A.P. Biology Name ___________________________

Photosynthesis Sheet 1 - Chloroplasts

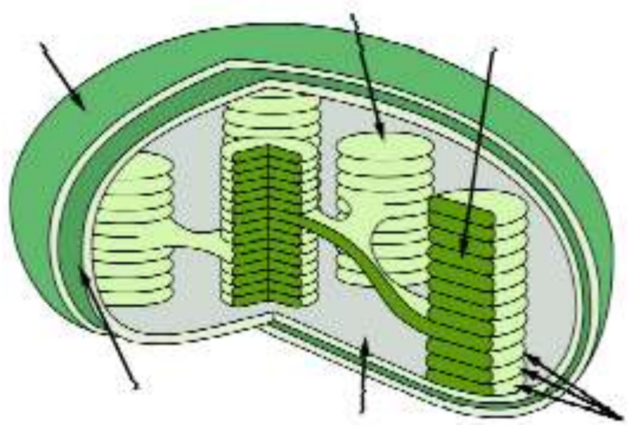
Chloroplasts

Are chloroplasts..............

_____________________ Membrane-bound or non-membrane bound?
_____________________ Large or small organelles?
_____________________ Found in all plant cells?
_____________________ Found in animal cells?
_____________________ Found in any protists?
_____________________ Found in any bacteria?
_____________________ Capable of self-replication?
_____________________ Capable of surviving on their own?
_____________________ Found in prokaryotic cells?
_____________________ Mobile or immobile within a cell?

Identify any structures you recognize on the chloroplast drawn to the right:

Outer membrane
Inner membrane
Thylakoids
Granum
Stroma
Intermembrane space



Any interior space surrounded by a thylakoid is called a(n) ______________________.
Stacks of thylakoids are termed ____________________.
The fluid within the interior of the chloroplast is called the _________________.
Do the thylakoids house the "light dependent reactions" or the "Calvin cycle reactions"?
Does G3P (sugar) synthesis occur in the stroma or grana?
Where are the ATP Synthase complexes found? _______________________________________
What are these ATP Synthase complexes for? ___________________________________
Where are the Photosystem I and Photosystem II complexes found? ____________________________

Interesting diddy:

In green plants, chloroplasts are surrounded by two lipid-bilayer membranes. They are believed to correspond to the outer and inner membranes of the ancestral cyanobacterium. Chloroplasts have their own genome, which is considerably reduced compared to that of free-living cyanobacteria, but the parts that are still present show clear similarities with the cyanobacterial genome. Plastids may contain 60-100 genes whereas cyanobacteria often contain more than 1500 genes. Many of the missing genes are encoded in the nuclear genome of the host. The transfer of nuclear information has been estimated in tobacco plants at one gene for every 16000 pollen grains.

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Review Sheet II - The Light-Dependent Reactions

Is / Is Not

Which of the following is (IS) and which is not (IS NOT) an event which occurs during the light reactions?

1. ______________ ATP generation.
2. ______________ CO_2 reduction.
3. ______________ Sunlight utilization
4. ______________ Chemiosmosis.
5. ______________ Thylakoid involvement.
6. ______________ The Calvin Cycle.
7. ______________ Oxygen release.
8. ______________ Splitting water.
9. ______________ Occurs in the stroma.
10. ______________ Hydrogen ion concentration.
11. ______________ ATP Synthase complexes.
12. ______________ NADP reduction.
13. ______________ Glucose synthesis.
14. ______________ Proton pumps.

Narrative Fill-ins

Noncyclic Photophosphorylation

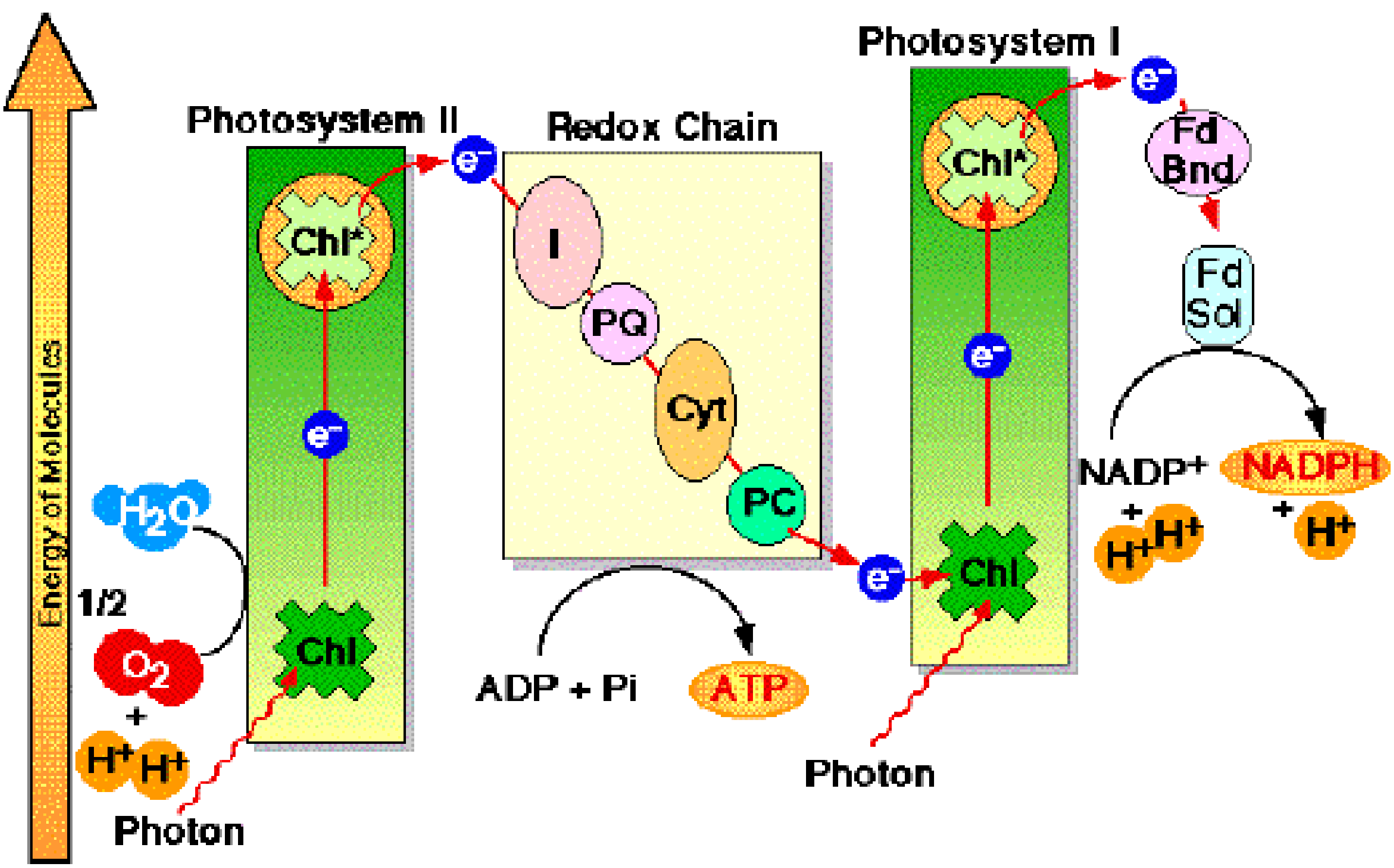
The light that falls upon the leaves of the green plant parts in the beautiful state of Michigan comes from the yellow orb in the day sky, the _____________. This flaming ball of hydrogen and helium rises in the _____________ and sets in the _______________. Light energy arrives on our planet (_____________) in packets of energy called _________________. Light strikes all of a plant's green cells, but the only organelle that is effected chemically is the _________________, the principle organelle of photosynthesis. Most of the light energy is funneled to the pigment _____________ __ of the P700 reaction center in Photosystem _____ (Roman Numeral). As 2 of the electrons in the reaction center assume "higher energy levels" in this reaction center, they are quickly "picked up" by an available electron acceptor. As a result of the loss of electrons, the chlorophyll a is said to be o________________ and the electron acceptor is r________________. The electron acceptor is merely the first protein in a series of proteins embedded in the thylakoids called the ETS. This particular ETS is NOT utilized in proton pumping or ATP generation.... it is utilized to transfer the electrons, plus 1 proton from the stroma, to $NADP^+$, forming ______________. This leaves the P700 reaction center shy _____ (#) electrons! This situation could not occur endlessly; the chlorophyll electrons must be replaced! The replacement electrons come from a partner photosystem, Photosystem II.

The events that occur in Photosystem I are occurring at the same time as those occurring in Photosystem II - they are both embedded in the thylakoids, sometimes right next to one another. Photons striking the leaf strike both photosystems. Those that strike Photosystem II are absorbed by the P_____ reaction center. As a result, 2 electrons are elevated to a "higher energy level" and, like Photosystem I, they are "accepted" or "picked up" by an electron acceptor. The electrons are (like Photosystem I) shuttled to an electron transport system (ETS). The electron exchanges that occur in *this ETS* ARE used to generate ATP (this is called Noncyclic Photophosphorylation). The energy released during the redox reactions in PS (Photosystem) II is transferred to ATP in the same way that it is during respiration; through the use of proton pumps and ATP synthase ports. As energy is released during the linear redox reactions of the ETS, the energy is used to pump protons _______________ (out of / into) the thylakoid lumen. When the electrons diffuse through the ATP synthase ports, ATP formation occurs. This ATP provides much of the energy that drives the reactions in the ____________ cycle. At the end of the ETS, the electrons are channeled to Photosystem I, where they are used to replace the lost electrons described in the first paragraph above!

Yet, there is still trouble in plant paradise. Now...Photosystem II has lost *its* electrons. Dang it! The plant looks around for an easy source of electrons to replace the lost PSII electrons. It scans all of the molecules.....proteins, oxygen, CO_2, enzymes, coenzymes, vitamins, starch,.....and then its gaze locks on water! Water!.....what a great source of electrons. Each hydrogen atom holds one fairly easy to obtain electron. The removal of hydrogen's electron disrupts the bond that holds hydrogen to oxygen, yielding free oxygen. An oxygen atom quickly bonds with another free oxygen atom to form diatomic O_2. The hydrogen ions (H^+) are simply protons that may be used during proton pumping to generate ATP chemiosmotically.

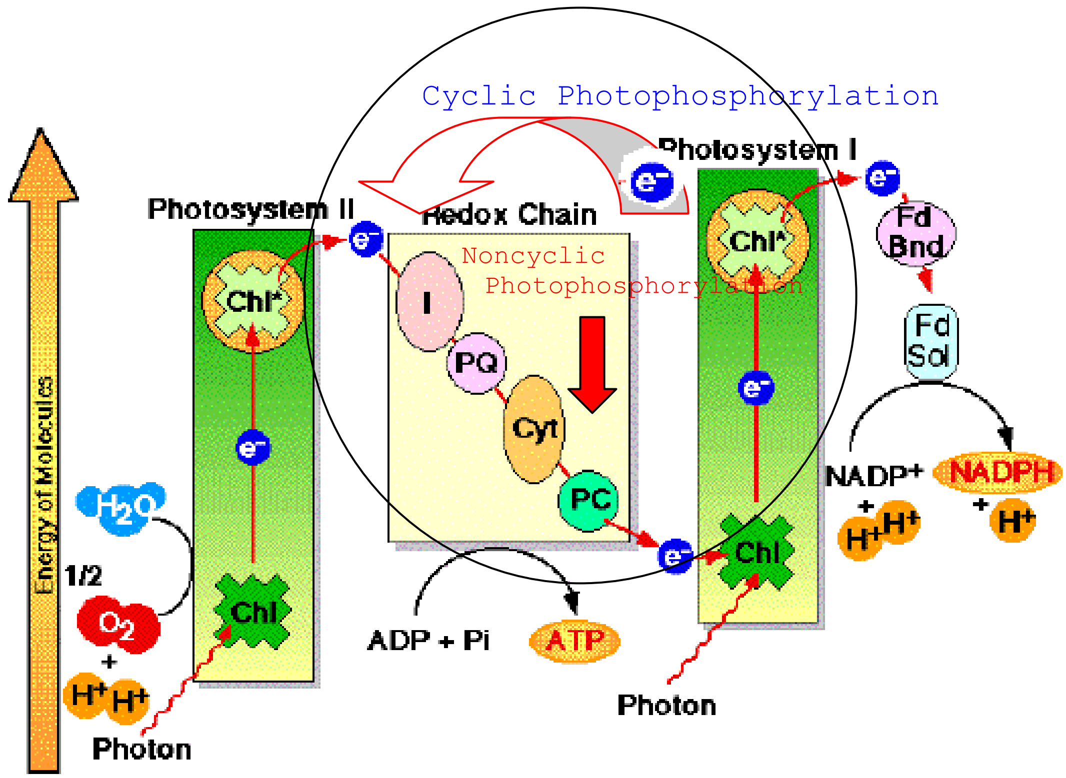
In summary, the events that occur during Noncyclic Photophosphorylation (shown in the Z-scheme below) result in:

- **Chemiosmotic ATP generation.**
- **$NADP^+$ reduction to NADPH**
- **The splitting of water molecules to release electrons, protons, and oxygen.**



Cyclic Photophosphorylation

The metabolic pathways described above generate ATP, but not enough to meet the ATP needs of the Calvin Cycle. Fortunately, there is a metabolic pathway that can be used to generate additional ATP (but no NADPH). This pathway is called Cyclic Photophosphorylation, and it uses the electrons made "available" when light strikes Photosystem I. If most of the $NADP^+$ in a plant cell exposed to bright sunlight has been reduced (making it unavailable to accept a pair of electrons), the pair of electrons can be transferred to the "top" of the redox chain that links Photosystem II with Photosystem I. ATP generation then occurs by chemiosmosis AND THE ELECTRONS ARE RETURNED TO PHOTOSYSTEM I. Because the electrons travel in a "circle" and return to a P700 complex, the metabolic pathway is called Cyclic Photophosphorylation.



Cyclic Photophosphorylation + or 0

1. ______ ATP is synthesized.
2. ______ $NADP^+$ is reduced.
3. ______ Thylakoids are required.
4. ______ Sunlight is required.
5. ______ The replacement electrons come from Photosystem II.
6. ______ Occurs when $NADP^+$ is in short supply.
7. ______ Creates NADPH for the Calvin Cycle.
8. ______ Occurs more often during "low light" conditions.

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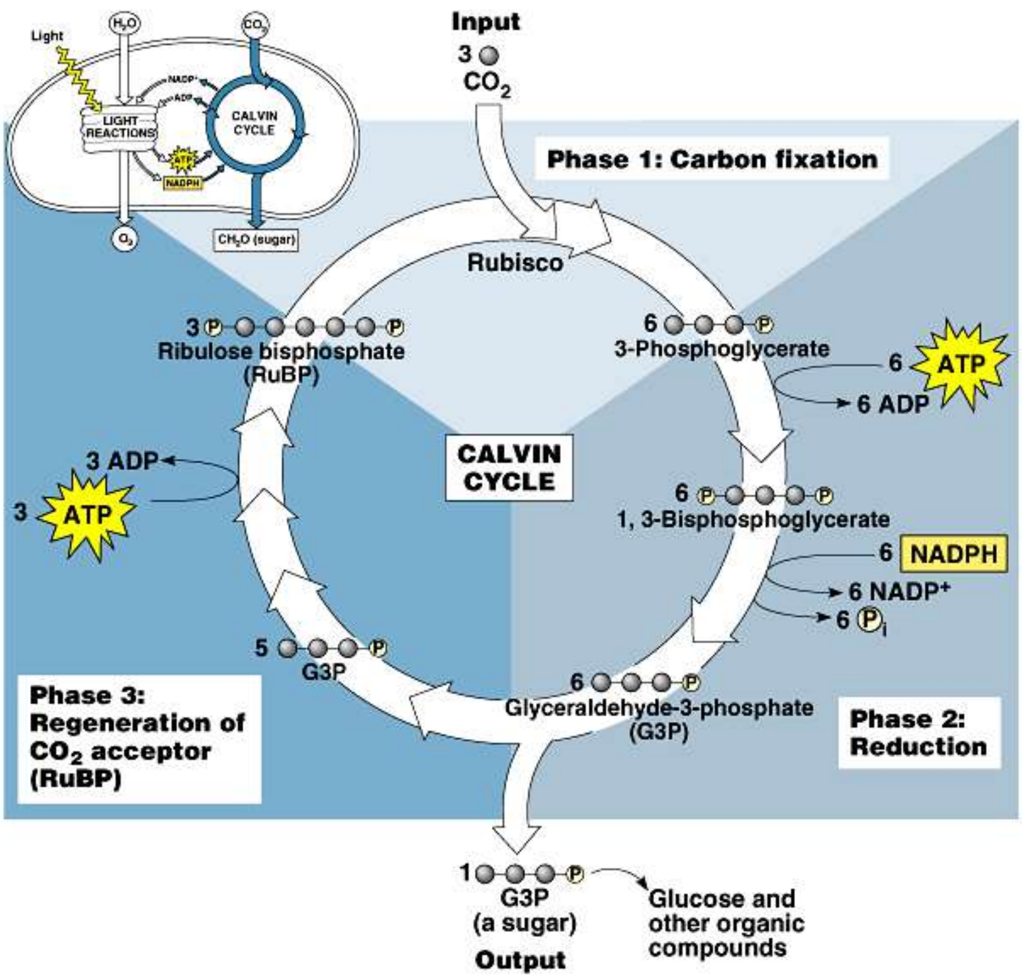
Review Sheet III - The Calvin Cycle (Light Independent Reactions)

The light reactions occur in order to convert the ____________ energy of sunlight into the _____________ energy of ATP and NADPH. In this form, the energy can be used to reduce the gaseous "reactant" _________ ____________ to form the organic molecule end-product of photosynthesis, ________________.

Fill-ins

1. ____________________ Where do the carbon atoms that end up in glucose come from?
2. ____________________ How many CO_2 molecules does it "take" to make 1 glucose molecule?
3. ____________________ Does glucose synthesis occur in the "first half" or "second half" of photosynthesis?
4. ____________________ The circular pathway that results in glucose synthesis is called the _____.
5. ____________________ This cycle's reactions are also called the light-_____ reactions.
6. ____________________ During each turn of this cycle, _____ (#) CO_2 molecule is "taken in".
7. ____________________ The enzyme responsible for pulling CO_2 into the Calvin cycle is nicknamed _____. This event is termed "carboxylation" or "carbon fixation" and is considered by most scientists the most important event in all of biochemistry. It is, indeed, the link between the non-living, physical earth and most life on the planet.

The Calvin Cycle



Refer to the Diagram on the Previous Page to answer the following questions:

1. ____________________ How many carbon atoms are there in RuBP.
2. ____________________ RuBp combines with _____ to form an unstable 6-C intermediary.
3. ____________________ This intermediary immediately splits to form 2 3-C _____ molecules.
4. ____________________ These 3-C molecules are *phosphorylated* with a phosphate group that comes from _____.
5. ____________________ The 3-C molecules are *reduced* by capturing Hs from _____.
6. ____________________ This energized, reduced molecule is glyceraldehyde - 3 - phosphate, AKA _____.
7. ____________________ G3P is the true end-product of photosynthesis and is used to assemble molecules of g_____.
8. ____________________ How many G3Ps does it "take" to "make", like, 1 molecule of glucose?
9. ____________________ 3 spins of the Calvin cycle generates ______ (#) G3P molecules.
10. ____________________ How many of these G3Ps are reformulated into RuBP?
11. ____________________ How many ATPs are dephosphorylated in 3 turns of the cycle?
12. ____________________ How many NADPHs are oxidized in 3 turns of the cycle?
13. ____________________ How many glucose molecules are produced in 3 turns of the cycle?
14. ____________________ How many glucose molecules are produced in 6 turns of the cycle?
15. ____________________ How many ATP are needed to form 1 G3P?
16. ____________________ How many NADPH are needed to form 1 G3P?
17. ____________________ If non-cyclic photophosphorylation generates equal numbers of ATP and NADPH, then how do the photosystems of the light reactions generate the extra ATP needed to run the Calvin Cycle?

What is the most likely eventual fate of product glucose? c_______ r_______________
What organic molecule is the glucose most likely to be "formed into"? ____________________

List 10 different organic molecules that plants can *make out of glucose*.

1.	6.
2.	7.
3.	8.
4.	9.
5.	10.

• *No other process is as important to life as photosynthesis* (fact or opinion?)