Section 4.2: Overview of Photosynthesis

I. Trapping Energy from Sunlight

A. Plants use energy in the form of ATP. Since sunlight is not available all the time they must harvest the ***sun's energy and store it for later use***.

- Photosynthesis = ***the process that uses the sun's energy to make simple sugars***.
- These simple sugars are then ***converted*** into complex carbohydrates, such as starches, which store energy.

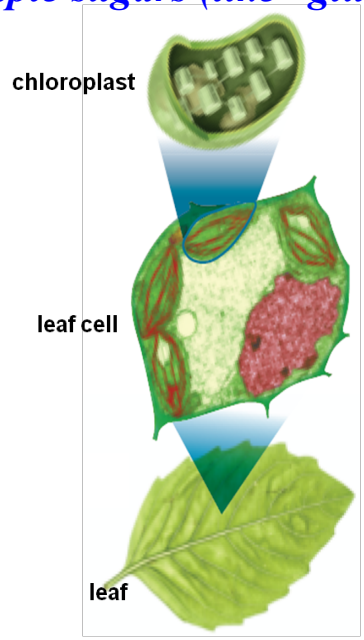
- **Photosynthesis happens in two phases**.

1. Light-dependent reactions - ***convert light energy into chemical energy (ATP molecules)***.

2. Light-independent reactions - ***produce simple sugars (like gluc***

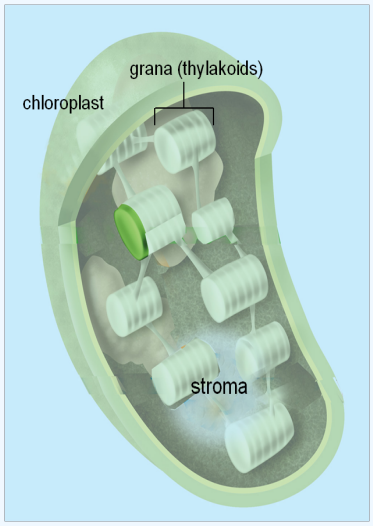
- General Equation for Photosynthesis

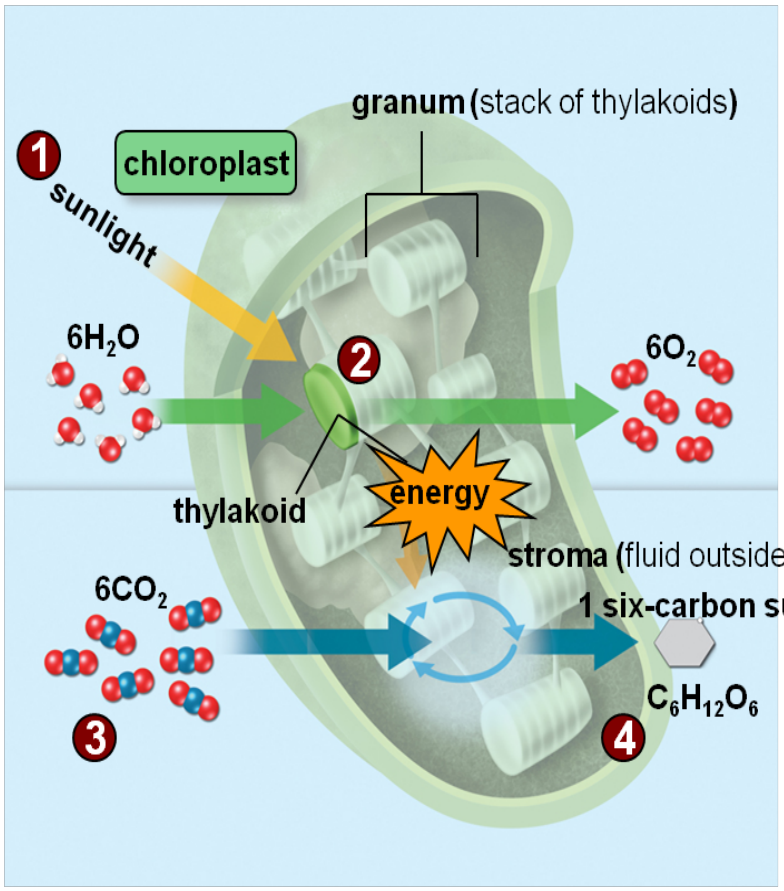
$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{light, enzymes}} C_6H_{12}O_6 + 6\,O_2$$

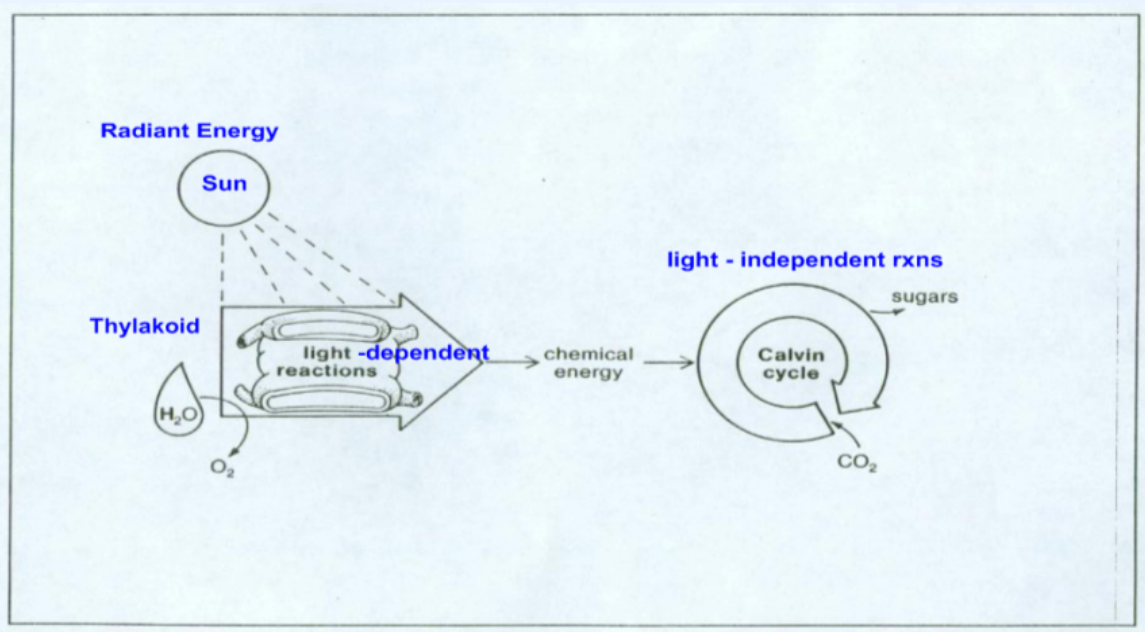


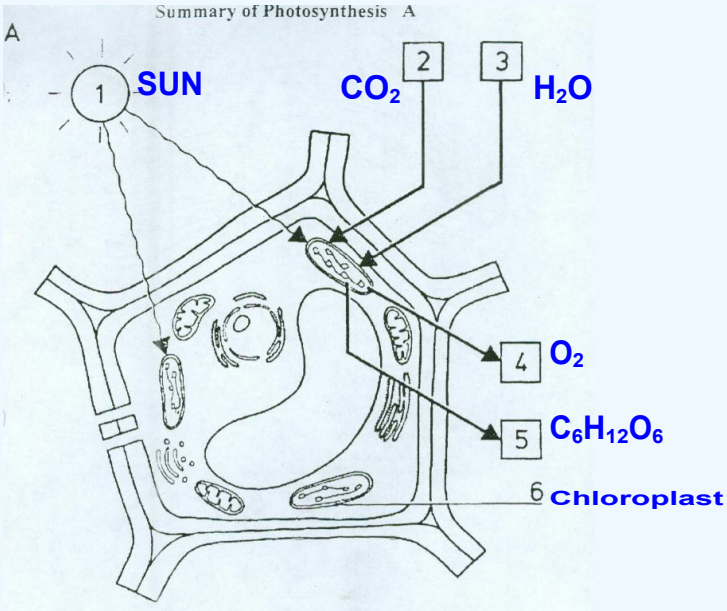
B. Chloroplast and pigments

- ***Chloroplast*** - cell organelle where photosynthesis occurs
- ***Thylakoid discs*** within the chloroplast contain pigments, i.e. chlorophyll, where light-dependent reactions occur.
- Stacks of thylakoid discs are called ***grana*** and ***stroma*** is the fluid surrounding.



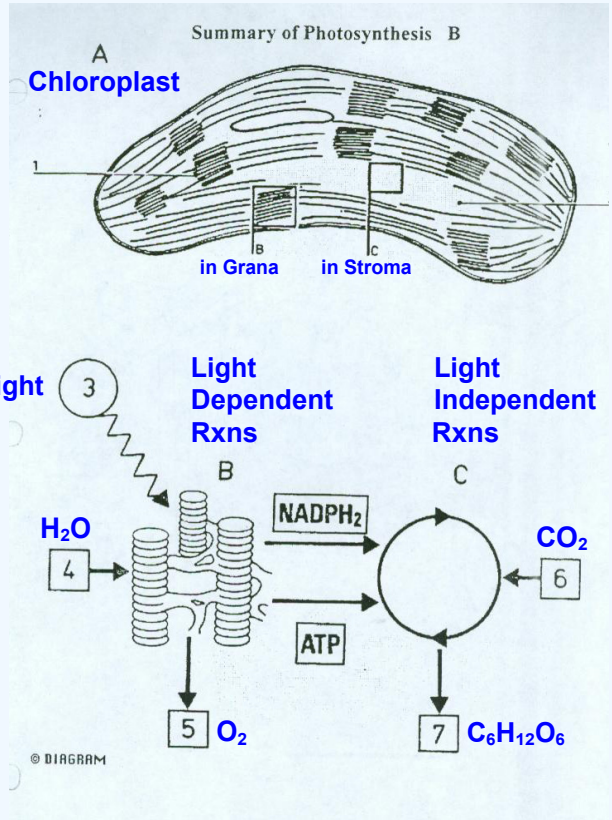


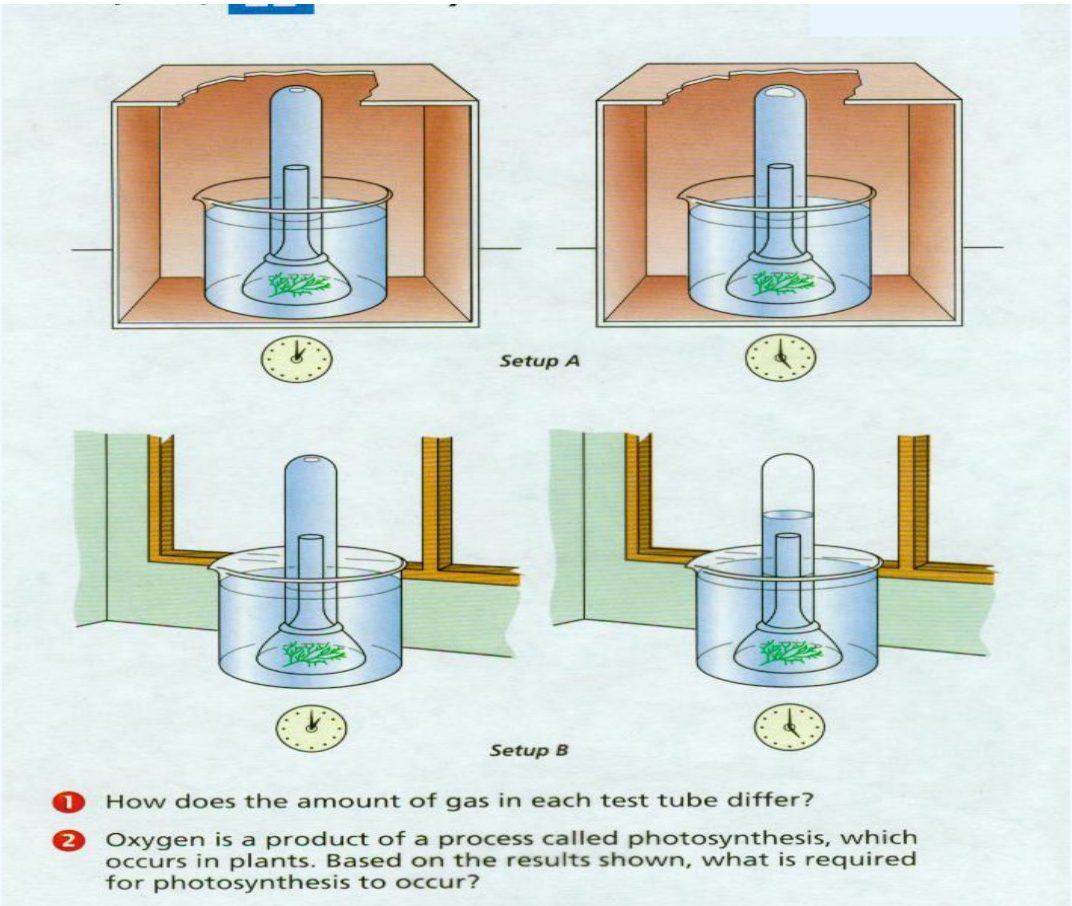




B

$6CO_2 + 6H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$

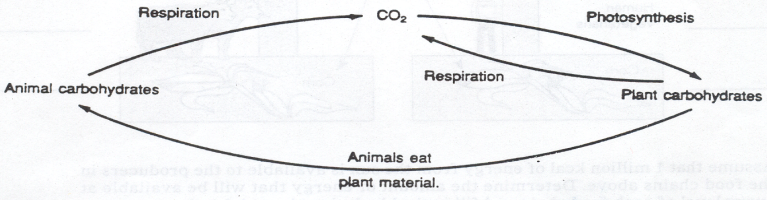

Summary of Photosynthesis
A
Chloroplast
1
B
C
in Grana
in Stroma
Sunlight
3
Light Dependent Rxns
Light Independent Rxns
B
C
H_2O
4
$NADPH_2$
CO_2
6
ATP
5 O_2
7 $C_6H_{12}O_6$
© DIAGRAM


Setup A
Setup B
1 How does the amount of gas in each test tube differ?
2 Oxygen is a product of a process called photosynthesis, which occurs in plants. Based on the results shown, what is required for photosynthesis to occur?

Analyzing Photosynthesis and Respiration

During photosynthesis, green plants use carbon dioxide and water to produce food in the form of glucose. During respiration, the glucose is broken down to be used as energy by the plant. As the glucose is broken down, oxygen is released by the plant. Carbon dioxide, oxygen, and water form a continuous cycle during these two processes.

Figure 1



Study the diagram of the carbon cycle that is shown in Figure 1. Then answer the questions, based on the diagram and your knowledge of photosynthesis and respiration.

1. The concentration of CO_2 in the atmosphere remains at a stable 0.004 percent. Which two processes keep this concentration stable? _____

_____

2. Plants depend upon the activities of animals for a continuing supply of which substance?

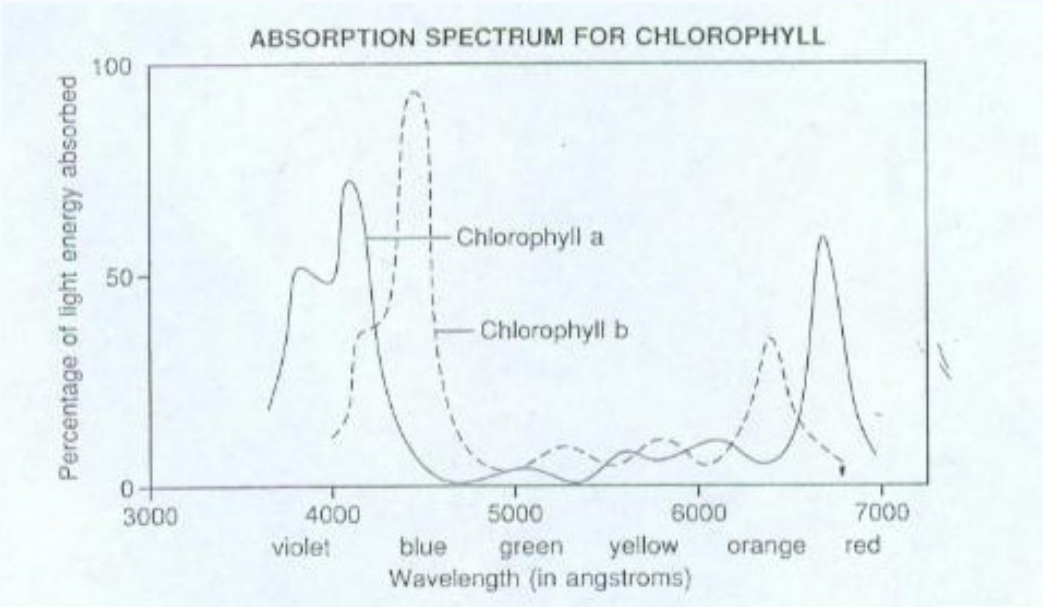
_____

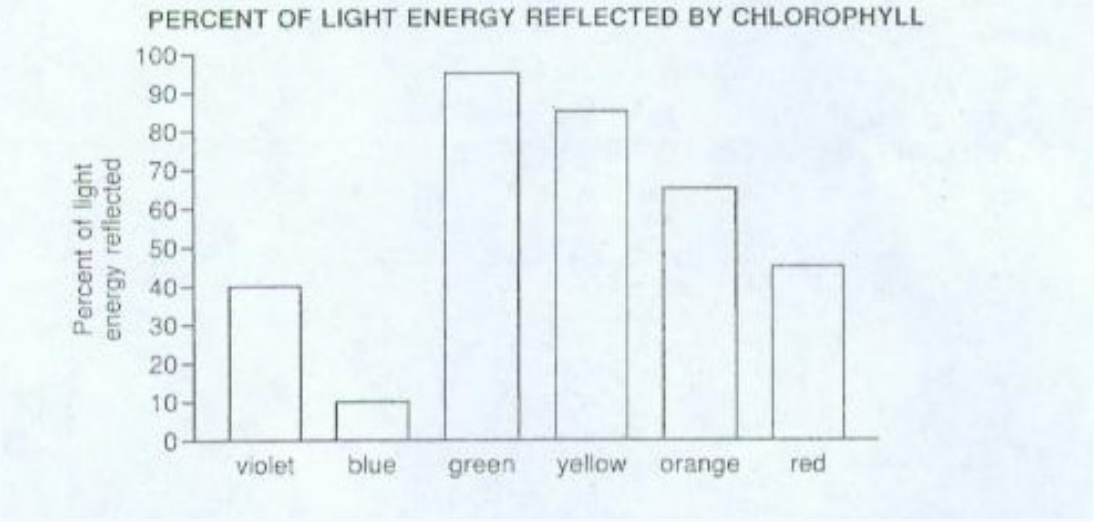
3. Which process removes CO_2 from the atmosphere? _____
4. Which process adds CO_2 to the atmosphere? _____
5. Into which organic compound does photosynthesis convert the carbon of CO_2?

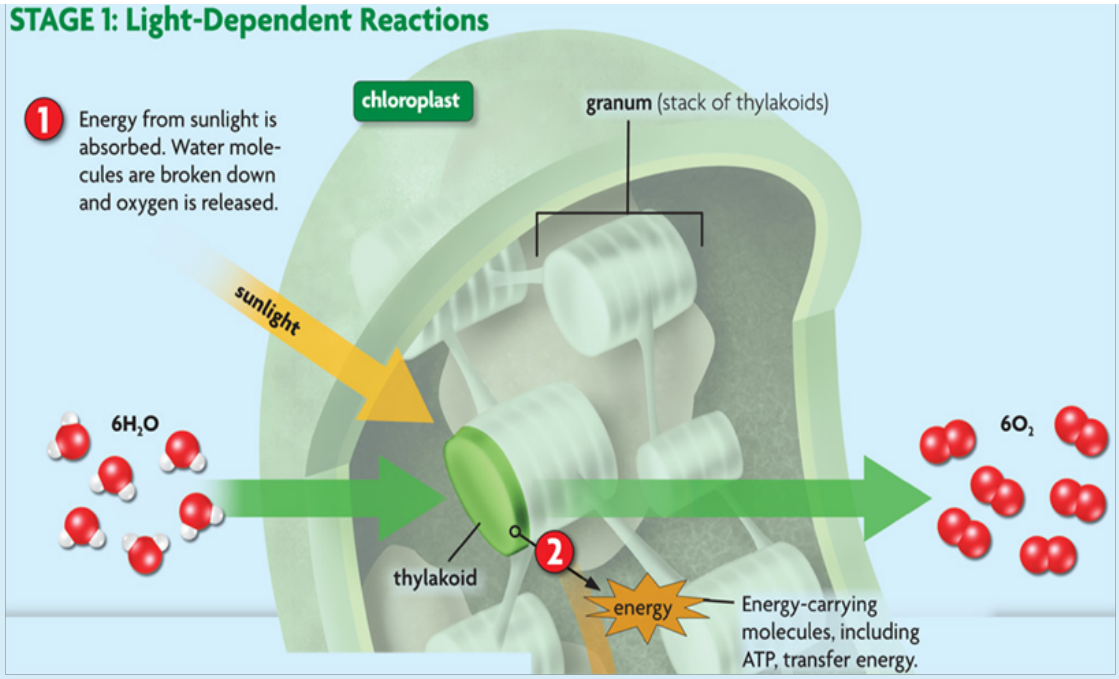
_____

6. After plants are eaten by animals, what process changes the carbon in these organic compounds back to CO_2? _____

LIGHT SPECTRUM = **ROYGBIV**




PERCENT OF LIGHT ENERGY REFLECTED BY CHLOROPHYLL
Percent of light energy reflected
100
90
80
70
60
50
40
30
20
10
0
violet
blue
green
yellow
orange
red


STAGE 1: Light-Dependent Reactions
1
Energy from sunlight is absorbed. Water molecules are broken down and oxygen is released.
chloroplast
granum (stack of thylakoids)
sunlight
6H2O
6O2
thylakoid
2
energy
Energy-carrying molecules, including ATP, transfer energy.

II. The Light-Dependent Reactions

A. Convert visible ***light*** energy into ***chemical*** energy that powers sugar production.

B. Takes place in the ***thylakoid*** of the chloroplast.

C. 2 groups of pigments (***photosystems I and II***) work in harmony to absorb ***light energy***.

- There is an ***electron transport chain*** between photosystems I and II.

- Both systems absorb ***light***, but at different ***wavelengths***. Remember when a wavelength is ***absorbed*** it is not seen.
- The ***photosystems*** work together to absorb light, concentrate, and transfer light energy to a special ***chlorophyll*** molecule called the ***reaction*** center.

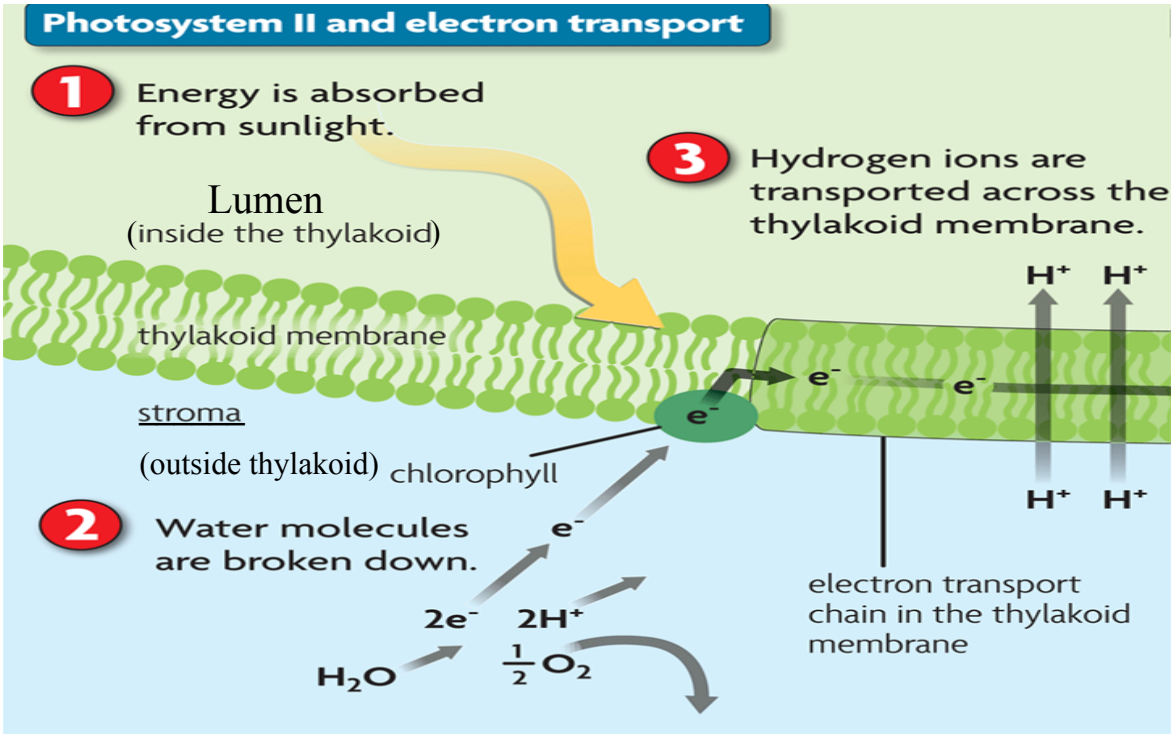
D. Absorption of light energy sets up a flow of ***electrons***.

- Electrons lost by photosystem ***I*** are replaced by photosystem ***II***.
- Electrons lost by photosystem II are replaced by electrons removed by splitting a ***water molecule***.
- Photolysis = The result of water being separated (**oxidized**) into ***oxygen***, hydrogen ions, and ***electrons***

$$H_2O \rightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$$

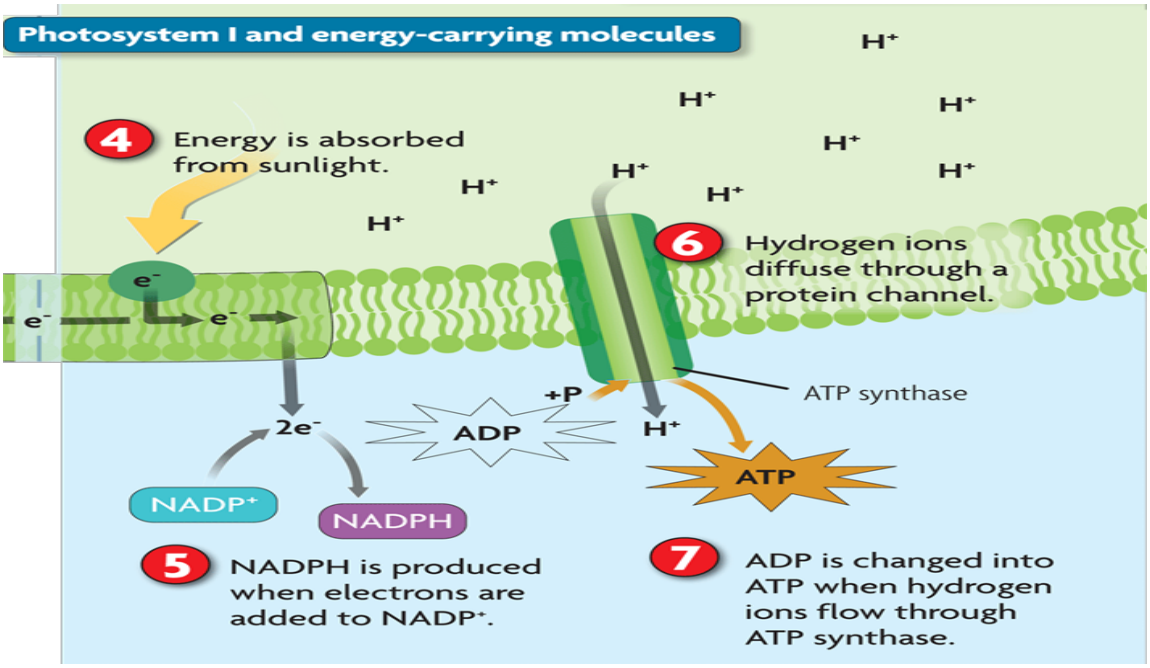
E. At end of electron flow the electrons along the hydrogen ions from water combine or **reduced** with a ***hydrogen*** carrier forming $NADPH_2$ (nicotinamide adenine dinucleotide phosphate).

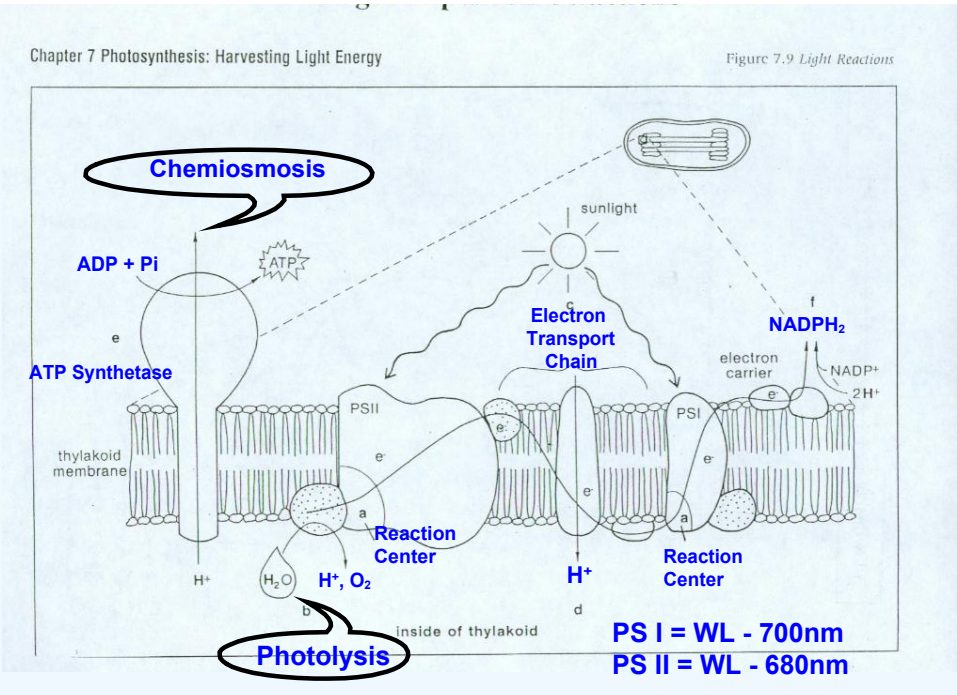
- The resulting molecule transports the hydrogen ions and electrons needed for the ***Calvin cycle***.



F. There is now active transport of hydrogen ions inside the ***thylakoid*** membrane.

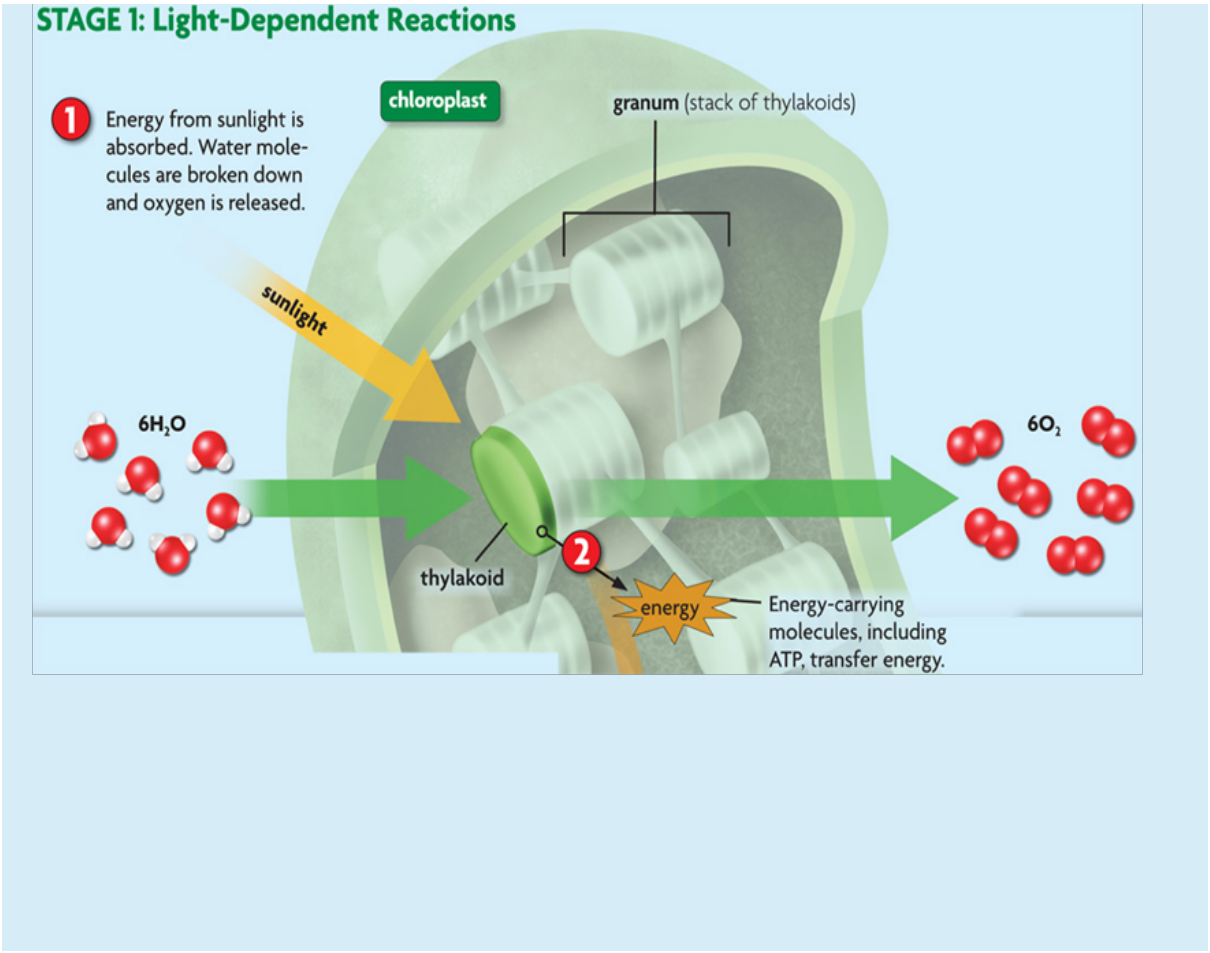
- There is a ***high*** concentration of hydrogen ions inside the thylakoid.
- Hydrogen ions now diffuse along a concentration gradient, passing through an ***enzyme*** complex, ATP synthetase.
- ATP synthetase uses energy from hydrogen ions to make or **reduce** ATP from ADP + P_i, process called ***chemiosmosis*****.**

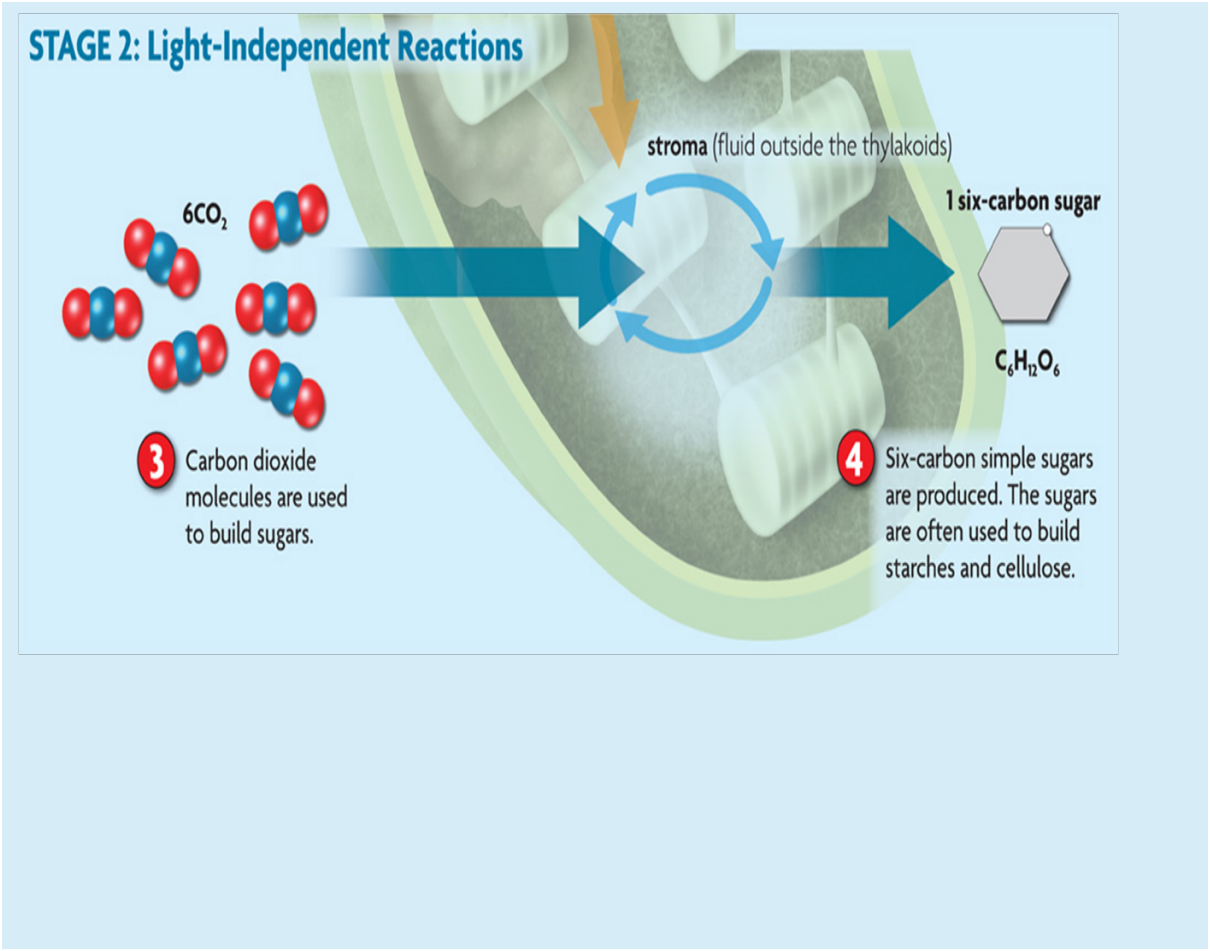

Photosystem I and energy-carrying molecules
H+
4 Energy is absorbed from sunlight.
e-
6 Hydrogen ions diffuse through a protein channel.
ATP synthase
+P
ADP
2e-
H+
ATP
NADP+
NADPH
5 NADPH is produced when electrons are added to NADP+.
7 ADP is changed into ATP when hydrogen ions flow through ATP synthase.


Chapter 7 Photosynthesis: Harvesting Light Energy
Figure 7.9 Light Reactions
Chemiosmosis
ADP + Pi
ATP
ATP Synthetase
sunlight
Electron Transport Chain
NADPH2
electron carrier
NADP+
2H+
PSII
PSI
thylakoid membrane
Reaction Center
Reaction Center
H+
H2O
H+, O2
H+
inside of thylakoid
Photolysis
PS I = WL - 700nm
PS II = WL - 680nm

Why not stop there?

1. ***ATP & $NADPH_2$*** are not stable compounds. Plants can't efficiently store nor transport them.
2. Plants can't directly use ATP or $NADPH_2$ as ***carbon*** skeletons for cell growth.
3. ATP and NADPH are used in Calvin Cycle to convert ***CO_2*** into stable easily transported sugars that contain energy and carbon skeletons for building cells and tissues.





III. The Dark Reactions (light independent) *Calvin* Cycle

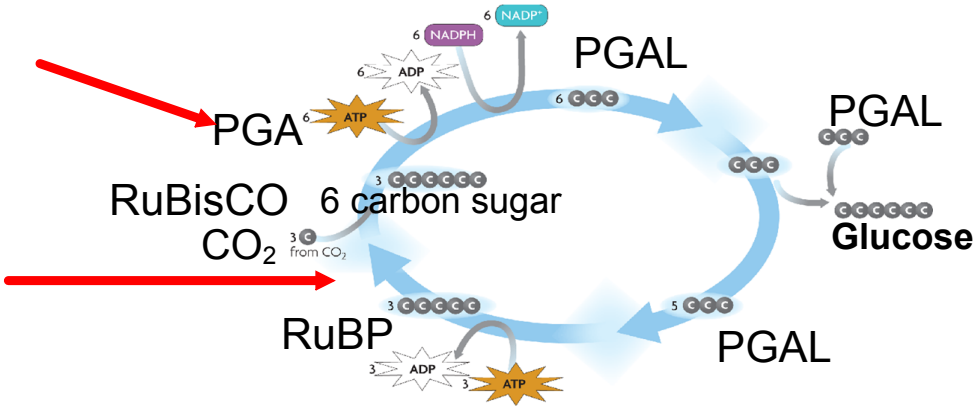
A. Does ***not*** involve light energy.

B. Must have the products of the ***light*** reactions (ATP and NADP and H^+)

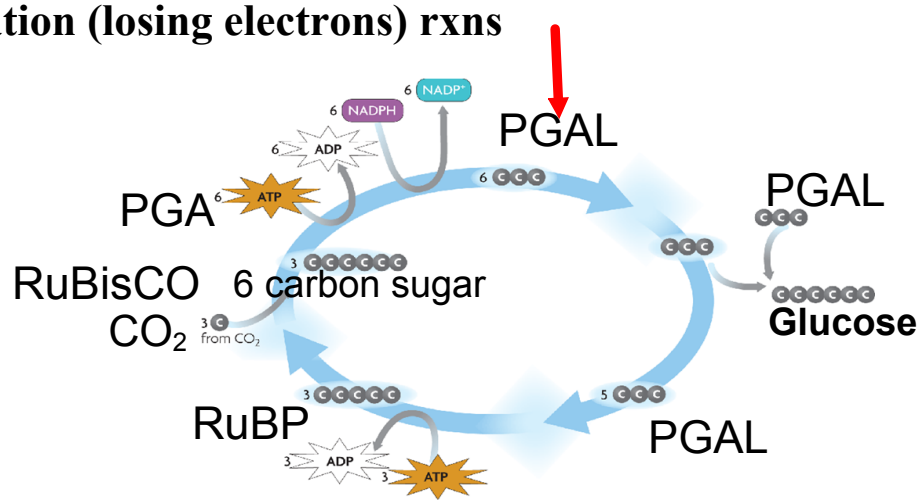
C. Occurs in the ***stroma*** of a chloroplast

D. Steps:

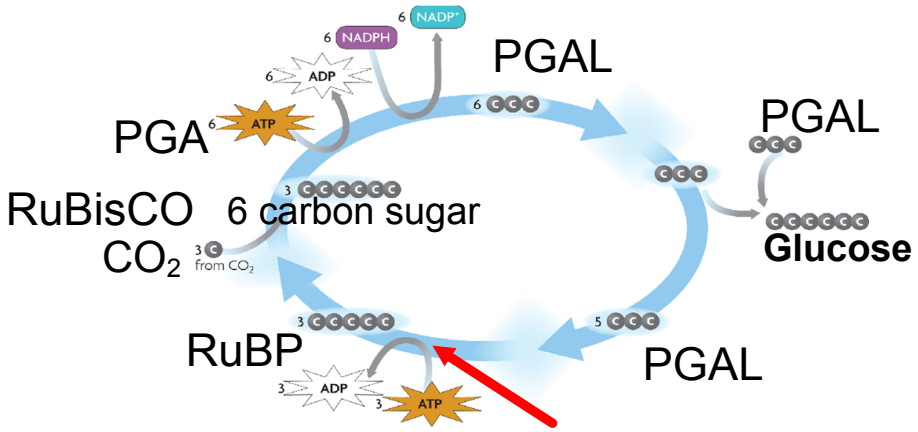
- CO_2 combines with a ***5*** carbon sugar ***RuBP*** (ribulose biphosphate) to make or **reduce** a 6 carbon molecule which immediately splits into 2 molecules of the 3 carbon acid ***PGA*** (phosphoglyceric acid)



- ATP and NADPH are used to convert each PGA to the 3 carbon sugar phosphate ***PGAL*** (phosphoglyceraldehyde)
- PGAL undergoes several reactions to form ***4,5,and 6*** carbon sugars. **Oxidation (losing electrons) rxns**

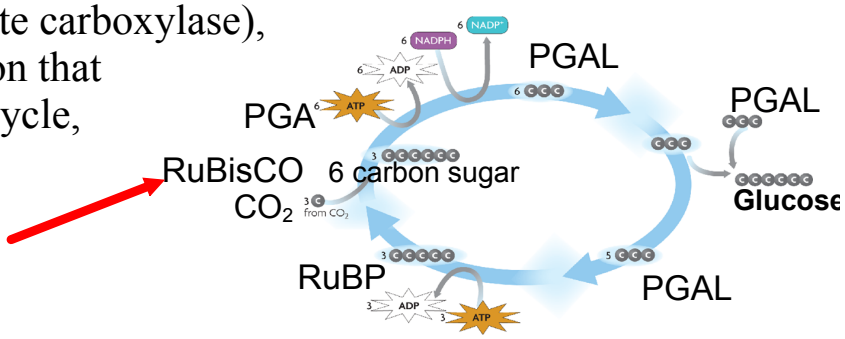


- The final step uses one ATP to **regenerate** RuBP from a 5 carbon compound, thus ***completing*** the cycle.

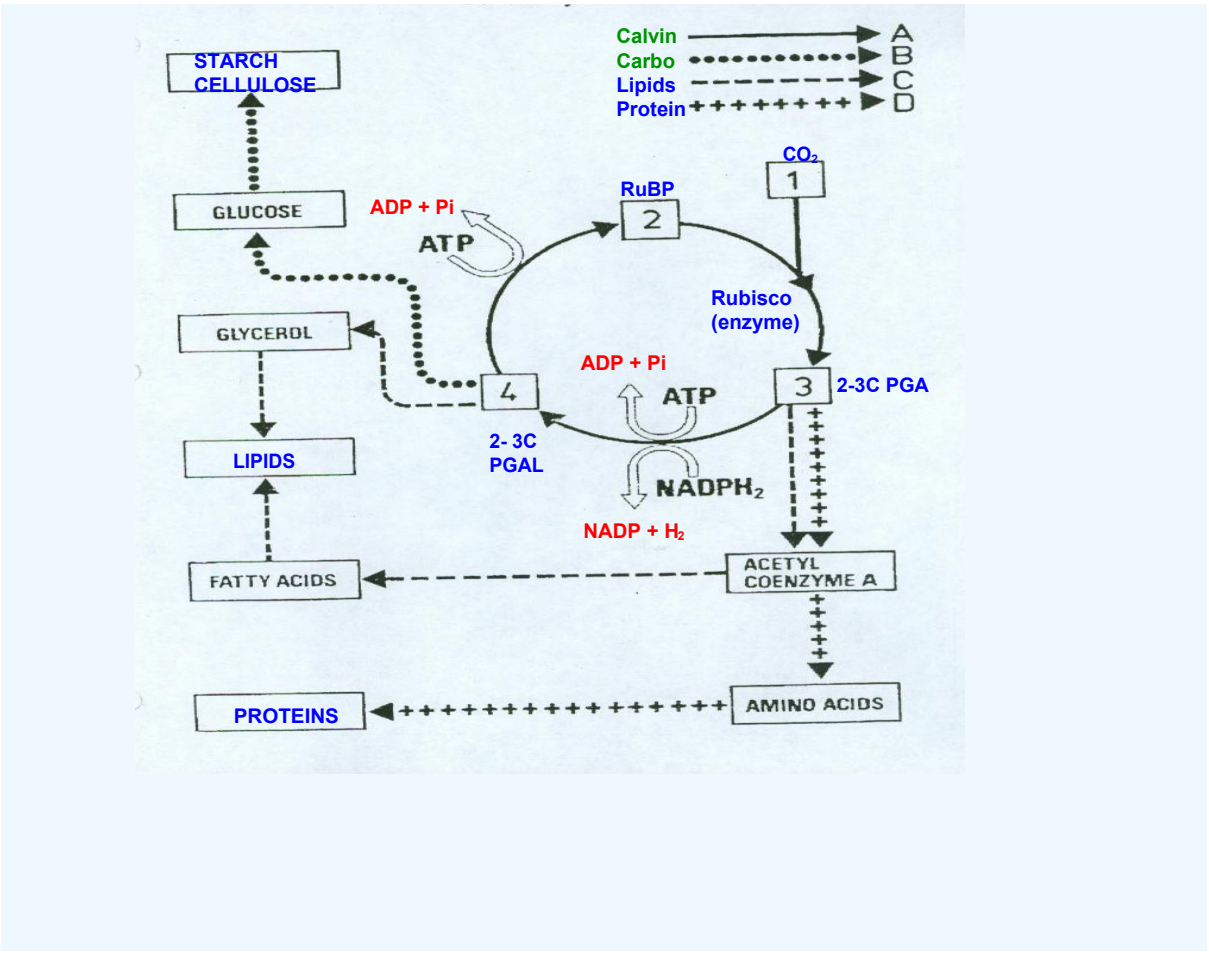


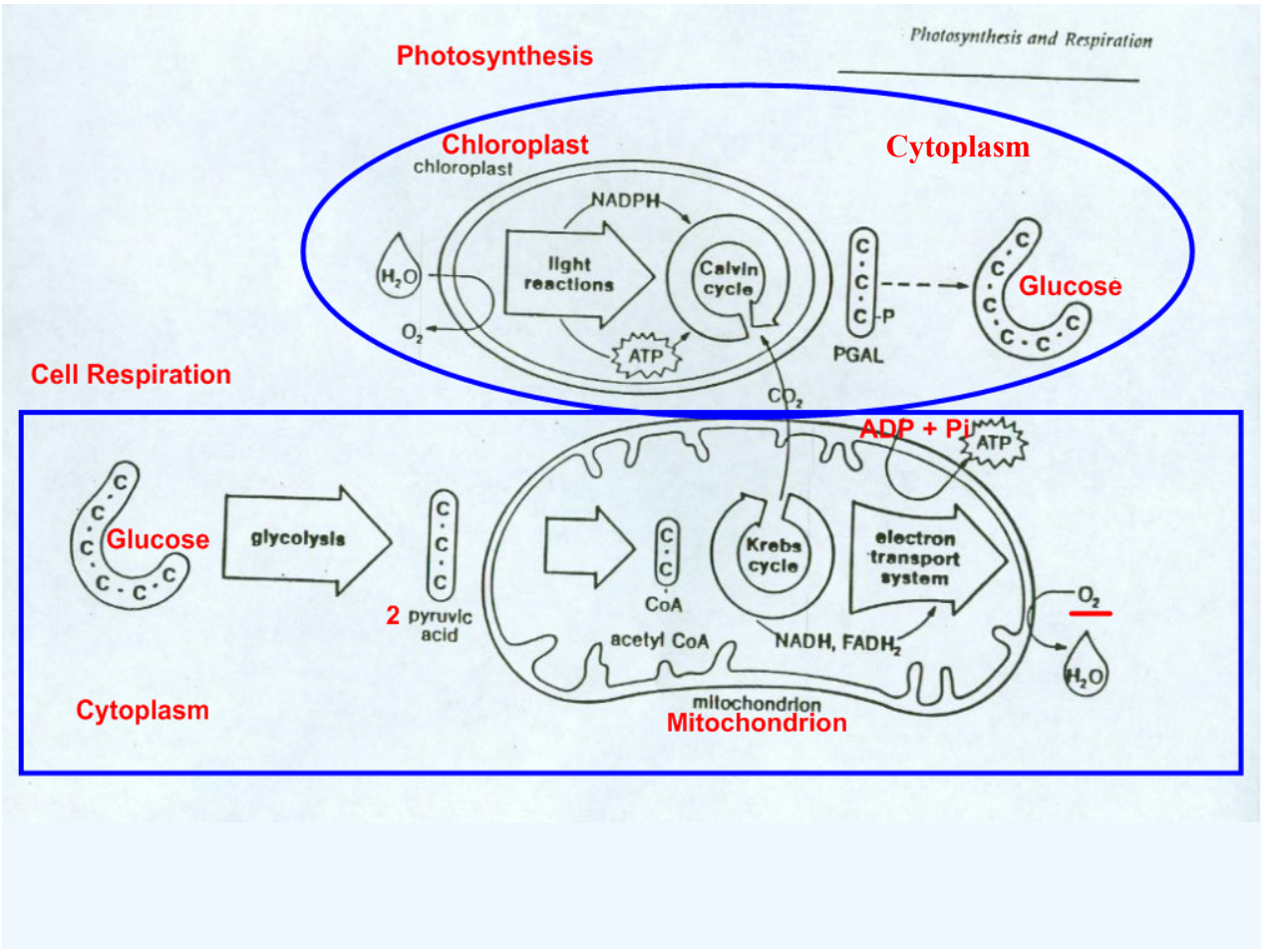
E. 3 turns of the cycle yields 6 PGAL.
5 of 6 PGAL are required to regenerate RuBP and one is available for use by the plant.

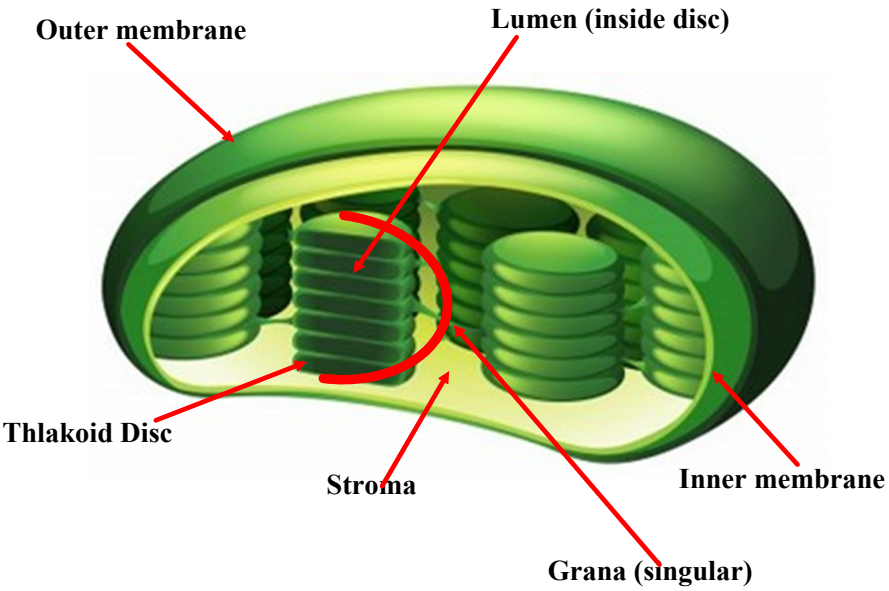
An enzyme, **(PreAP only)** ***Rubisco*** (ribulose biphosphate carboxylase), catalyzes the reaction that fixes ***CO_2*** into the cycle, ***"carbon fixation"***

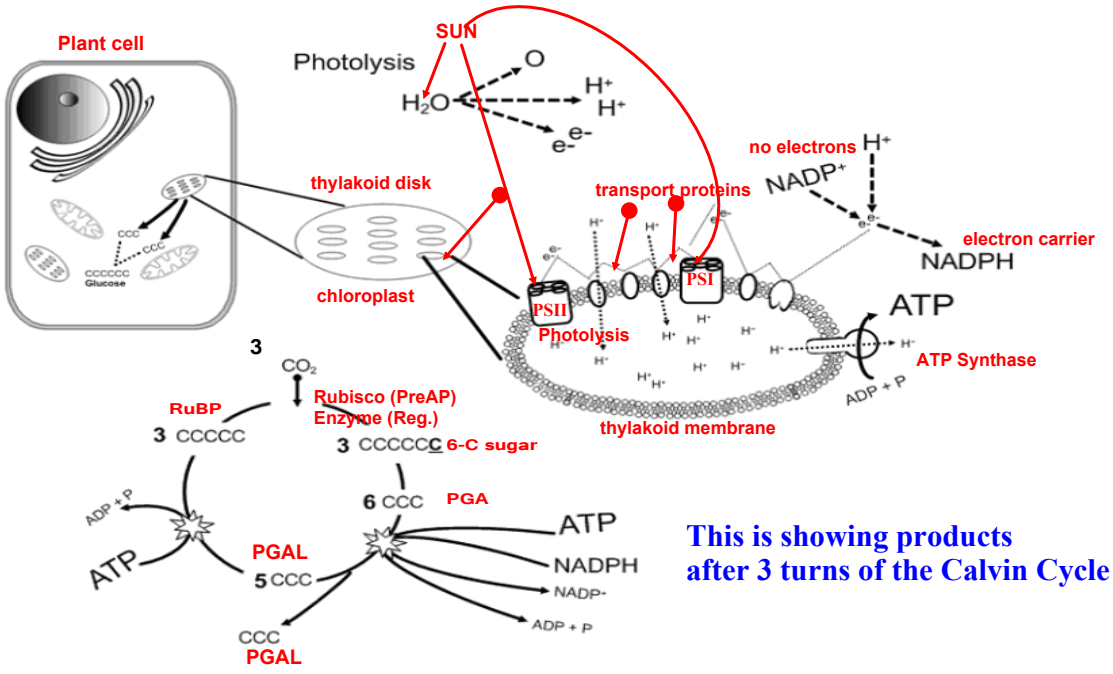


Mark out "F"


Calvin
Carbo
Lipids
Protein
A
B
C
D
STARCH
CELLULOSE
GLUCOSE
GLYCEROL
LIPIDS
FATTY ACIDS
PROTEINS
ADP + Pi
ATP
RuBP
2
CO2
1
Rubisco
(enzyme)
3
2-3C PGA
ADP + Pi
ATP
4
2- 3C
PGAL
NADPH2
NADP + H2
ACETYL
COENZYME A
AMINO ACIDS


Photosynthesis and Respiration
Photosynthesis
Chloroplast
chloroplast
Cytoplasm
NADPH
light
reactions
Calvin
cycle
H2O
O2
ATP
PGAL
P
Glucose
Cell Respiration
CO2
ADP + Pi
ATP
Glucose
glycolysis
2 pyruvic
acid
CoA
acetyl CoA
Krebs
cycle
electron
transport
system
NADH, FADH2
O2
H2O
Cytoplasm
mitochondrion
Mitochondrion





This is showing products after 3 turns of the Calvin Cycle