Dr. Mallery Biology 150 - Workshop Fall Semester

PHOTOSYNTHESIS - ANSWERS

IN THE GRAND SCHEME (Fill-in some blanks)

In Photosynthesis plants convert _**light**_ energy of the sun into __**chemical bond**__ energy stored in _**organic**_ molecules. Plant are _**autotrophic**_ organisms that "feed themselves", in the sense that they make their own organic molecules from _**inorganic**_ raw materials. Some bacteria are _**chemoautotrophs**_, which means they use energy from oxidizing inorganic substances to produce organic compounds.

FOR REVIEW…

Have each member of your Learning Community, in turn, define the KEY TERMS given below and tell how it may relate to the concepts of energy and metabolism. As a group, help each other answer any questions concerning any portion of the review section that any person does not understand before proceeding further.

a) Thylakoid - a flattened membrane sac inside the chloroplast, used to convert light energy into chemical bond energy. Stacks of thylakoid membranes are called grana.

b) Stroma - the fluid (aqueous) portion of the chloroplast surrounding the thylakoid membranes, contains bacterial size ribosomes, DNA, enzymes of CO_2 fixation, and solutes. Also called **chloroplasm**.

c) Calvin Cycle - a major biochemical pathway of photosynthesis involving the reduction of atmospheric carbon dioxide into carbohydrate, as glucose

d) Electromagnetic energy - the entire spectrum of radiation, produced by the fusion reactions of the sun; expressed in wavelengths, which run from less than a nanometer to more than a kilometer. A portion of the spectrum is referred to as the visible spectrum, which includes the light seen by the human eye, and runs from 340 nm to 720 nm.

e) Absorption spectra - a graphical plot of the amount of light absorbed by a purified form of a molecule vs. the wavelengths of the electromagnetic (visible light)

f) PEP Carboxylase - an enzyme found in C4 plants, which reduces carbon dioxide by combination of CO_2 with PEP to make malate. The efficiency of PEP carboxylase for CO_2 is much greater than that of RuBP carboxylase, the enzyme of CO_2 reduction in C3 plants.

g) Pigment - classes of molecules capable of absorption of light energy (chlorophylls, carotenoids, phycobilins)

h) CAM Plant - a plant that uses Crassulacean acid metabolism (CAM), an adaptation for photosynthesis In arid conditions, first discovered in the plant family Crassulaceae. CO_2 entering open stomata during the night is first converted into organic acids (malate) which releases CO_2 for use in the Calvin cycle during the day, when the stomata are closed, thus these processes are temporally separated.

i) Photosystem - a light harvesting complex located within the thylakoid membranes & consisting of an antennae complex of chlorophyll molecules & a reaction center pigment molecule

j) Cyclic electron flow - a route of electron flow, during the light reactions of photosynthesis, which Involves only photosystem I (PSI), produces ATP, but not NADPH, and has the electron returning to its original source pigment - P_{700}.

k) Chemiosmosis - the ability of some membranes (mitochondrial cristae and chloroplast thylakoid) to Use small amounts of captured redox energy to pump hydrogen ions from one compartment to another, creating a H^+ gradient, and then to harness the energy in this H+ gradient to make ATP by phosphorylation of ADP through the enzyme ATP synthase.

l) Phosphorescence- luminescence, which is caused by the absorption of radiation at one wavelength followed by a significantly delayed re-radiation at a different wavelength and that continues for a noticeable time after the incident radiation stops; as opposed to **fluorescence,** which is luminescence that is caused by the absorption of radiation at one wavelength followed by nearly immediate re-radiation often at a different wavelength and that ceases almost immediately when the incident radiation stops

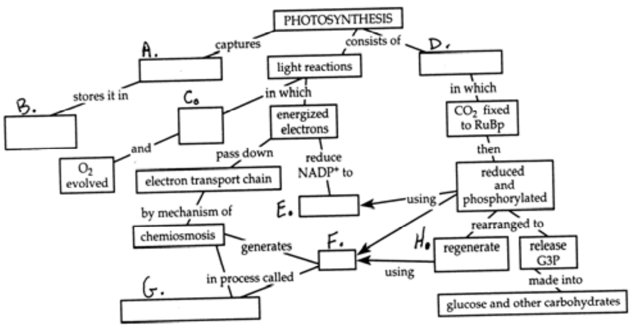
m) Photorespiration - a metabolic pathway that consumes oxygen (like cell respiration) and releases carbon dioxide, generates no ATP, and decreases photosynthetic output of carbohydrate. It occurs most commonly on hot, dry, bright days, when plant stomata are closed and the oxygen concentration in the leaf exceeds that of carbon dioxide in Calvin plants.

n) Phycobilin- a class of accessory pigment composed of a protein and a chromophore group (molecule which absorb light); two examples include phycoerythrin (red algae pigments) and phycocyanin (blue-green algae pigments)

o) Plastoquinone - a cytochrome-like component of the photsynthetic electron transfer chain which undergoes a redox reaction by gaining/losing electrons and/or protons.

CONCEPT MAPS

Fill in the following concept map that summarizes this section on Photosynthesis.



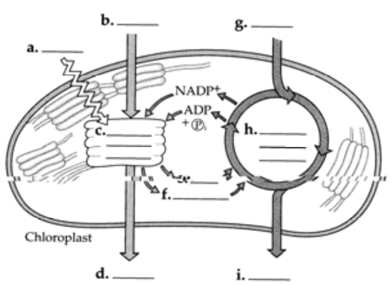
A. light energy
B. organic molecules
C. water is split
D. Calvin cycle
E. NADPH
F. ATP
G. photophosphorylation
H. regenerate RuBP

MORE FILL-IN THE BLANKS…

Chloroplasts are found primarily in the __**mesophyll**___ tissues of a leaf, and contain the pigments _**chlorophyll**_, __**carotenes**__, __**phycobilins**__. The gases _**CO_2**_ and _**O_2**_ enter and leave the leaf through _**stomata**_. Veins carry water from the roots to the leaves and distribute _sugars _ made in the leaf to other non-photosynthetic tissues.

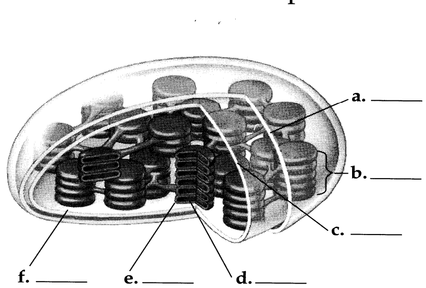
LABEL IDENTIFICATIONS

A. Fill in the blanks in this overview of photosynthesis in a chloroplast.



a. light
b. H_2O
c. light reaction take place in grana
d. O_2
e. ATP
f. NADPH
g. CO_2
h. Calvin Cycle in the stroma
i. CH_2O (sugars)

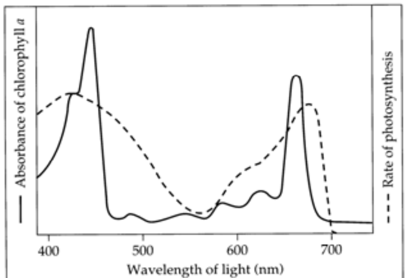
2. Label the indicated parts in this diagram of the chloroplast.



a. outer membrane
b. granum
c. inner membrane
d. thylakoid compartment
e. thylakoid
f. stroma (chloroplasm)

C. Label the absorption spectra and the action spectra in the graph below.

What is the difference between these two spectra? On this plot draw an action spectra for rhodopsin, a human visual pigment.



Absorption and action spectra for photosynthesis

The solid line is the absorption spectra showing absorption maxima at 450nm and 660nm indicating that it is probably a chlorophyll. The dashed line is the action spectra. An absorption spectra is a plot vs. wavelength of the amount of light absorbed, which an action spectra is a plot vs. physiological activity.

An action spectra for rhodopsin would reveal a maxima of optical nerve activity near 500nm in the green regions of the visible spectrum.

SOME INTERACTIVE THOUGHT QUESTIONS…

1. Why is no oxygen generated by cyclic electron flow?

   No electrons are released from PSII (P_{680}) and therefore without an oxidized P_{680} there is no need to split water to re-reduce the P_{680}.

2. Where do the electrons from P_{700} go during non-cyclic electron flow?

   Electron from P_{700} in PSI are transferred from the primary electron acceptor to ferredoxin, then NADP reductase transfers the electrons to NADP to form NADPH.

3. During chemiosmosis in chloroplasts the proton gradient across the membranes is as great as 1.0 to 2.0 pH units. Name the side of the membrane with the lowest pH?

   Inside the thylakoid compartment (the locule space) space is the site of the lowest pH, greatest H^+ concentrations.

4. Name 3 things which contribute to the formation of a large pH difference across thylakoid membranes?

   a) the transport of protons into the thylakoid compartment by the electron transfer chain; b) protons splitting from water remaining in the thylakoid compartment; and c) the removal of hydrogen in the stroma during the reduction of NADP+ to NADPH.

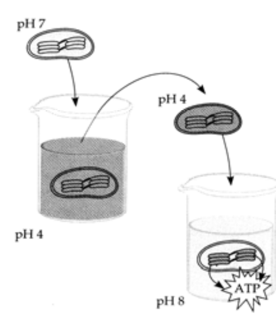
5. What possible explanation is there for photorespiration, a process that can result in the loss of as much as 50% of the carbon dioxide reduced in the Calvin Cycle?

   Photorespiration may be an evolutionary relic from the time when there was little oxygen in the atmosphere and the ability of the enzyme Rubisco to distinguish between O_2 and CO_2 was not that critical. Now in our oxygen rich atmosphere, Photorespiration seems to be a great agricultural liability.

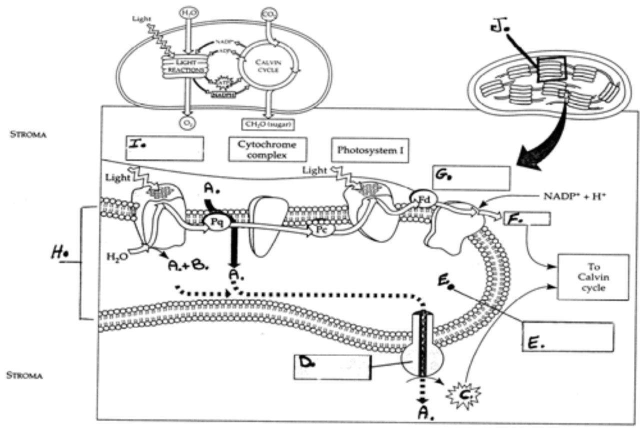
6. Exactly where does the Calvin Cycle take place in C_4 plants? *In the Bundle Sheath cells.*

7. Why are C_4 plants able to photosynthesize in arid, dry conditions, while C_3 plants would be undergoing Photorespiration? *Carbon is initially fixed (reduced) into a four-carbon compound in the mesophyll cells by PEP-carboxylase. When this compound is broken down in the bundle sheath cells, CO_2 is maintained at a high enough concentration that Rubisco does not accept O_2 and cause Photorespiration.*

8. In the figure to the right the isolated chloroplasts were first allowed to equilibrate in an acidic solution at pH 4.0. After the chloroplast's thylakoid compartments reached a pH of 4.0, the chloroplasts were collected and transferred to a basic solution at pH 8.0. This caused the chloroplasts to make ATP, even if placed in the dark. Explain? *The higher concentration of H+ ions inside the locules after being equilibrated at pH 4.0 means that these H+ ions will move from the locules, with the existing H+ ion gradient, back out into the high pH media (low H+ concentrations) of the stroma, probably through the ATP synthase in these membranes, thereby making ATP.*



ELECTRON FLOW IN THYLAKOID MEMBRANES… Label the diagram below (A. through I.), which depicts the molecules and components of electron flow in photosynthesis.



a. hydrogen ions (H+)
b. hydroxyl ions (OH)
c. ATP
d. ATP synthase
e. locular space
f. NADPH
g. NADP Reductase
h. thylakoid compartment
i. photosystem II

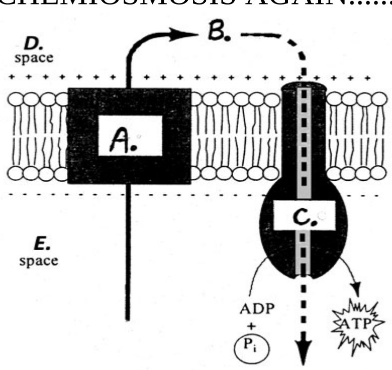
A PROBLEM… Given the following data:

1. the maximum rate of photosynthesis of green plants is about 20 mg glu/dm^{-2}/hr^{-1}
2. the heat of combustion of glucose is 686 Kc/mole
3. the gram molecular weight of glucose is 180 gm,

How much energy (Kcal/m) could be made over a 18 hr lighted period, by a green plant, which has a leaf surface area of 2000 dm^{-2}.

If 1 dm^{-2} make 20 mg of glucose in 1 hour then 2,000 dm^{-2} (20 mg x 2,000 dm^{-2}) would make 40,000 mg or 40 gm of glucose. thus in 18 hours this amount leaf tissue would make (40gm x 18hr) or 720 gm of glucose. 720 gm of glucose is (720gm / 180gm) 4 moles of glucose. Thus if 1 mole of glucose releases 686 Kc/mole, then 4 moles (4 x 686Kc/mole) would release 2,744 Kc of energy, enough to run one hard working undergraduate student for a day.

CHEMIOSMOSIS AGAIN....... Questions a. to f. use the figure on the left.



a. What is the molecule at label B. is figure to the left? *hydrogen ions*

b. What is name of the system identified by label A? *Electron transfer chain*

c. What is label C. identifying ? *ATP synthase*

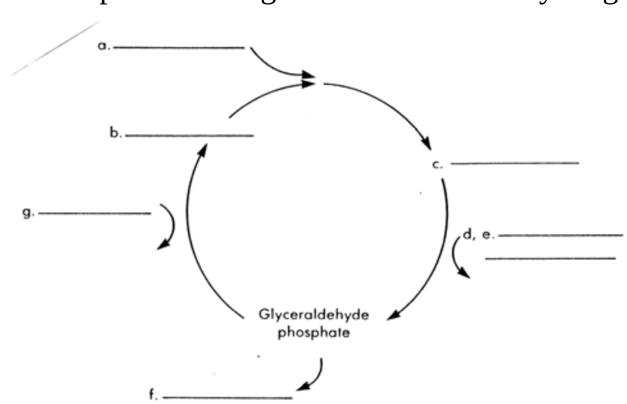
d. What is name of the cellular process identified by the labels A., B., & C.?
Chemiosmosis (oxidative phosphorylation)

e. What is the name of the space labeled D.
1. in chloroplast=***locule space*** 2. in mitochondria=***peri-mitochondrial space***

f. What is the name of the space labeled E.
1. in chloroplast = ***stroma (chloroplasm)*** 2. in mitochondria = ***Matrix (mitoplasm***

DARK REACTIONS OF PHOTOSYNTHESIS

A little easier this time. Using the following terms to complete the diagram of the Calvin Cycle given below. A term may be used more than once.



1. ATP –> ADP + Pi	**a. 2 and 6**
2. CO2	**b. 6**
3. glucose and other sugars	**c. 5**
4. NADPH –> NADP+	**d. & e. 1 and 4**
5. PGA	**f. 3**
6. RuBP	**g. 1**