Photosynthesis

Life in the Sun

- Light is central to the life of a plant
- Photosynthesis is the most important chemical process on Earth
  - It provides food for virtually all organisms
- Plant cells convert light into chemical signals that affect a plant's life cycle

Energy Storage and Transformation

2 Types of processes

Photosynthesis- solar energy is converted to chemical bond energy within carbohydrates

Cellular respiration- carbohydrates are converted into useable forms of energy such as ATP, which provides energy for various different systems. E.g. synthesis of chemicals, active transport, and contraction of muscle fibers

Life on Earth is solar powered

On a global scale the productivity of photosynthesis is astounding

Photosynthesis produces 160 billion metric tons of carbohydrates each year

Overview of photosynthesis and respiration

SUN

RADIANT ENERGY

PHOTOSYNTHESIS

RESPIRATION

CELL ACTIVITIES

GLUCOSE

ATP(ENERGY)

Terms

1st law of thermodynamics

Energy cannot be created or destroyed, but energy can change forms. The amount of energy within a closed system remains constant.

2nd law of thermodynamics

All conversions of energy produce some heat, which is not useful energy. The amount of energy that is unavailable for work is referred to as entropy.

I. Photosynthesis Stores Energy as Carbohydrate.

A. Light energy is stored in plants when photosynthesis converts inorganic compounds to organic.

B. Glucose is the organic storage form of chemical energy. (Savings!)

C. The energy from glucose is converted into ATP in cell respiration. (Cash!)

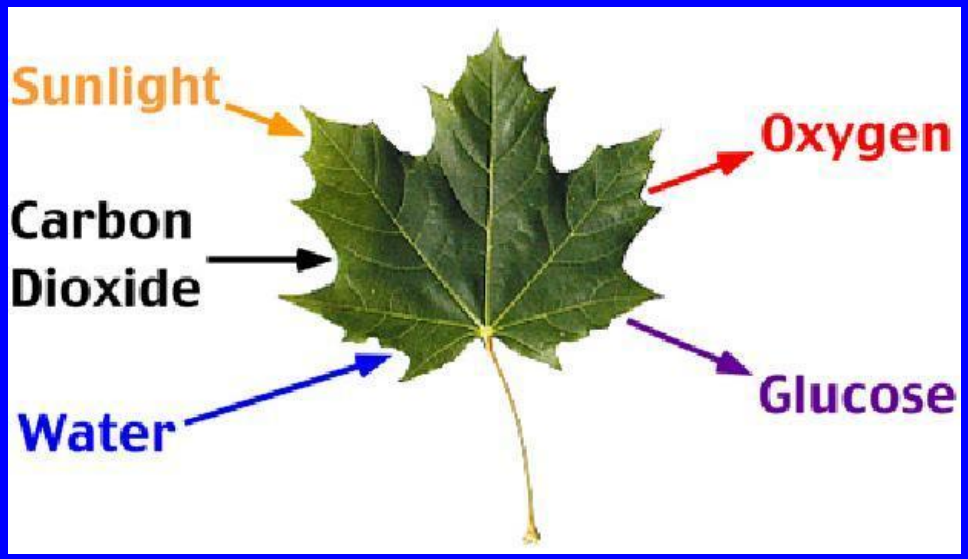
D. Photosynthesis produces glucose.

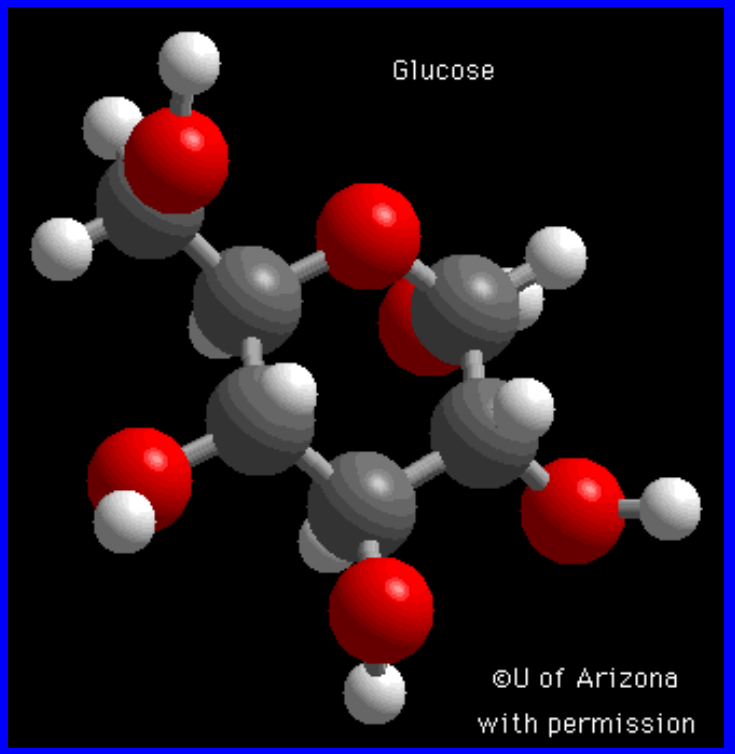
E. The equation for photosynthesis is:

Light

$12\ H_2O + 6\ C0_2 \qquad C_6H_{12}0_6 + 6\ H_2O + 6\ O_2$

$C_6H_{12}O_6$ = sugar





- Stomata, open and closed
- Site of gas exchange O_2, H_2O and CO_2

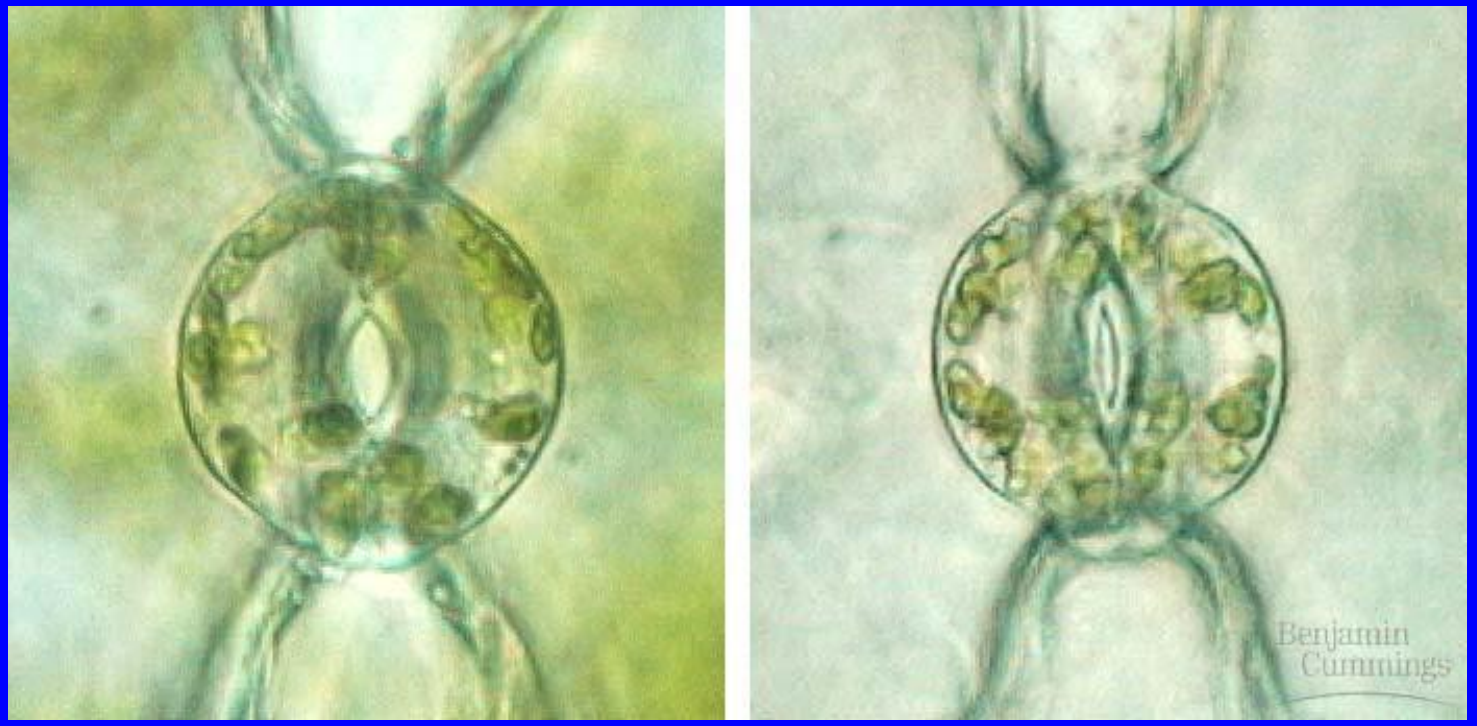


Figure 7.2x2

This reaction occurs inside of plants, and specifically within the leaves. When light reaches the surface of a green leaf one of three things can happen to the light:

- Reflected back off of the leaf
- Transmitted right through the leaf
- Absorbed by the leaf, by chlorophyll which is found in the chloroplasts

- The full range of radiation is called the electro-magnetic spectrum

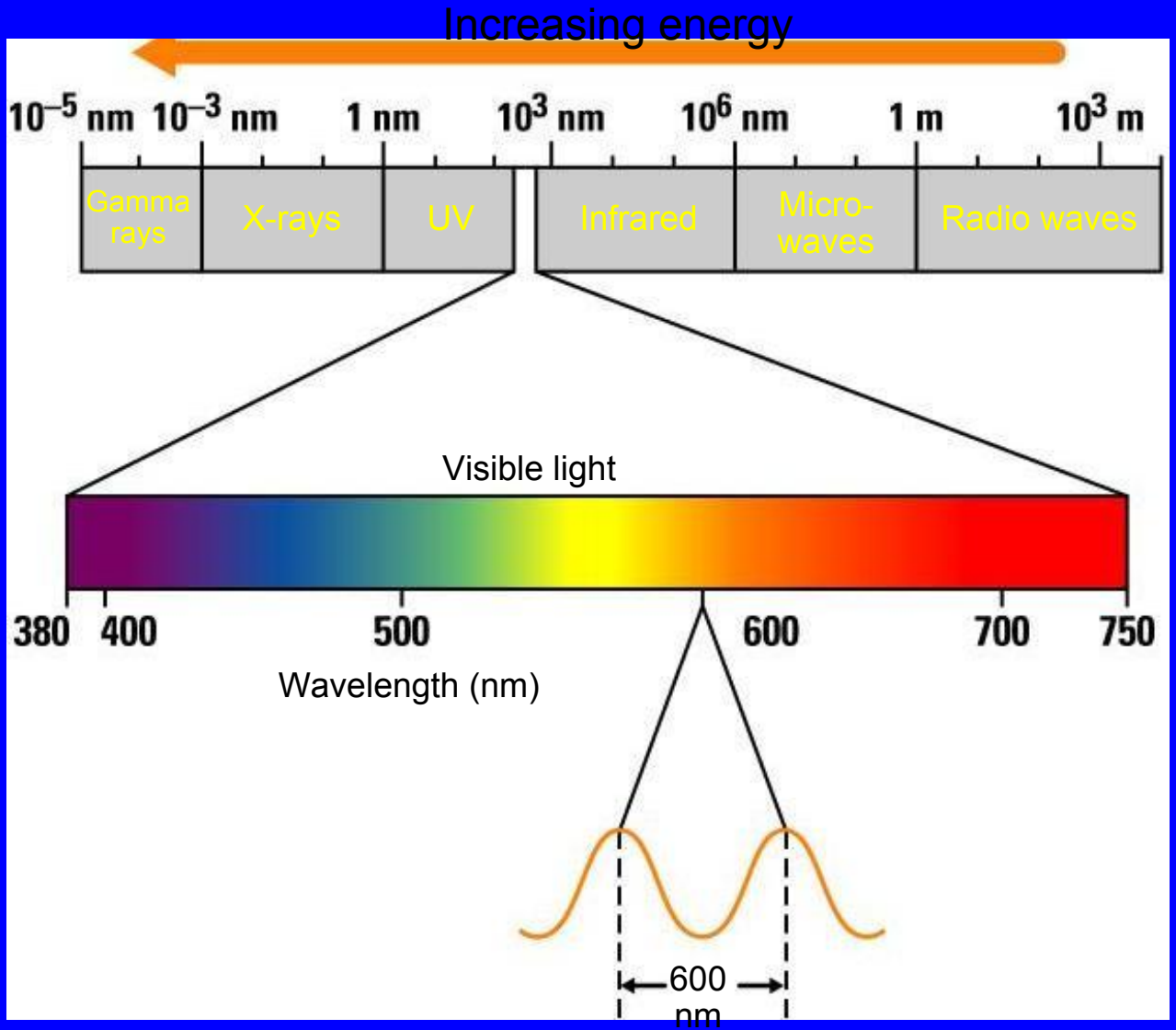


Figure 7.5

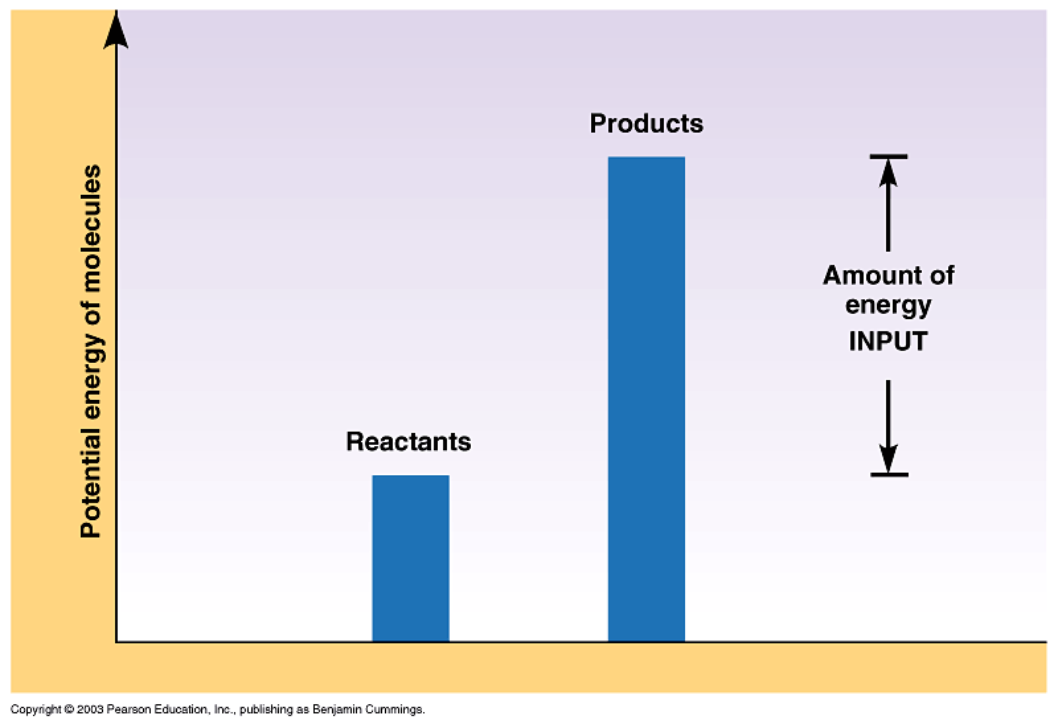
The color of a pigment is determined by the wavelengths of light that are reflected. There are at least 6 different types of chlorophyll found in photosynthetic plants with chlorophyll a and b being most common and present in most green land plants. These 2 chlorophylls absorb light chiefly of the violet, blue, orange, and red wavelengths.

•In the fall, chlorophyll breaks down due to a lack of soil nitrogen. This makes the accessory pigments visible.

Terms to Know

Endergonic Reactions

- Requires energy
- Products have more energy



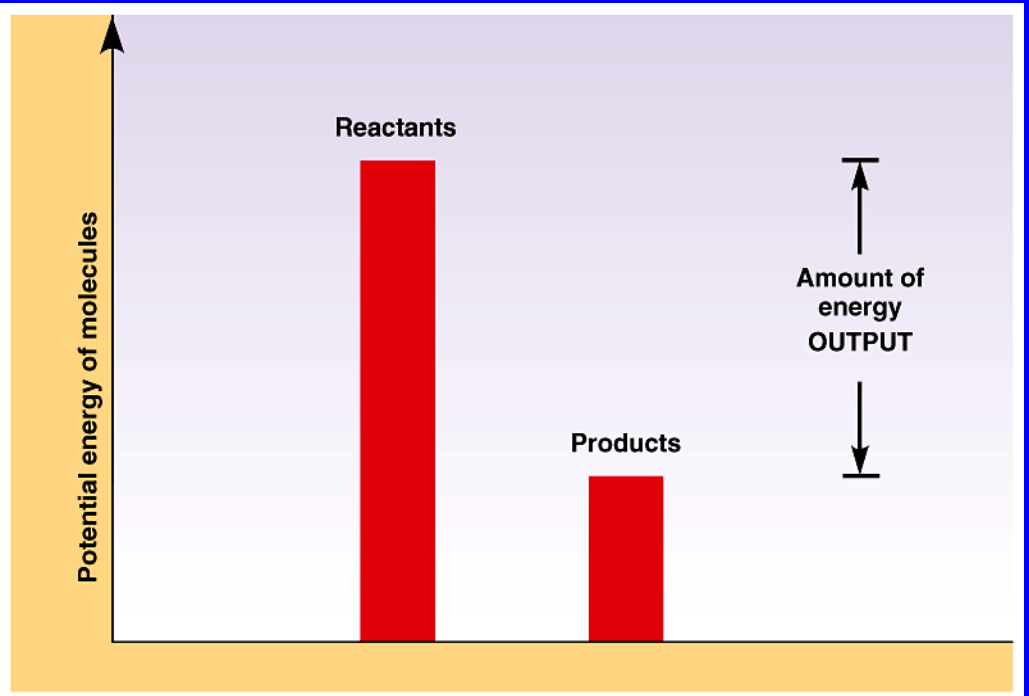
Exergonic Reactions

Releases energy

- Products have less energy
- Ex. Burning

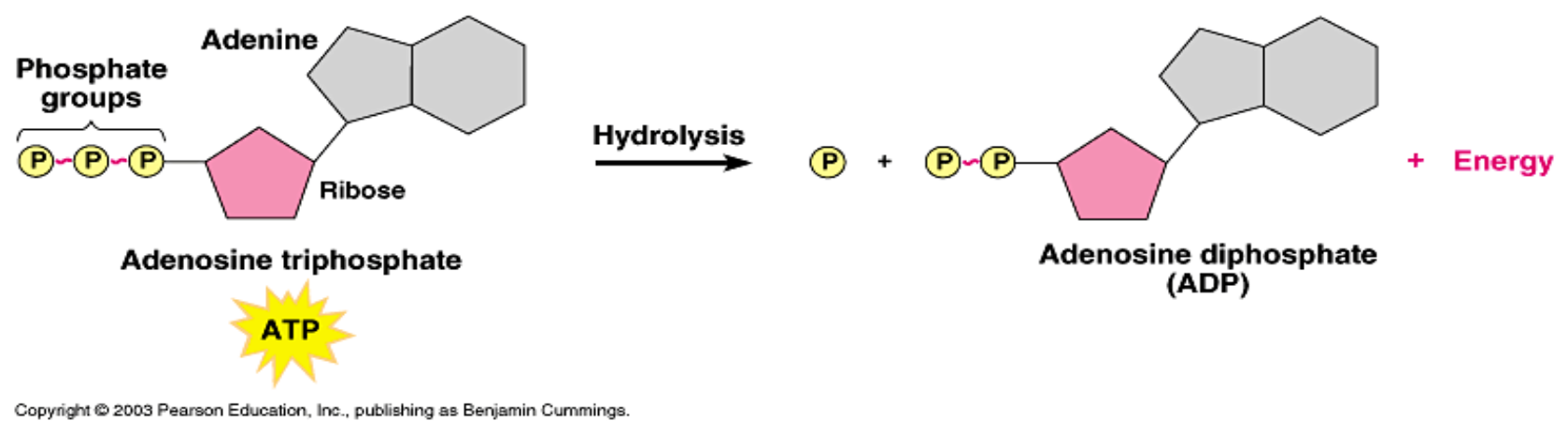
Cellular metabolism

- All reactions in a cell



Terms to know:

ATP (adenosine triphosphate) is a useable form of chemical energy. ATP is a five-carbon sugar (ribose), a nitrogen base (adenine), and 3 phosphate molecules.



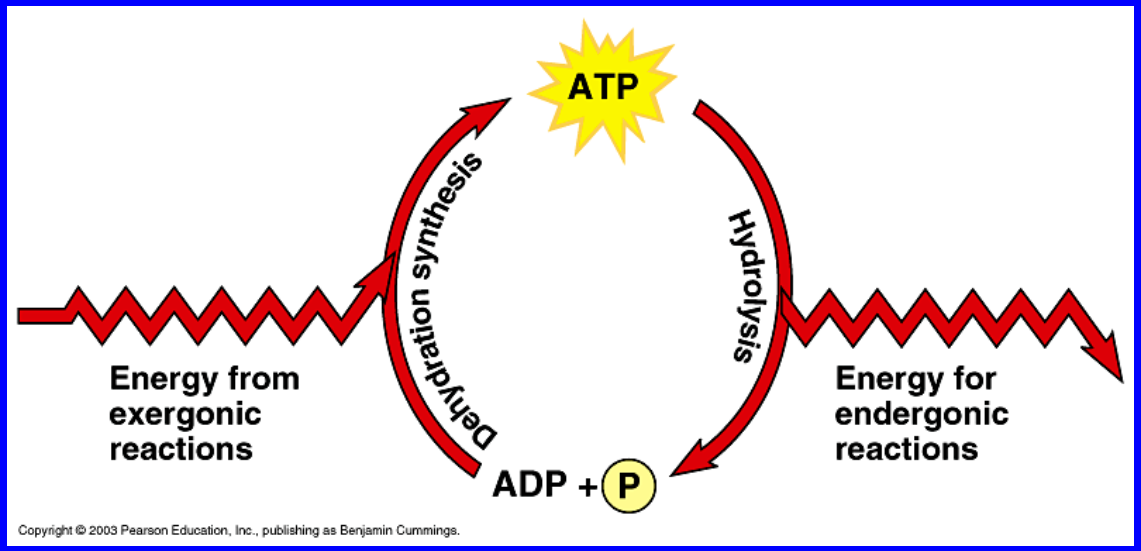
Can be thought of as a gold coin that cells use to pay for work.

When energy is required for cell functions special enzymes extract a phosphate molecule to produce ADP (adenosine diphosphate) and energy.

ATP $\xrightarrow{\quad}$ ADP + P + energy

Which can be reduced even further to AMP (adenosine monophosphate) and energy. However, the bond energy is not as great, so you don't get as good of a bang for your buck.

- ATP cycle
  - Release of third phosphate from ATP
    - Makes energy available to do work
    - ATP becomes ADP (diphosphate)
  - When energy released from food can add phosphate to ADP making ATP



The supply of ATP must be constantly replenished by phosphorylation (the addition of phosphate molecules). This energy production in cells takes place within the electron transport system.

Some elements are strong electron donors and tend to lose their electrons to other elements to become stable. Other elements want to accept these extra electrons to become stable.

The transfer of electrons from one element to another produces more stable ions or compounds and releases energy, which is used to make ATP.

II. Oxidation Reduction Reactions

A. Electrons can carry energy with them when they are transferred to a new compound.

B. When a molecule loses an electron it is oxidized. (OIL)

C. When a molecule gains an electron it is reduced. (RIG)

D. Photosynthesis is where electrons carry energy from sunlight into sugars by reduction.

Photosynthesis

H_2O + CO_2

Energy

Which splits water

ATP and NADP H_2

Light is Adsorbed By Chlorophyll

Calvin Cycle

ADP NADP

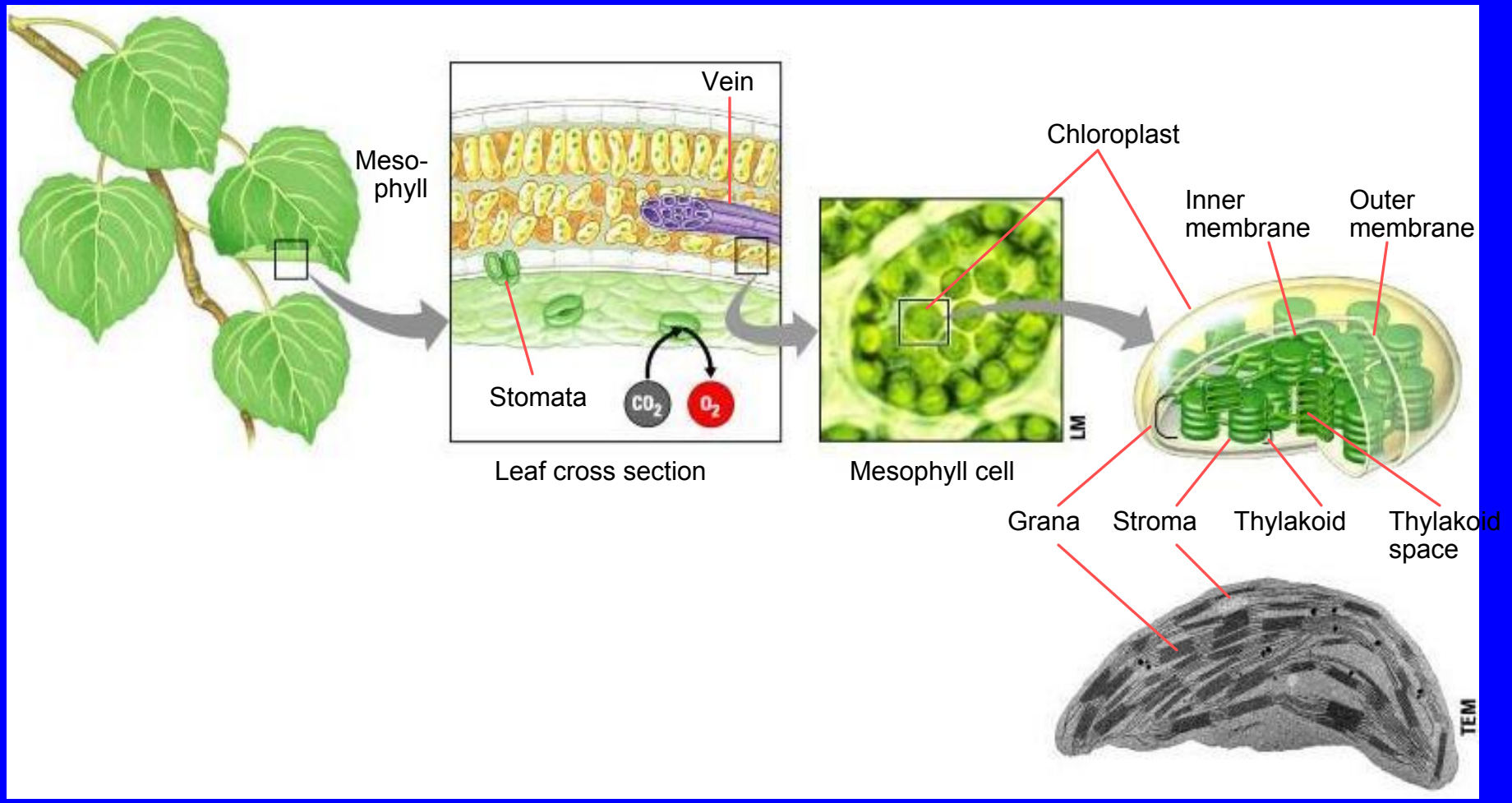
Chloroplast

Used Energy and is recycled.

O_2 + $C_6H_{12}O_6$

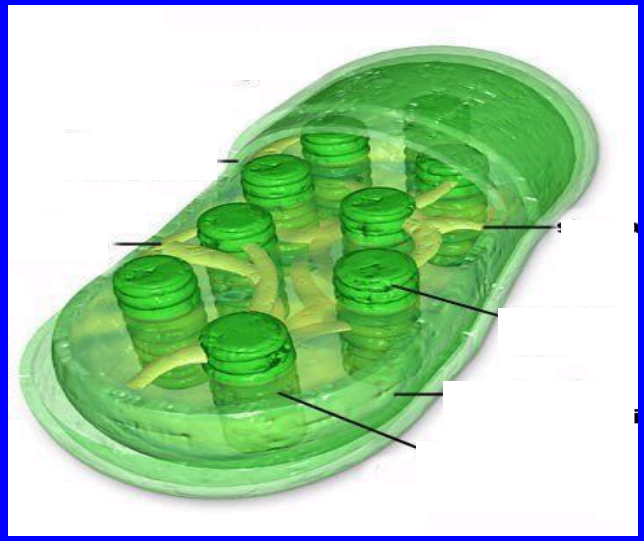
Light Reaction

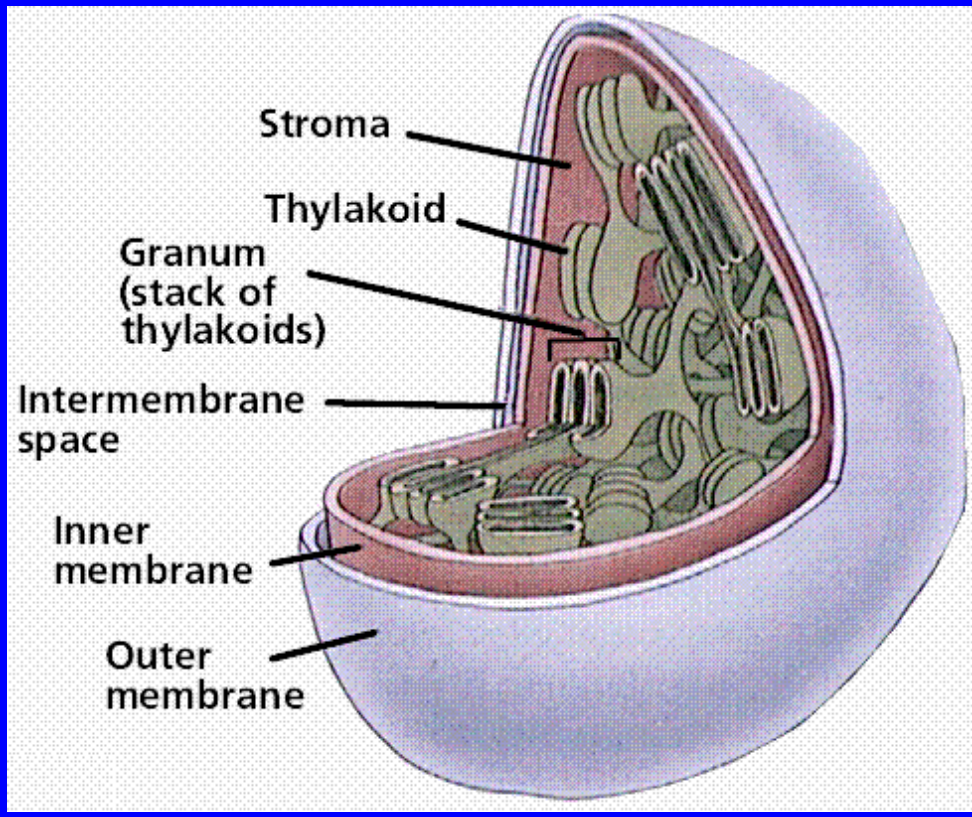
Dark Reaction


Meso-
phyll
Vein
Stomata
CO_2
O_2
Leaf cross section
Chloroplast
Inner
membrane
Outer
membrane
LM
Mesophyll cell
Grana
Stroma
Thylakoid
Thylakoid
space
TEM

Photosynthesis occurs in the chloroplast.

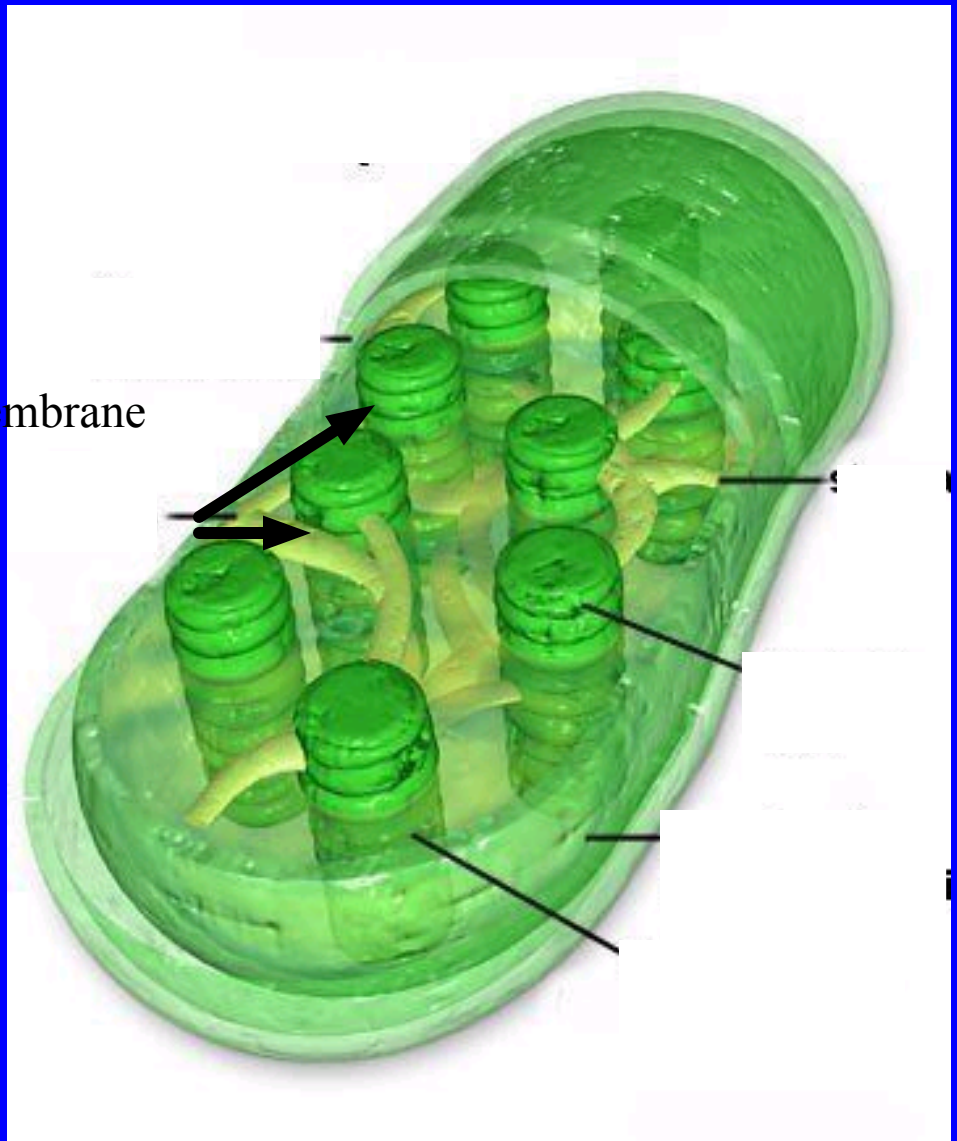
Chloroplasts contain many granum, which are composed of many thylakoids stacked on top of each other like pancakes. The space surrounding the granum is known as the stroma. Light Reactions occur in the grana and Dark Reactions take place in the stroma of chloroplasts. Light is captured by chlorophyll, which is the pigment that makes plants green.



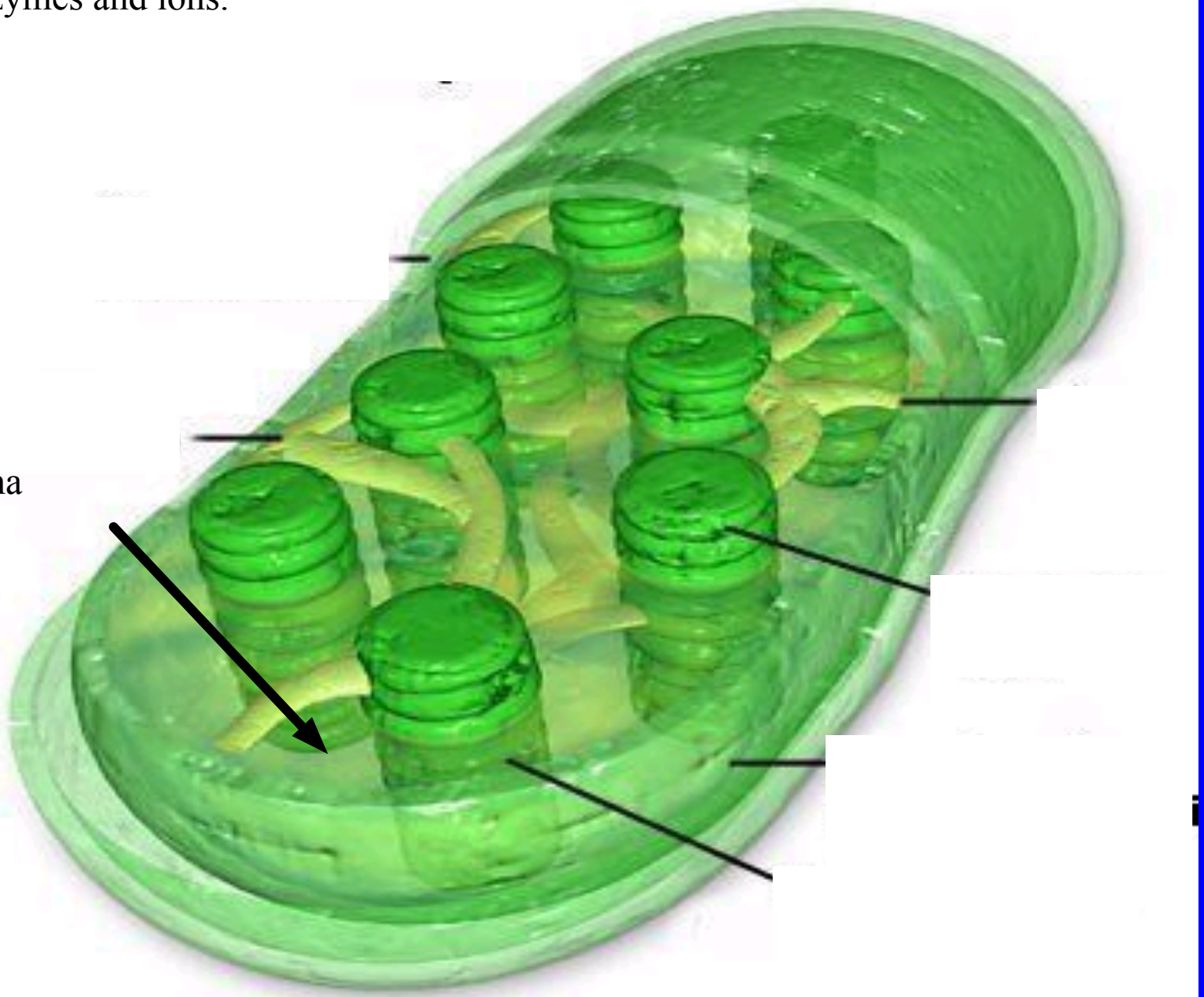


a. The chloroplast has a double outer membrane.

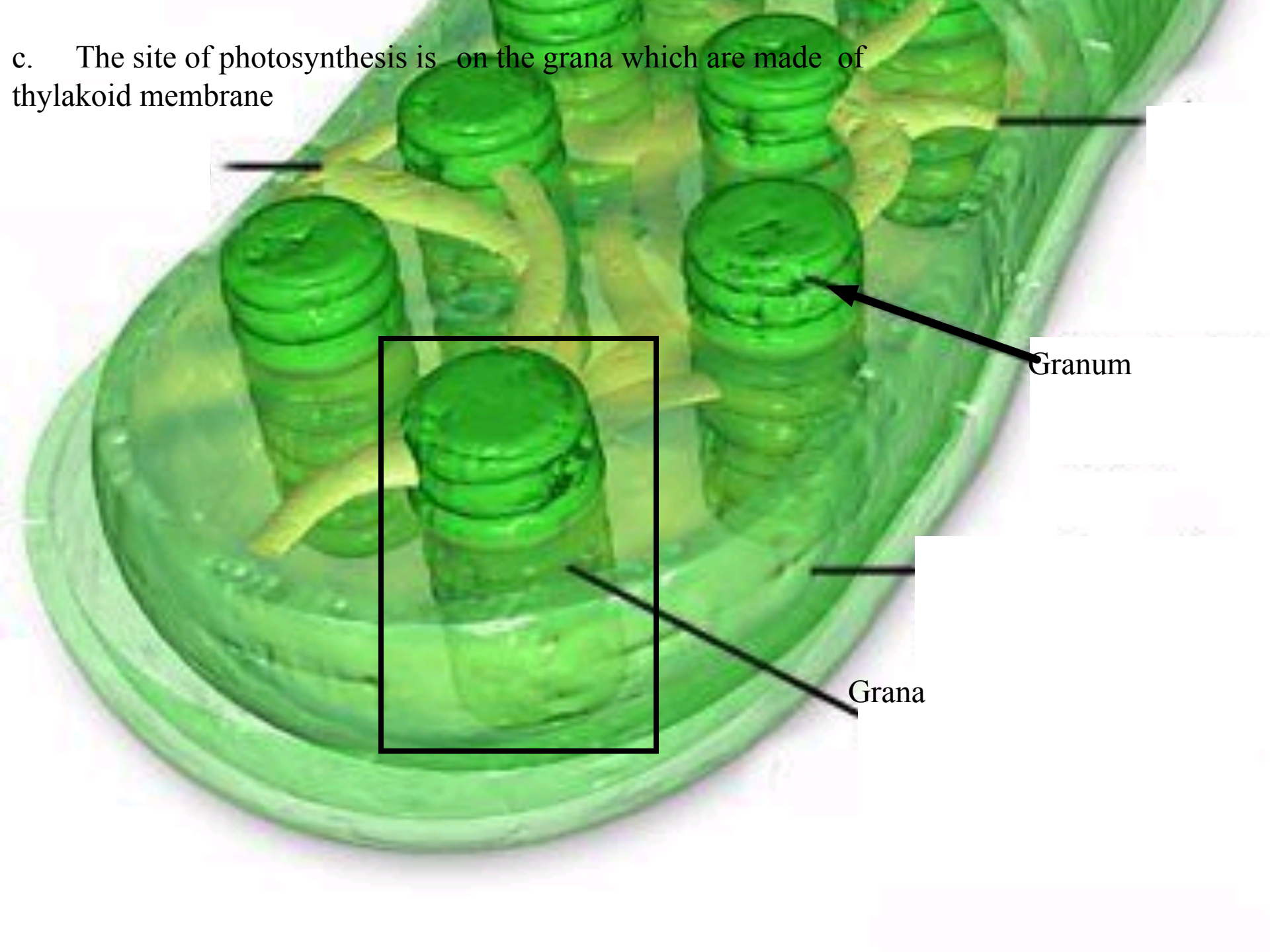
Double Membrane



b. The chloroplast is filled with stroma which is a fluid that contains enzymes and ions.



c. The site of photosynthesis is on the grana which are made of thylakoid membrane

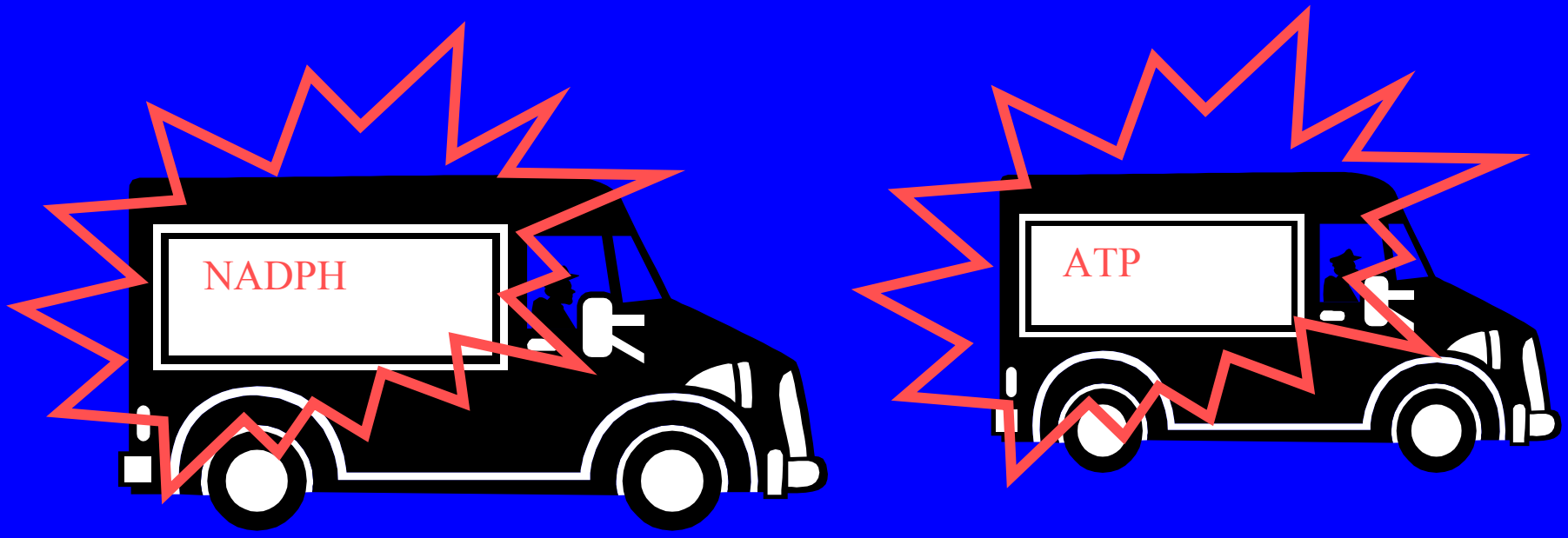


In simplified terms, photosynthesis occurs when CO_2 (carbon dioxide) is absorbed into the air spaces of a leaf primarily through diffusion. This CO_2 combines with H_2O (water) in the presence of light energy to produce a sugar molecule (glucose), water, and free oxygen.

Production of the glucose ($C_6H_{12}O_6$) molecule happens in two reactions.

The photosynthesis reaction can be seen as being as light dependent and light independent reactions.

A. Light Dependent Reaction - light energy is harnessed to make high energy carrier molecules ATP and NADPH.



a. Photosystem II (Light Reaction)

Light energy is absorbed by chlorophyll and then

Part of the energy splits water into 2 Hydrogen (H^+) and an Oxygen (O_2) (photolysis). Oxygen is released from the plant and Hydrogen becomes attached to a carrier molecule called $NADP^+$ (nicotinamide adenine dinucleotide phosphate, a strong electron acceptor), which is reduced to form NADPH and carried to the dark reaction.

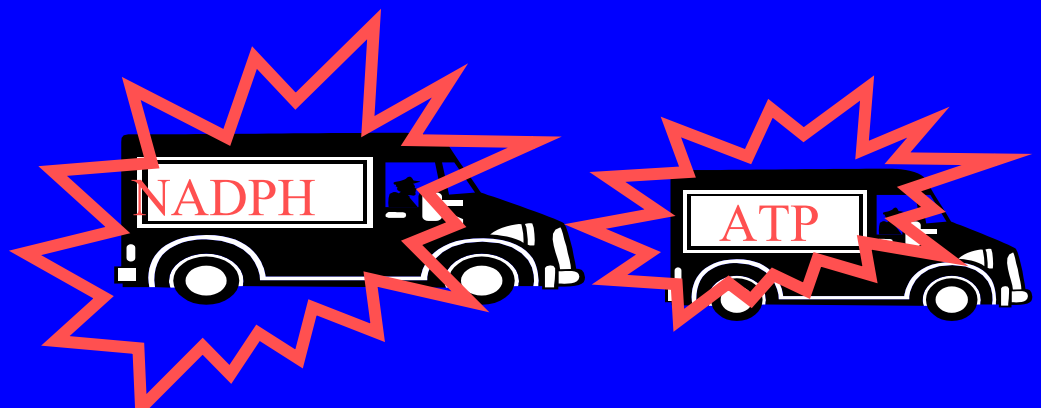
The other part of the energy is used to form a bond between ADP and phosphate to produce ATP.

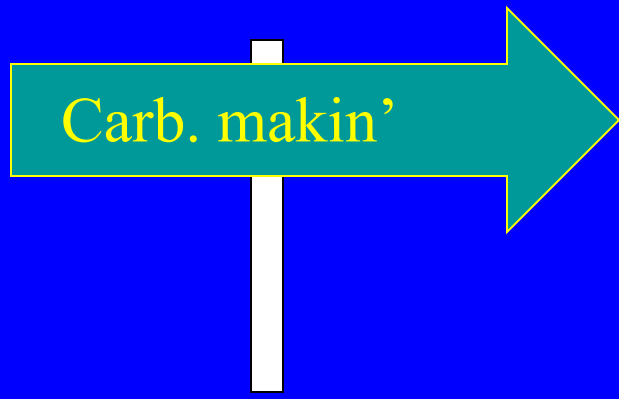
ATP is needed in the dark (light independent) reaction for its available energy and NADPH is needed for its reducing power and hydrogen.

$$ADP + P + NADP^{+} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} ATP + NADPH + H^{+}$$

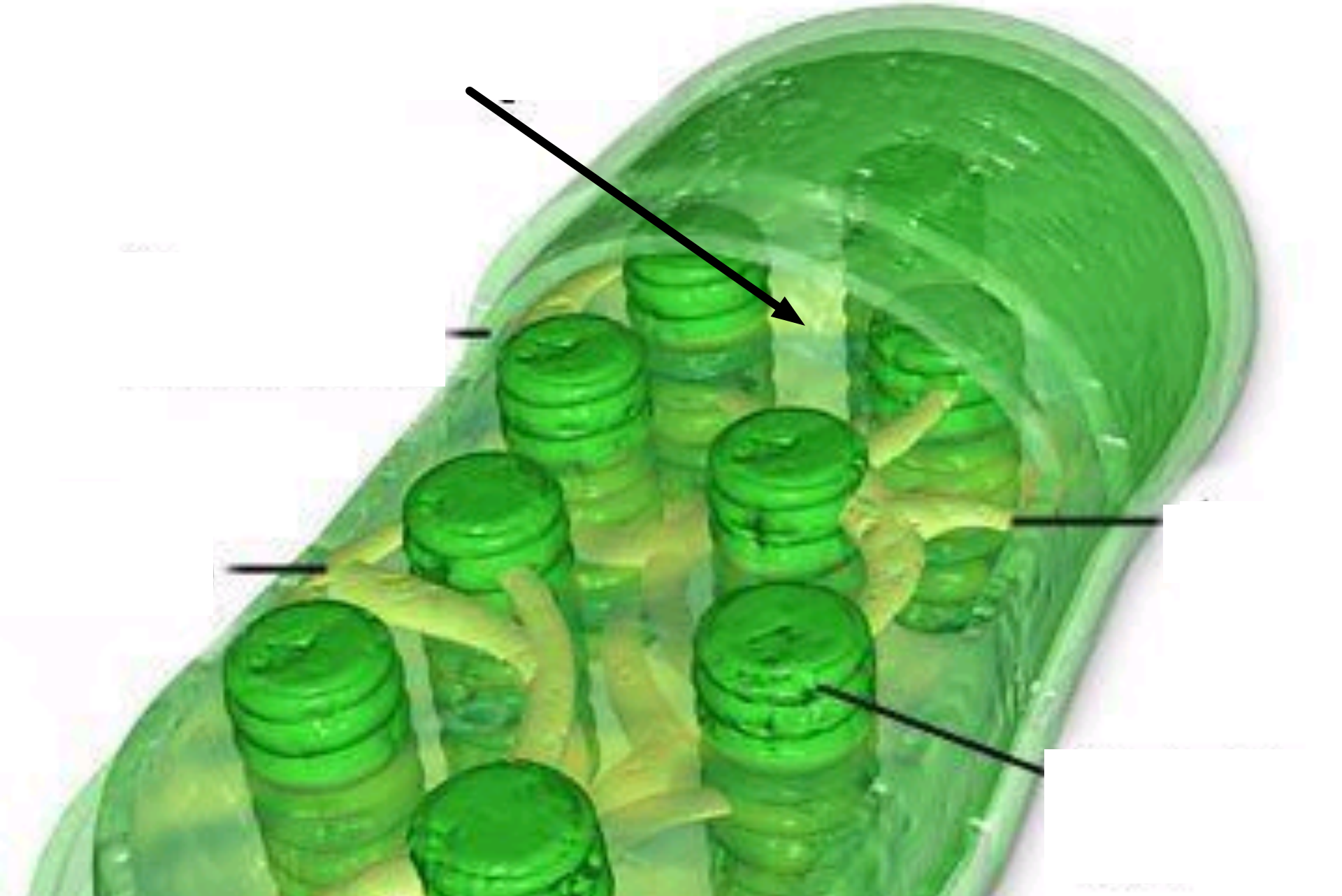
Photosystem 1 (Dark Reaction) (aka The Calvin Benson Cycle)

1. Energy rich ATP and NADPH are used as energy sources to build carbohydrate.
2. During the Calvin Cycle, CO_2 from the atmosphere will be "fixed" (made solid) to form carb.





3. The reactions of the Calvin Cycle occur in the stroma.



Energy supplied by breakdown of ATP

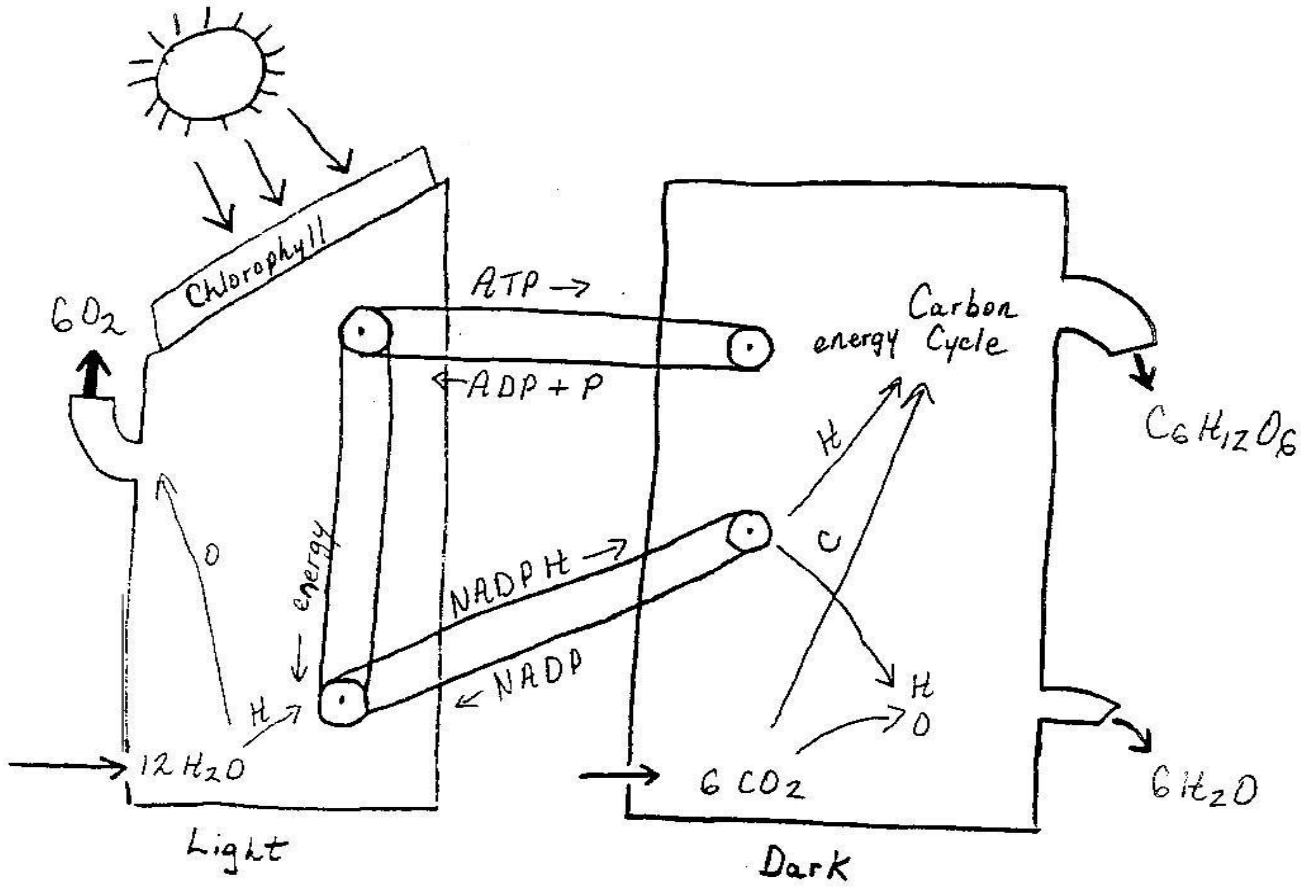
1. CO_2 taken up and rearranged in a succession of carbon compounds through the carbon cycle.

2. NADPH carrier molecules release hydrogen atoms.

a. 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen combine to form glucose

b. the six remaining O atoms and 12 remaining H atoms combine to form water which is released as a byproduct

Photosynthesis
Light/Dark Reactions



$$CO_2 + H_2O + ATP + NADPH + H^+ \longrightarrow C_6H_{12}O_6 + ADP + NADP^+ + O_2 + H_2O$$

The Details

a. 6 CO_2 from the air are combined with 6 molecules of RuBP (RuBP = Ribulose biphosphate = a five carbon sugar).
   i. An enzyme called "Rubisco" makes this possible.

b. The result is a 6 carbon intermediate molecule which is unstable.

c. The 6 intermediates split into 12 molecules called PGA. Each is 3 carbons long.

Trivia: PGA = phosphoglycerate

d. The energy from 12 ATP and 12 $NADPH_2$ are added to form 12 PGAL.

i. PGAL are energy rich

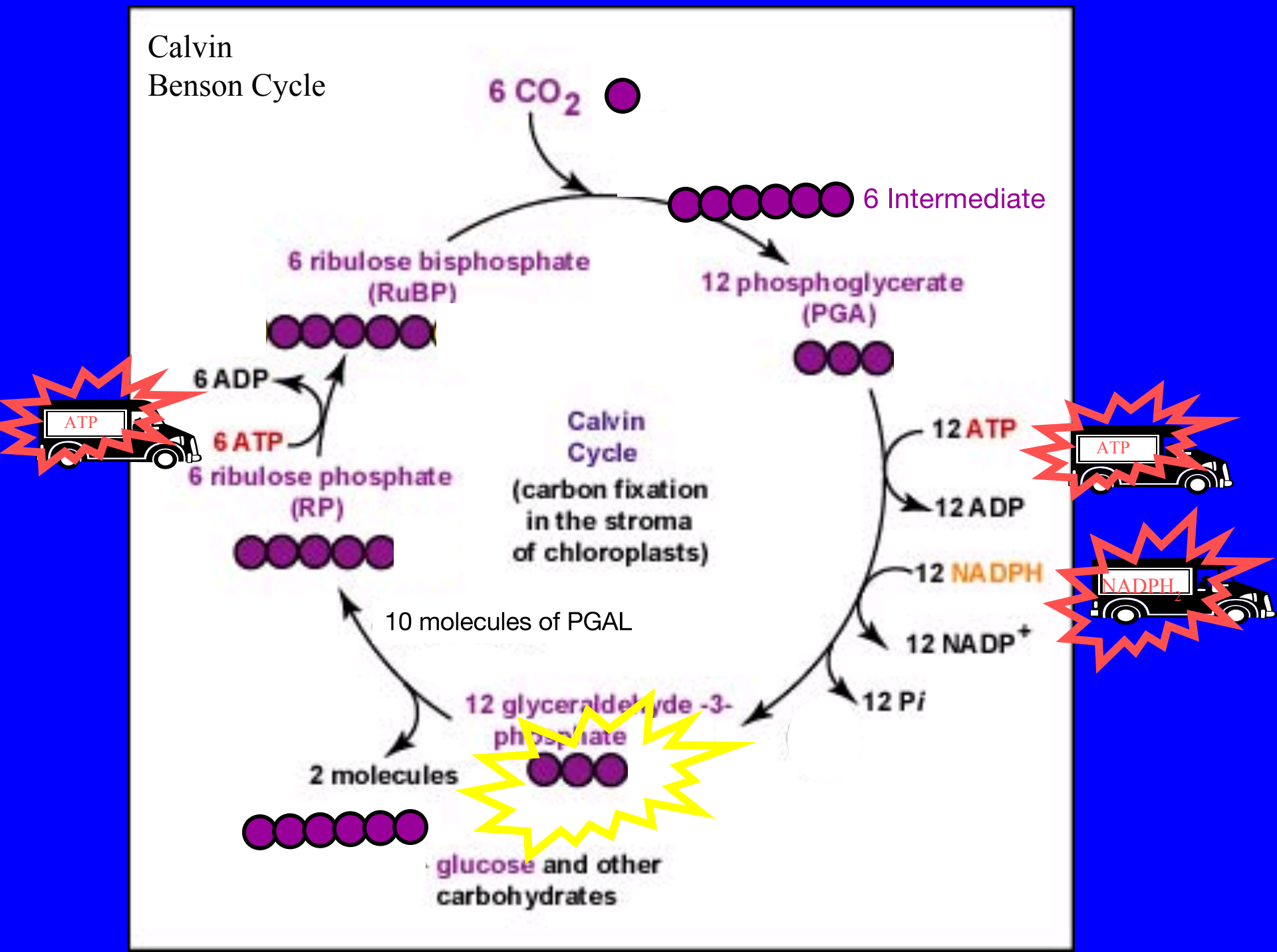
ii. PGAL = Think of L for "Light energy!"

e. Two PGAL combine to form one glucose molecule.

f. The 10 leftover PGAL are rearranged to form 6 RuBP using 6 ATP molecules as energy

g. Repeat.

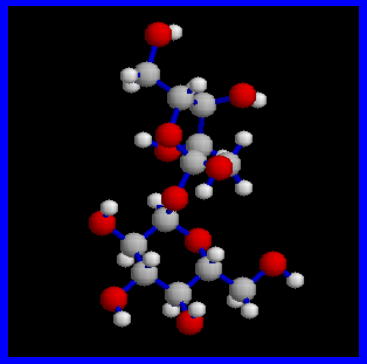
Calvin
Benson Cycle



IV. The Metabolic Fates of Glucose

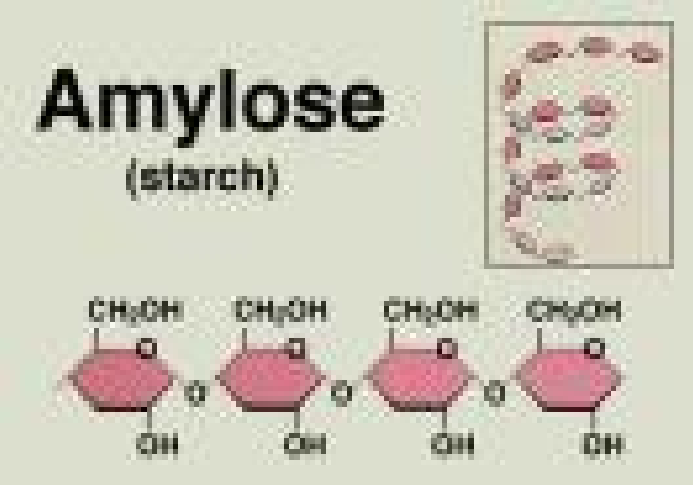
A. Once glucose is formed it may be:

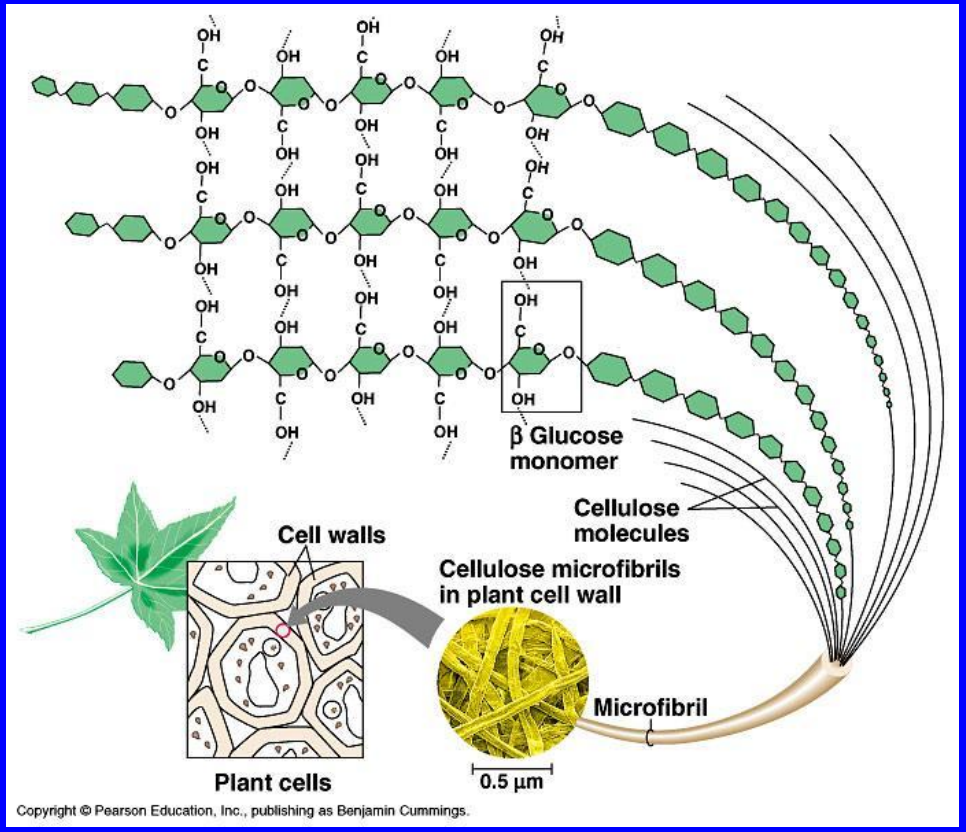
1. Stored as pure glucose.



2. Combined with another sugar to form a disaccharide. eg malto

3. Combined with many sugars to form a polysaccharide.
   a. Amylose (starch)
   b. Cellulose (wood)





4. Oxidized (burned) to form ATP