on the diagram above showing the **Linear Electron Flow during the light reactions of photosynthesis that serve to drive electrons from water to NADPH**.

1.

2.

3.

4.

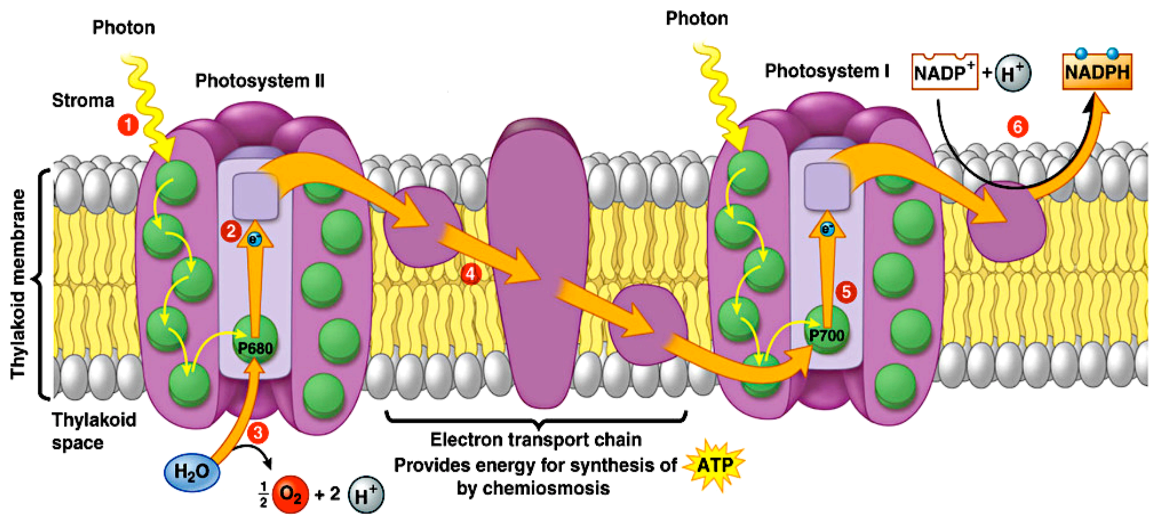
5.

6.

7.

8.

16. What is the **purpose again of the ATP and the purpose of the NADPH produced in the light reactions**?



17. a. As review, where did the **electrons come from that replaced the lost electrons of Photosystem II's central pair of chlorophyll a molecules**?

b. Where did the **electrons come from that replaced the lost electrons of Photosystem I's central pair of chlorophyll a molecules**?

c. **Where do the now high-energy electrons** (originally obtain from water) **end up at the end of the Light Reactions and Photosystem I**?

18. a. **What happens to the ELECTRONS** during **Cyclic Electron Flow**?

b. **What happens to electrons' ENERGY** during **Cyclic Electron Flow**?

c. What items are **NOT produced during Cyclic Electron** that is produced during Lineal Electron Flow?

____________________ + ____________________

d. What items **IS produced during Cyclic Electron** that is also produced during Lineal Electron Flow?

____

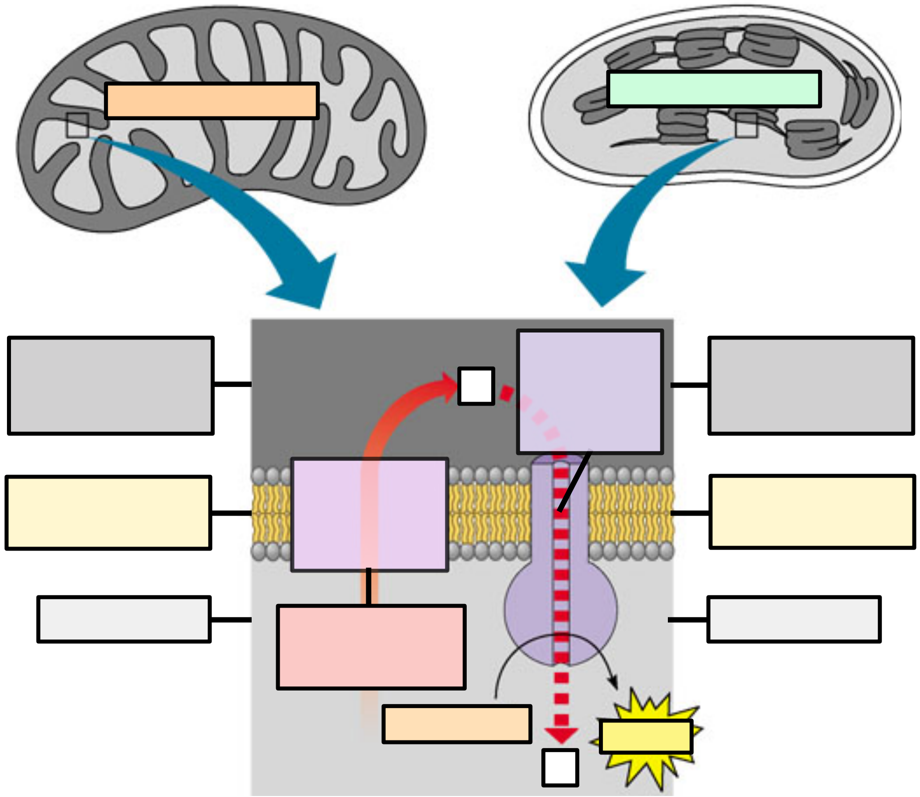
e. ATP is produced during Cyclic Electron Flow. What are two **benefits to plants or cyanobacteria evolving the ability to engage in Cyclic Electron Flow**?

1.

2.

f. *Think* = **In Cyclic Electron Flow, no water is split** so there is no release of ____________.

19. a. First label the diagram below comparing **chemiosmosis in mitochondria and chloroplasts**.



b. Indicate on the left side of the diagram on which side of the **inner mitochondrial membrane** of the mitochondria you would find a **higher [H⁺] and a lower [H⁺] when the Electron Transport Chain of Aerobic Respiration is active**.

c. Indicate on the right side of the diagram on which side of the **thylakoid membrane** of the chloroplast you would find a **higher [H⁺] and a lower [H⁺] when the Light Reactions of Photosynthesis are active**.

20. a. When you are asked to **COMPARE** two processes, you are to identify **SIMILARITIES**. What is the **similar process called used to generate ATP when comparing the process both in chloroplasts and in mitochondria**?

b. **Describe** this similar process by which both chloroplasts and mitochondria generate ATP.

21. a. What do we call the **making of ATP from ADP and inorganic Phosphate by ATP Synthase in the mitochondria**?

b. What do we call the **making of ATP from ADP and inorganic Phosphate by ATP Synthase in the chloroplas**t?

22. When you are asked to **CONTRAST** two processes, you are to identify **DIFFERENCES**. Though similar in mitochondria and chloroplasts, two key differences in oxidative phosphorylation between these organelles exists as far as the origin of electrons passed through the ETC and the origin of the energy harvested. **Explain.**

Difference in origin of the electrons passed through the ETC during cellular respiration vs photosynthesis =

Difference in origin of the energy used to make and stored on ATP during cellular respiration vs photosynthesis =

23. a. At the end of the Electron Transport Chain in **Cellular Respiration**, where do the **electrons that pass through the ETC end up** once their potential energy has been extracted for use in building ATP?

b. At the end of the **Light Reactions of Photosynthesis**, where do the **electrons that pass through the ETC end up** once their potential energy has been increased through the help of light energy?

24. a. In both photosynthesis and cellular respiration, a **proton gradient** (a **Proton Motive Force**) is **built across a membrane** as a way of **storing Potential Energy** extracted through an ETC from high-energy electrons. In what **direction are protons pumped in the mitochondria during cellular respiration**?

b. In what **direction are protons pumped in the chloroplast during photosynthesis**?

c. What **location in the mitochondria** functions as the **hydrogen ion** (and Potential Energy) **reservoir**?

d. What **location in the chloroplast** functions as the **hydrogen ion** (and Potential Energy) **reservoir**?

e. Because of the direction protons are pumped in to build the Proton Motive Force necessary for Chemiosmosis *(the diffusion of protons down their electrochemical gradient through ATP Synthase)* and ATP Synthesis, **when the Electron Transport Chains are active, what location in the mitochondria becomes temporarily acidic** (becomes l lower in pH) **and what location becomes temporarily basic** (becomes higher in pH).

Becomes Acidic During Cellular Respiration =

Becomes Basic During Cellular Respiration =

f. Because of the direction protons are pumped in to build the Proton Motive Force necessary for Chemiosmosis *(the diffusion of protons down their electrochemical gradient through ATP Synthase)* and ATP Synthesis, **when the Light Reactions are active, what location in the chloroplast becomes temporarily acidic** (becomes lower in pH) **and what location becomes temporarily basic** (becomes higher in pH).

Becomes Acidic During Photosynthesis =

Becomes Basic During Photosynthesis =

g. In both photosynthesis and cellular respiration, a the **facilitated diffusion of protons** down their gradient through ATP Synthase, an **exergonic process**, **releases the stored Potential Energy** of the proton gradient, which is then **coupled to ATP Synthase catalyzing the endergonic reaction of building ATP from ADP and inorganic Phosphate ions**. In what **direction do protons diffuse as they pass through ATP Synthase in the mitochondria**?

h. In what **direction do protons diffuse as they pass through ATP Synthase in the chloroplast**?

i. In what **location** (relative to the inner mitochondrial membrane) **is ATP being made in the mitochondria**?

j. So in what **location** (relative to the thylakoid membrane) **is ATP being made in the chloroplast**?

25. Assume hydrogen ions can freely cross the outer membranes of mitochondria and chloroplasts.

a. Describe how you would change the pH outside an isolated mitochondrion in order to <u>artificially</u> cause ATP synthesis (even if no electrons are flowing through the Electron Transport Chain).

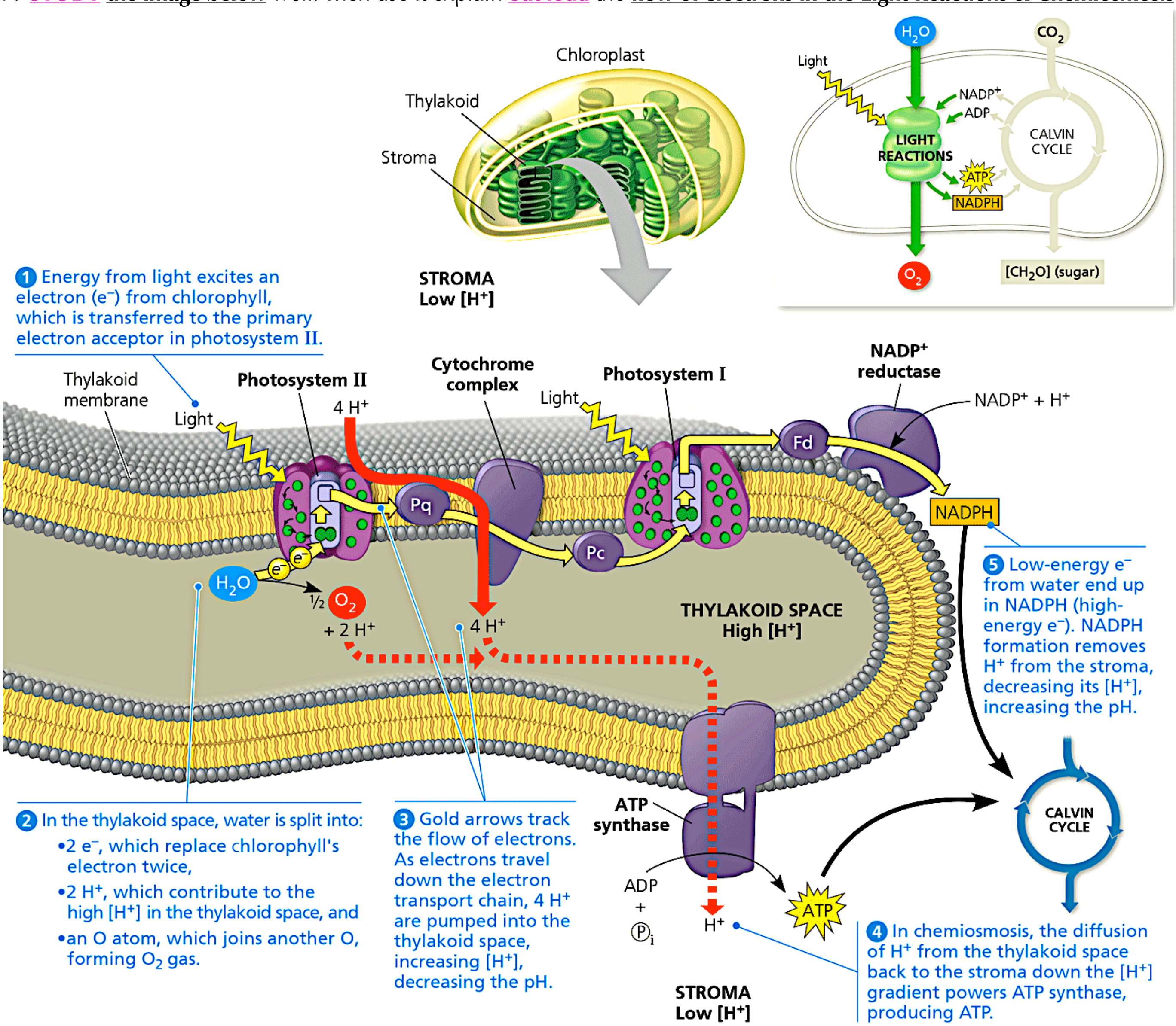
b. Describe how you would change the pH outside an isolated chloroplast in order to <u>artificially</u> cause ATP synthesis (even if no electrons are flowing through the Electron Transport Chain).

(Check your answer to 24 by going to the Ch.10 **Figure Questions** for **Figure 10.16** in Appendix A of your book)

26. *Think* = In an experiment, isolated chloroplasts placed in a solution with the appropriate components can carry out ATP synthesis. Predict what would happen to the rate of synthesis if a compound is added to the solution that makes membranes <u>freely permeable</u> to hydrogen ions? Briefly explain your answer.

(Check your answers to #25 by going to the Ch.10.3 ***Concept Check Question #3*** *in Appendix A of your textbook)*

27. **<u>STUDY</u>** **<u>the image below</u>** well. Then use it explain <u>out loud</u> the **<u>flow of electrons in the Light Reactions & Chemiosmosis</u>**!



28. To review, during the light reactions, the pH inside the thylakoid drops to 5 while the stroma rises to 8. List the **3 events that build build the proton gradient, storing potential energy, across the thylakoid membrane**.

1.

2.

3.

29. As a review, note that the **light reactions store chemical energy** in ________________ and ________________ , which shuttle the energy to the carbohydrate-producing _________________ Cycle.