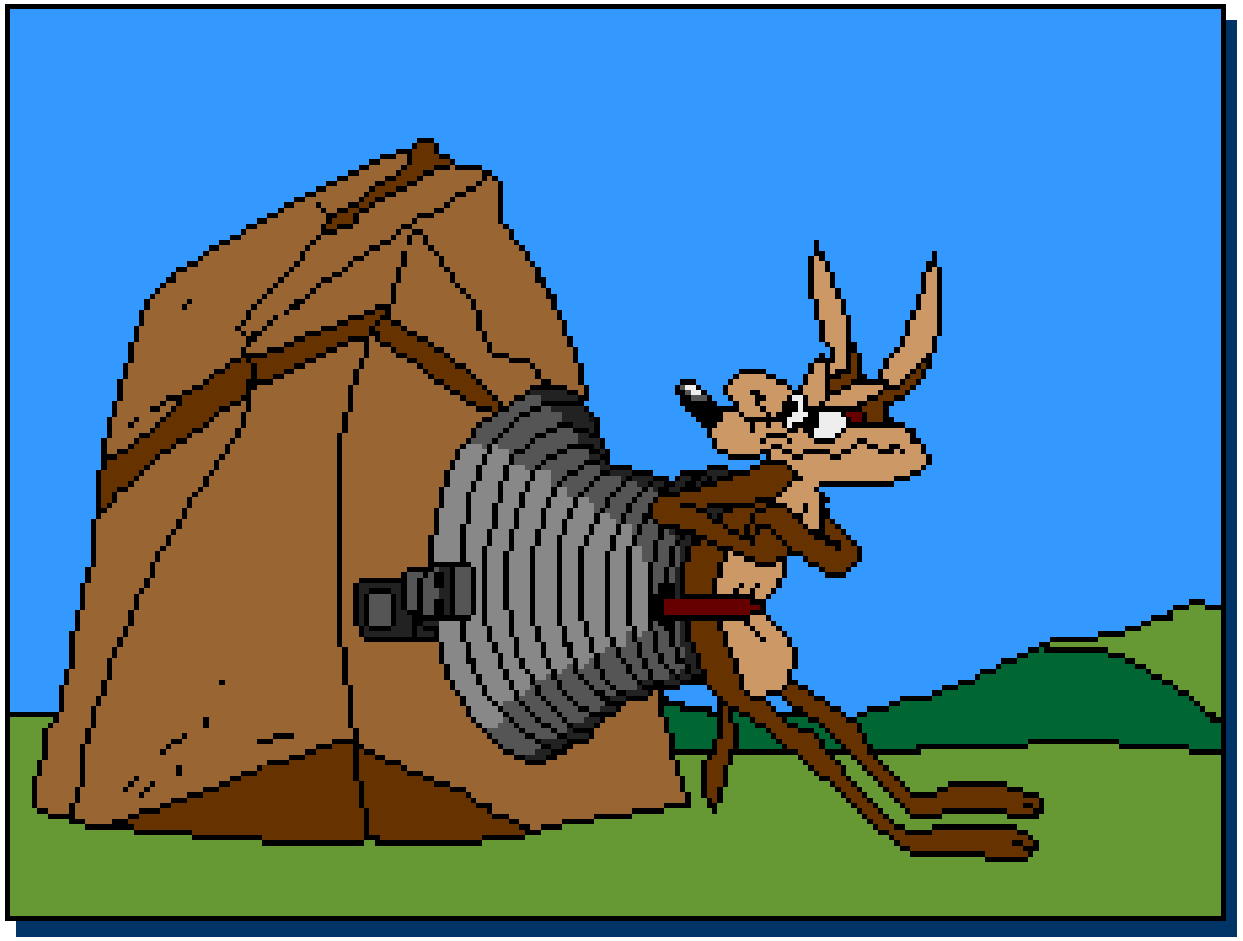
Energy in a Cell
Chapter 9

ATP, Photosynthesis, Respiration

ATP – Energy Currency of the Cell

ATP
Adenosine triphosphate



Potential Energy – held in phosphate bonds in ATP

Potential Energy in Green Plants (The coiled spring is ATP)

Cell Energy

- Essential to life
- **All living organisms must be able to:**
- Produce energy (or obtain it) from the environment
- Store energy
- Use energy in a controlled manner

- Sun – ultimate source of all our energy
- Photosynthesis - process by which plants store energy from the sun
- ATP – energy storage units
- Respiration – process by which organisms use energy in a controlled manner

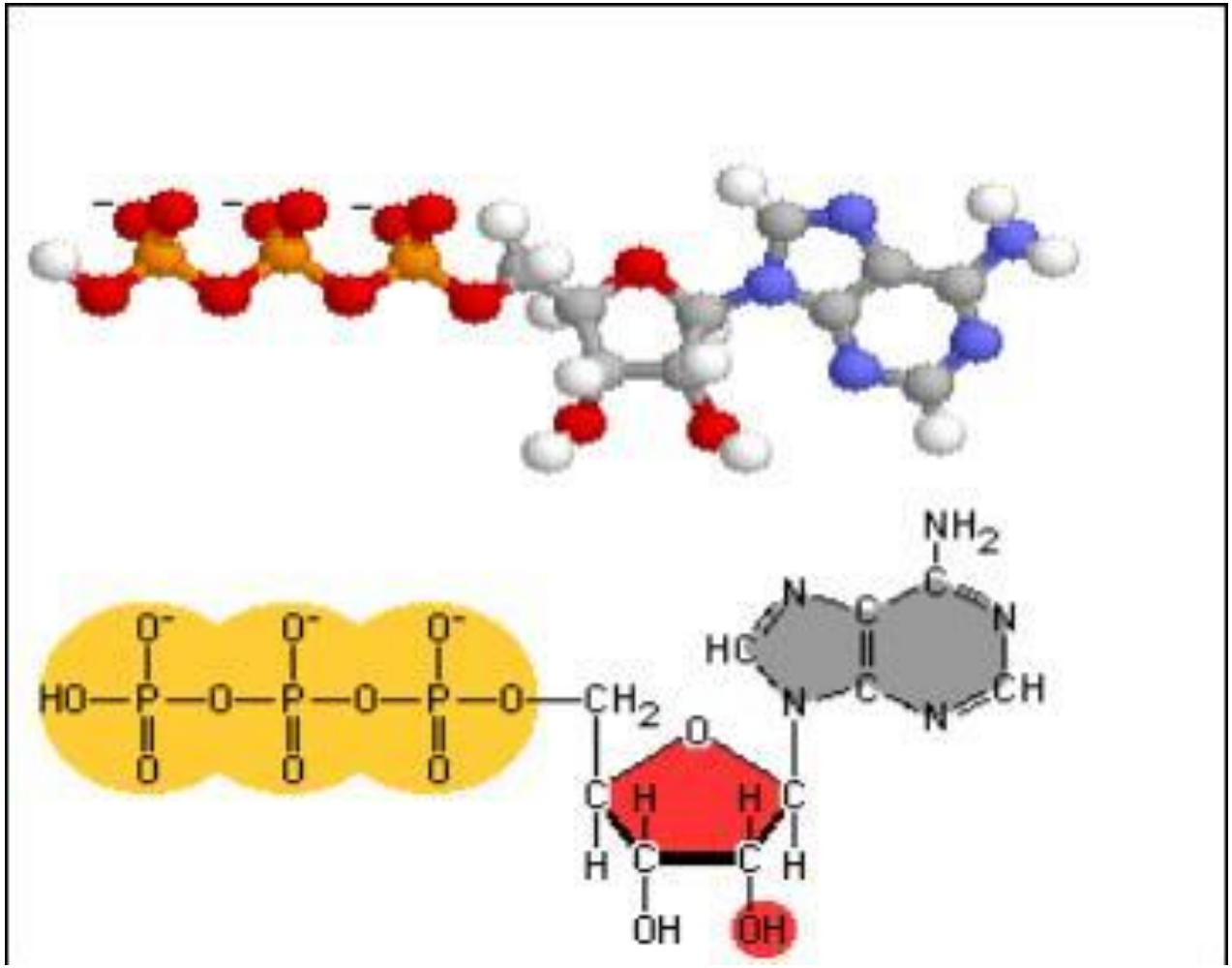
Fire - Uncontrolled Release of Energy (lots of wasted energy)

Respiration – Controlled, Efficient

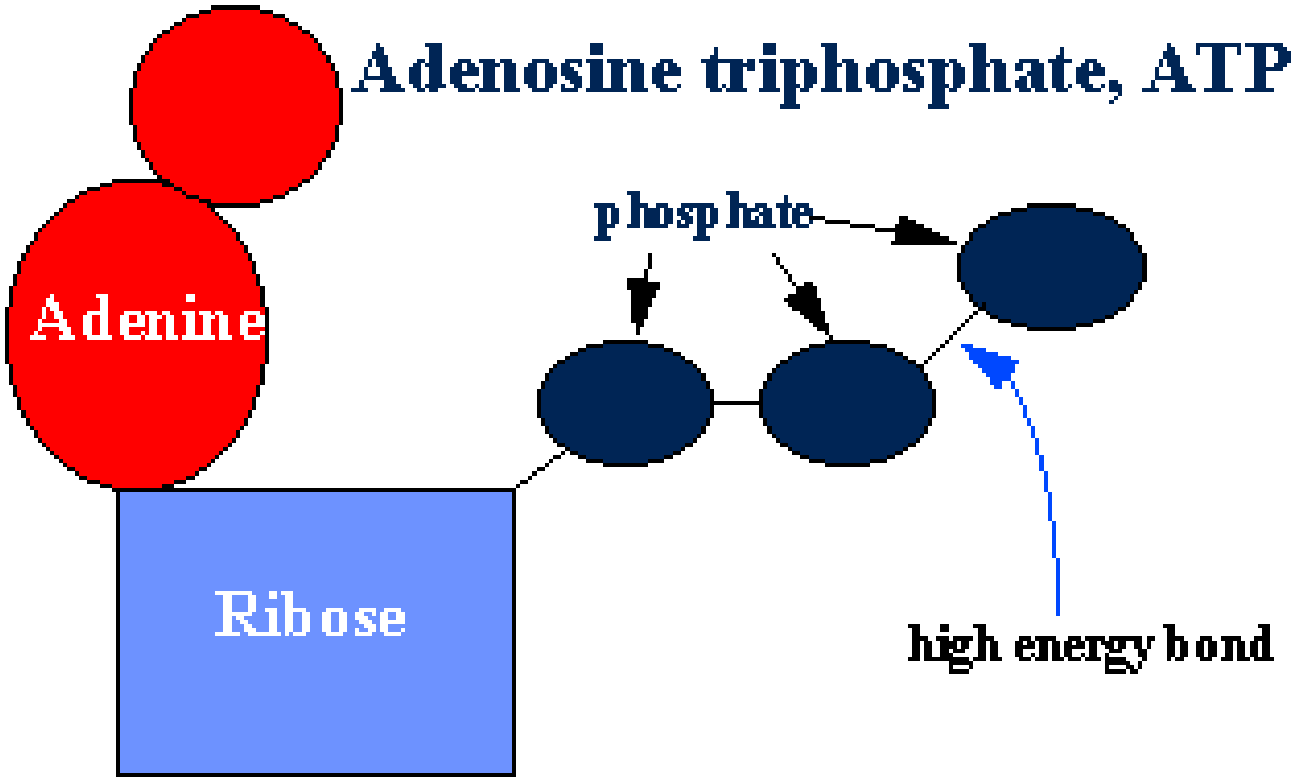
Cells need energy for

- Cell division
- Movement
- Production and storage of proteins/enzymes
- Transport of proteins
- Active transport
- Muscle contraction
- Heart pumping
- Thinking
- Elimination of wastes

ATP Molecule



ATP


Adenosine triphosphate, ATP
phosphate
Adenine
Ribose
high energy bond

- **AMP – adenosine monophosphate**

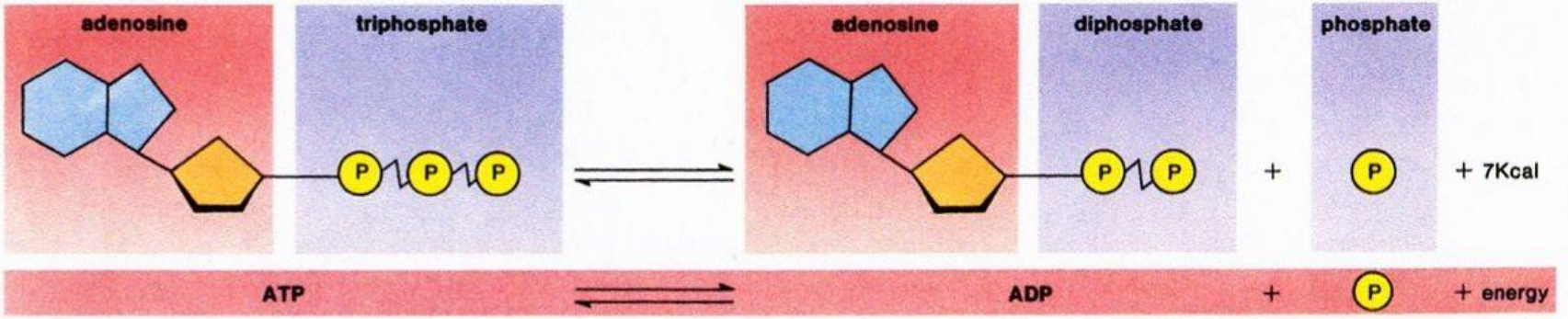
  1 phosphate group, less energy required to add one phosphate, less energy available
- **ADP – adenosine diphosphate**

  2 phosphate groups, more energy required to add 2nd phosphate, more energy available
- **ATP – adenosine triphosphate**

  3 phosphate groups, most energy required to add 3rd phosphate, most energy available

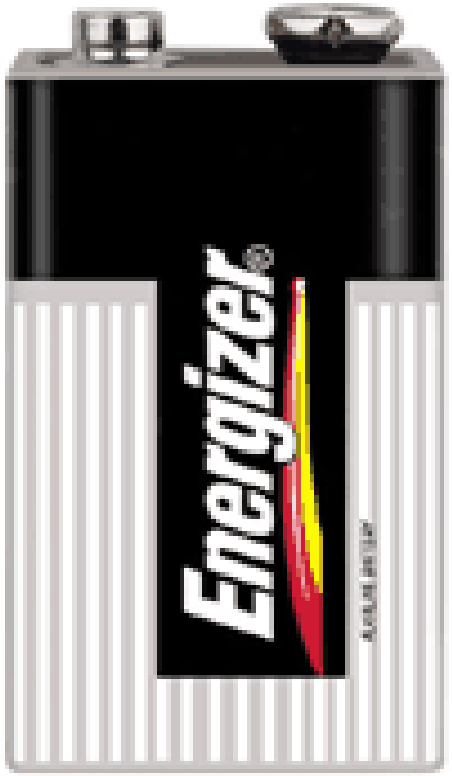
ATP Formation & Breakdown

- We get energy to move by breaking down ATP into ADP + P during respiration



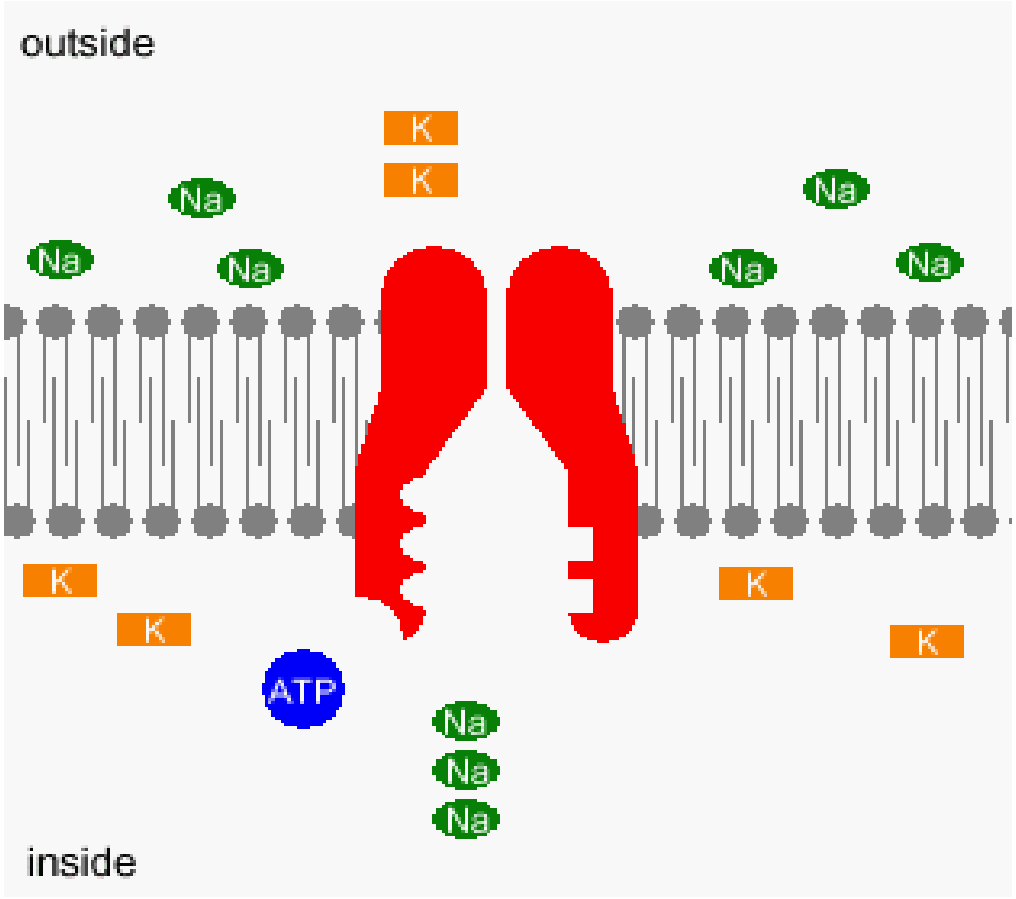
ATP Formation and Breakdown
Figure 7.11

A battery sitting on a table has potential energy but does no good unless it’s plugged in to something



Once the battery is plugged into the active site, something can work

Proteins have an active site where ATP gets “plugged in” so the protein can work



- ATP is like the fresh battery or the coiled spring
- ADP is like the used battery or uncoiled spring which must be taken out and recharged or smushed together again
- The energy is in the chemical bonds holding the phosphate groups together
- The energy is in the coiled spring

Photosynthesis

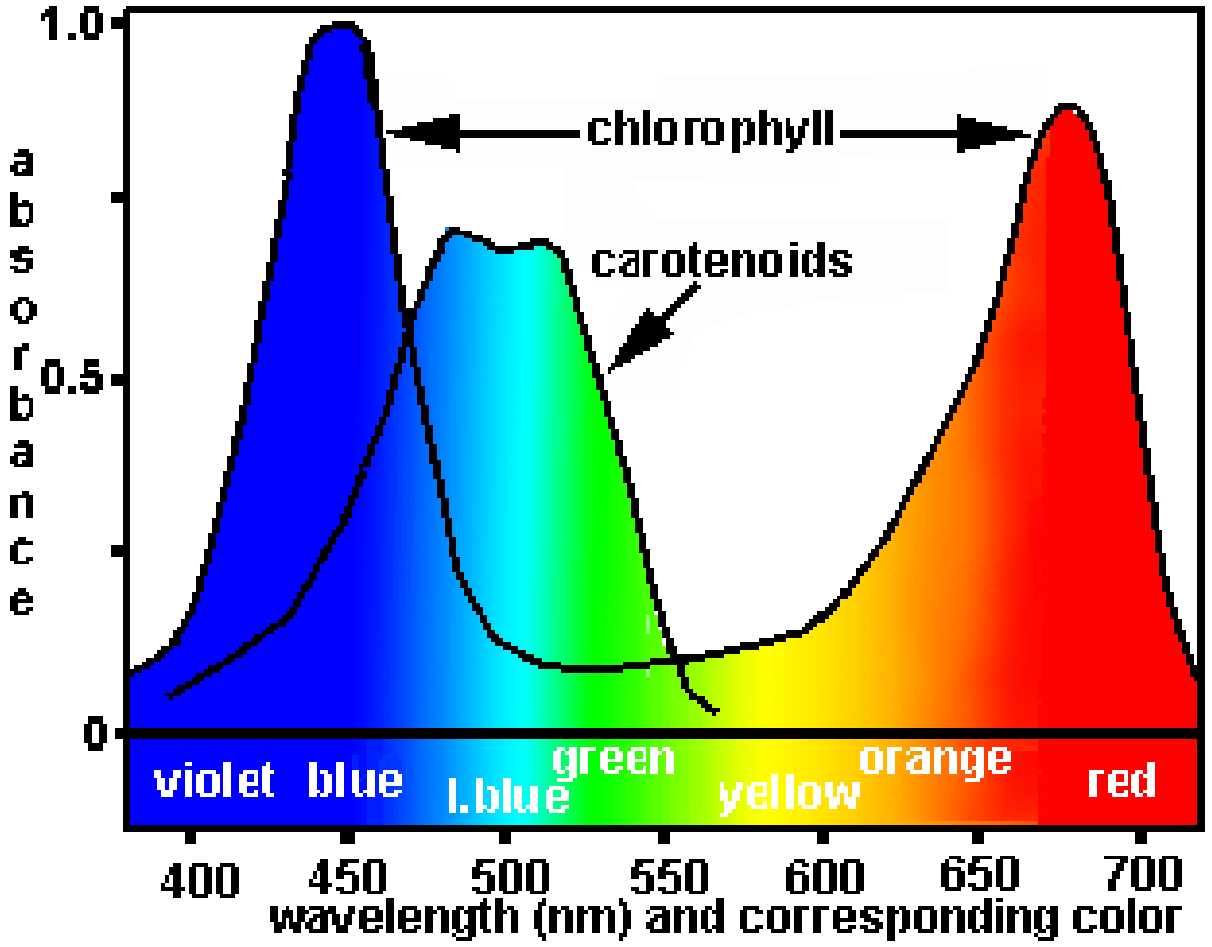
- Making the battery
- Building the spring
- Capturing the energy of the sun so that we can use it

Photosynthesis

- The process plants use to trap the sun's energy and build carbohydrates (glucose & starch) that store energy

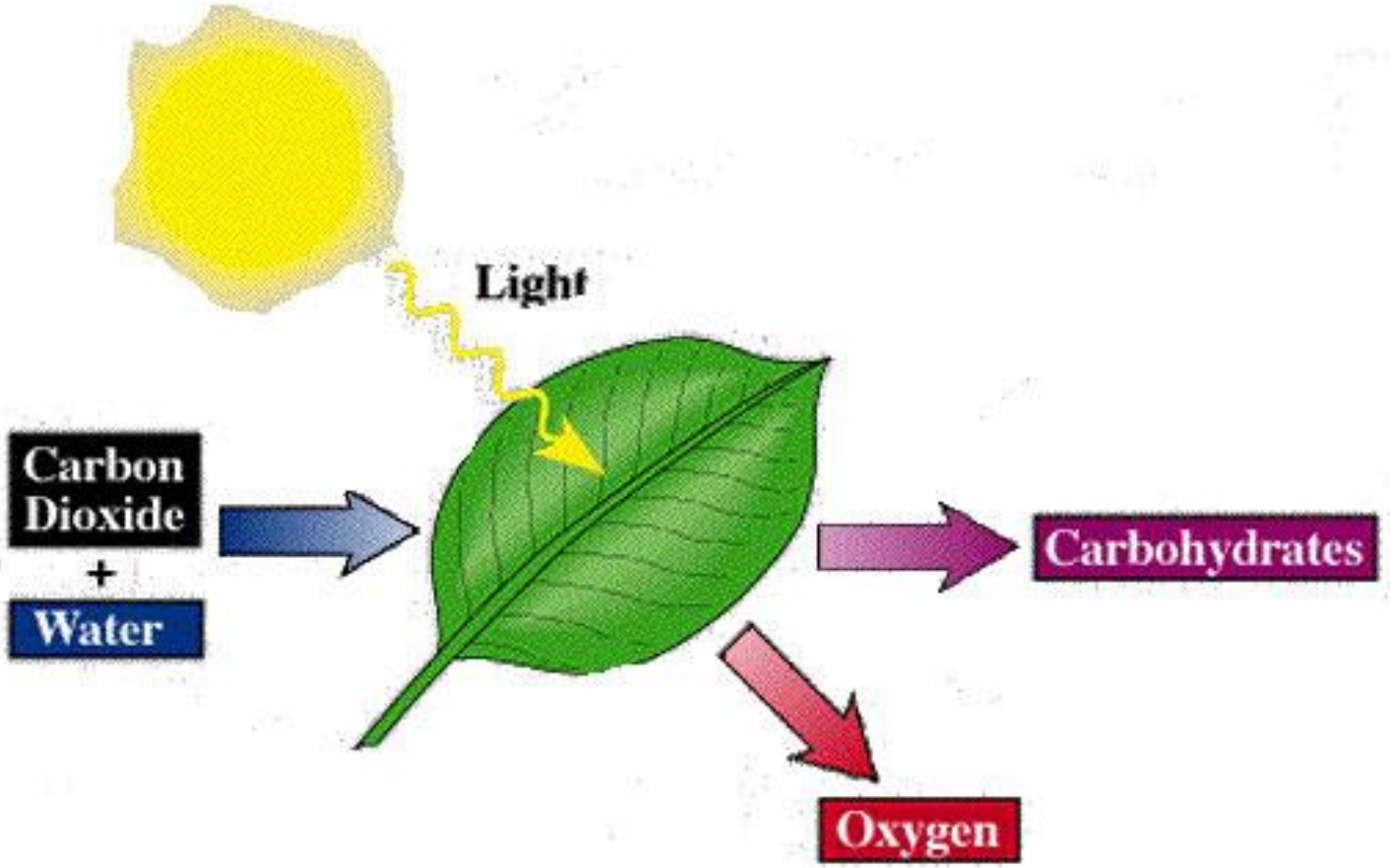
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Leaves - Chlorophyll absorbs blue and red light ...**Reflects Green**

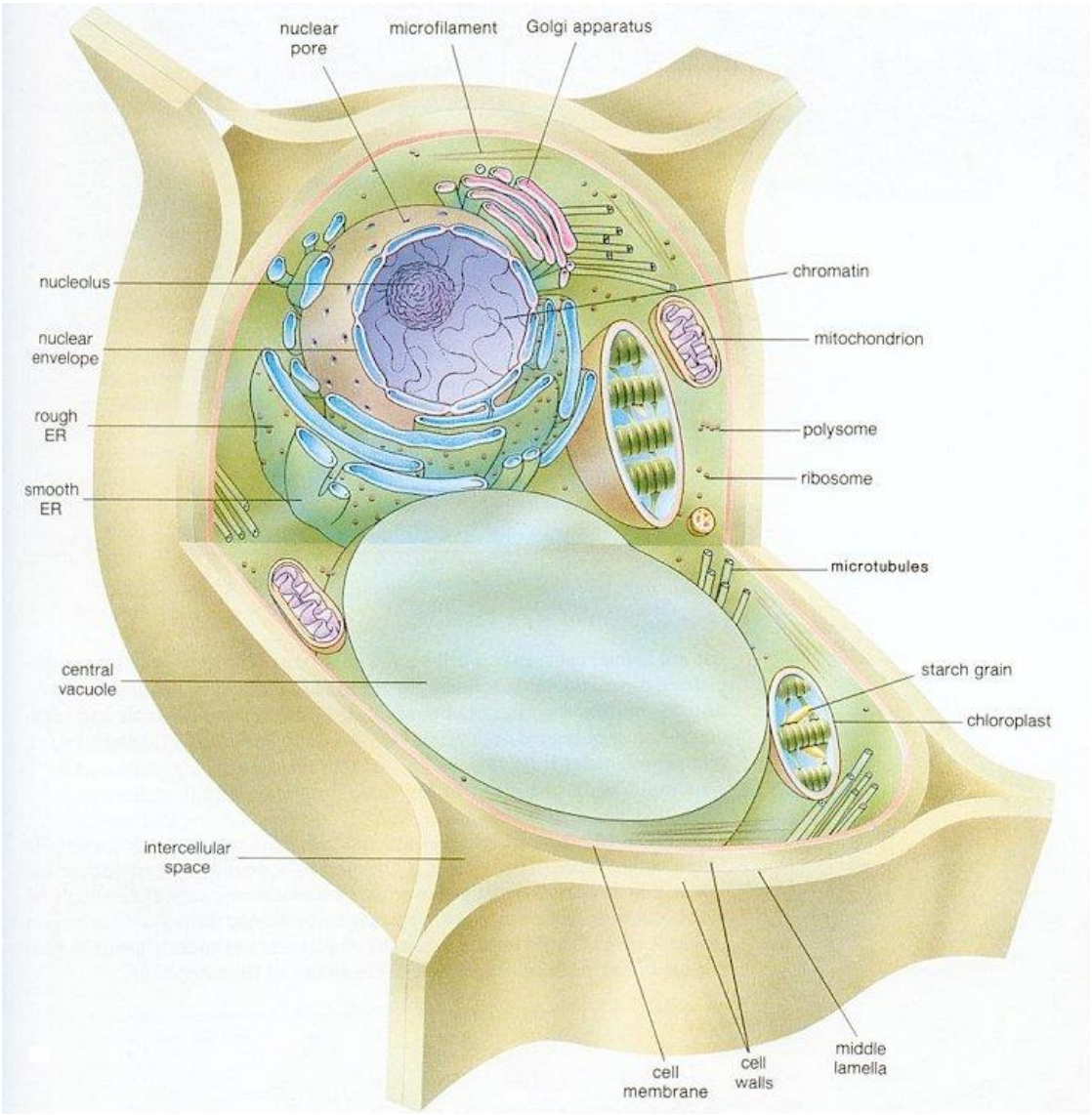


So…Leaves appear **green** to our eyes

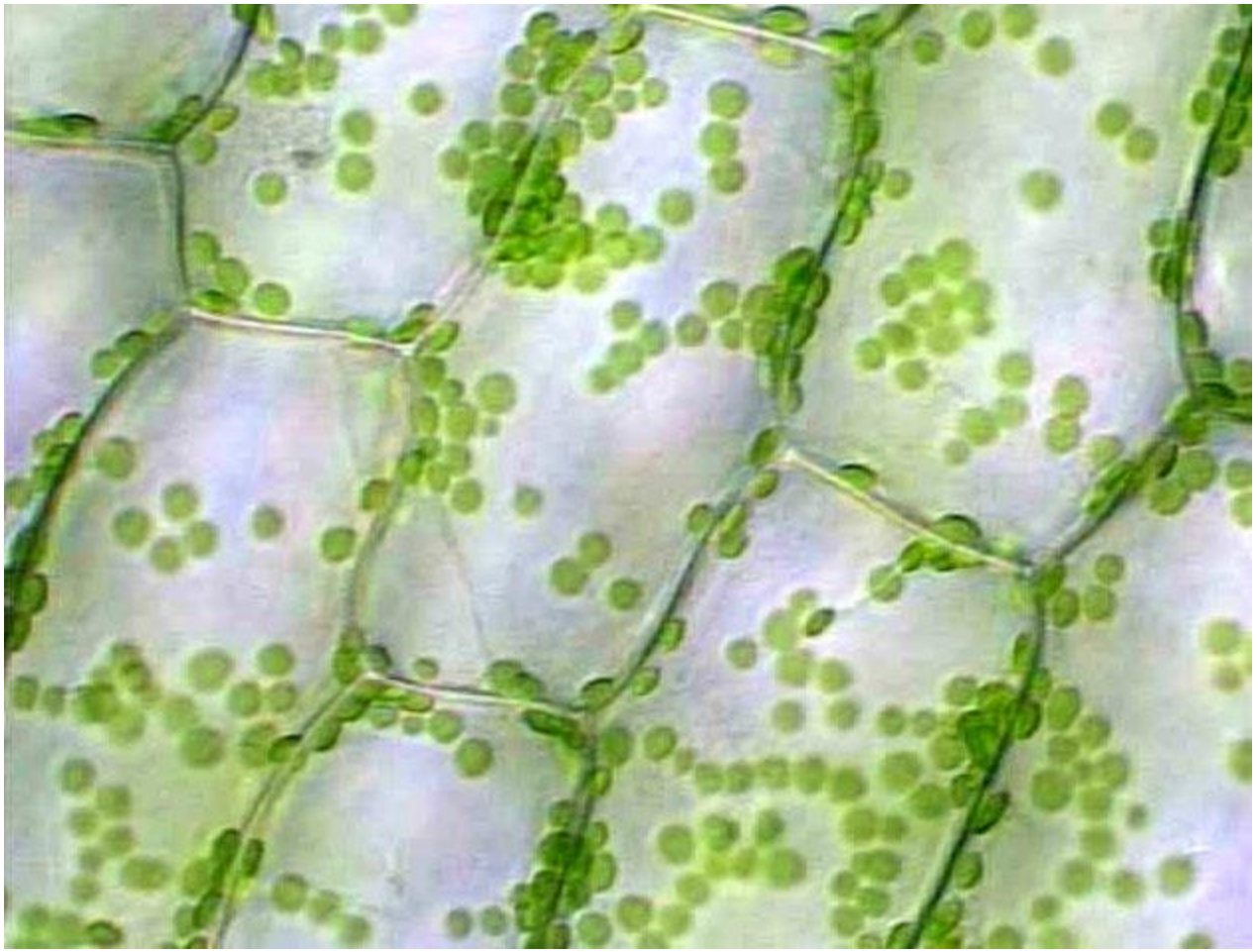
Photosynthesis Occurs in Plant Leaves



In plant Cells



In the Chloroplasts



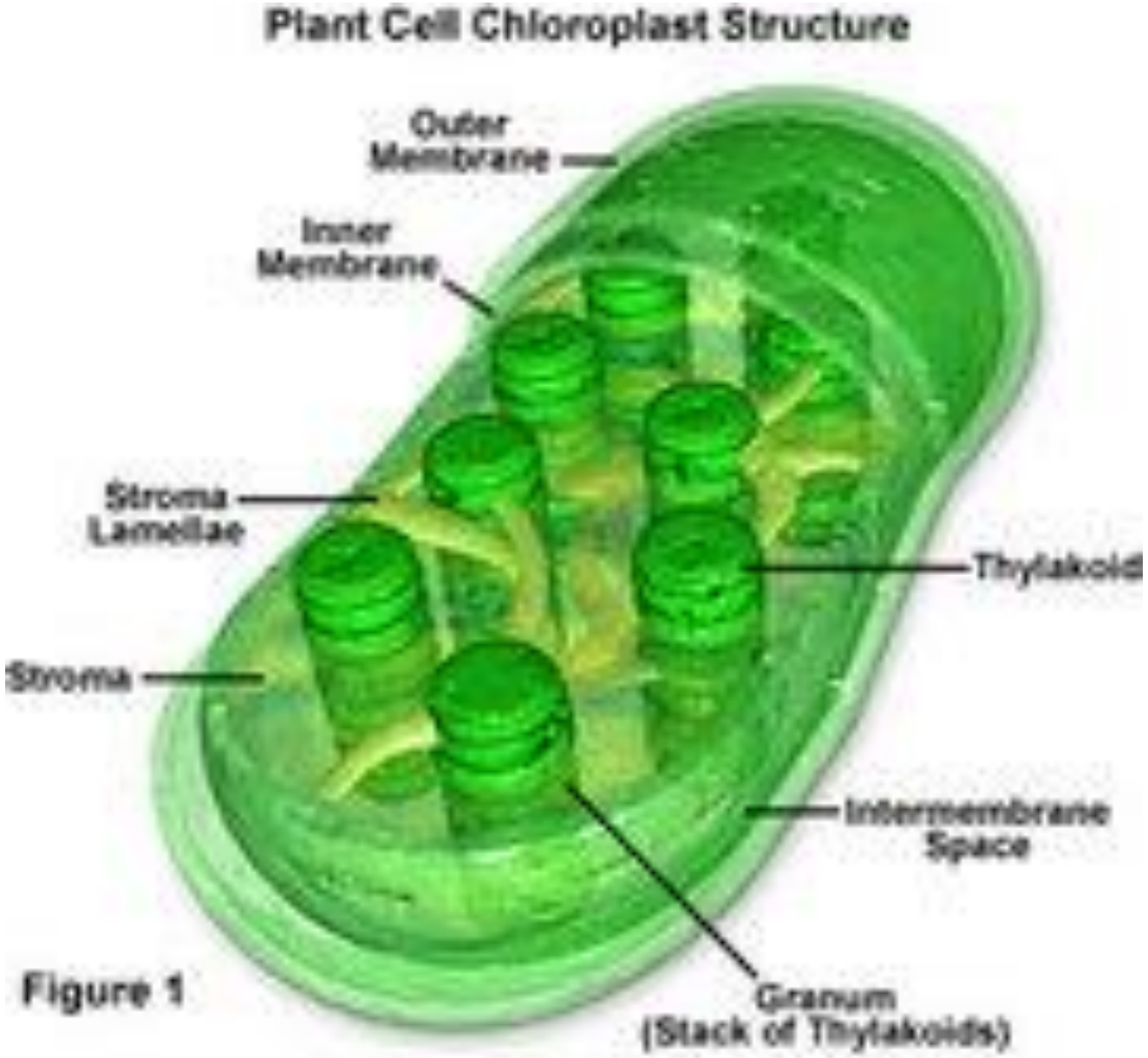
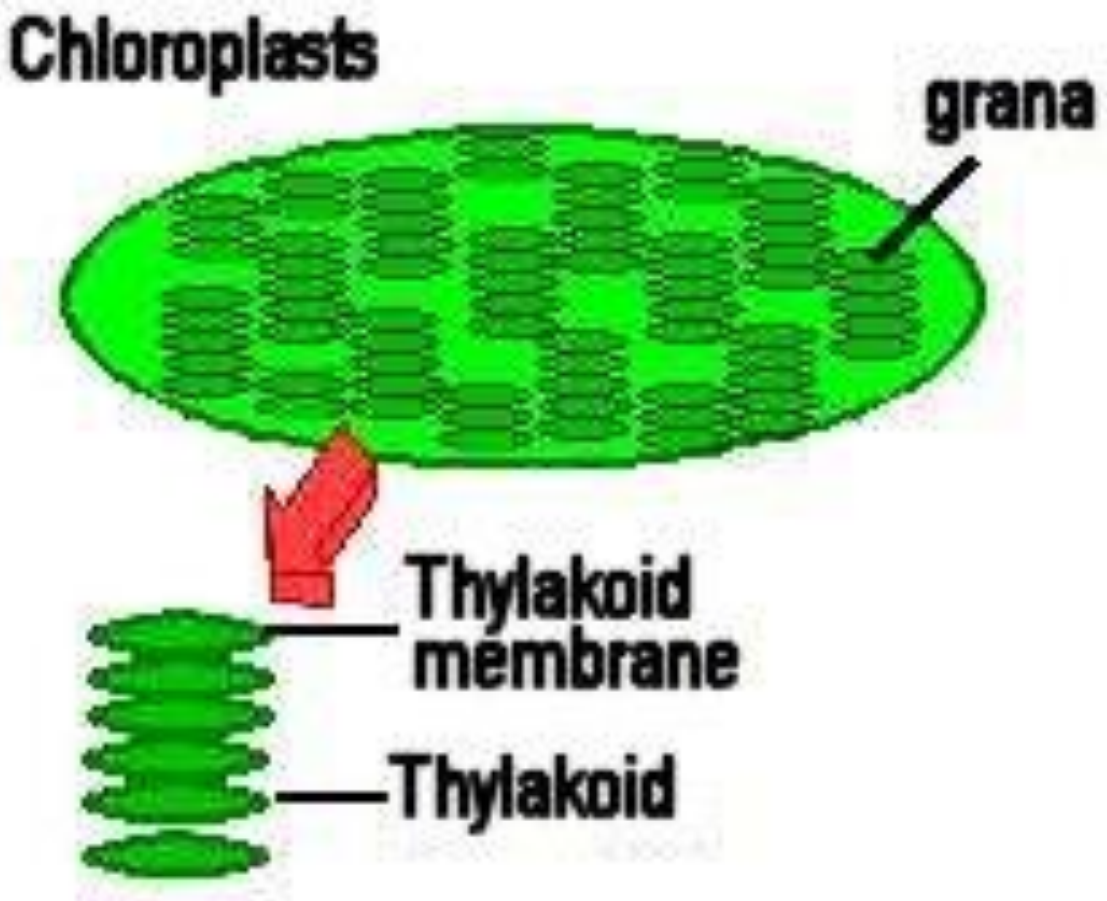
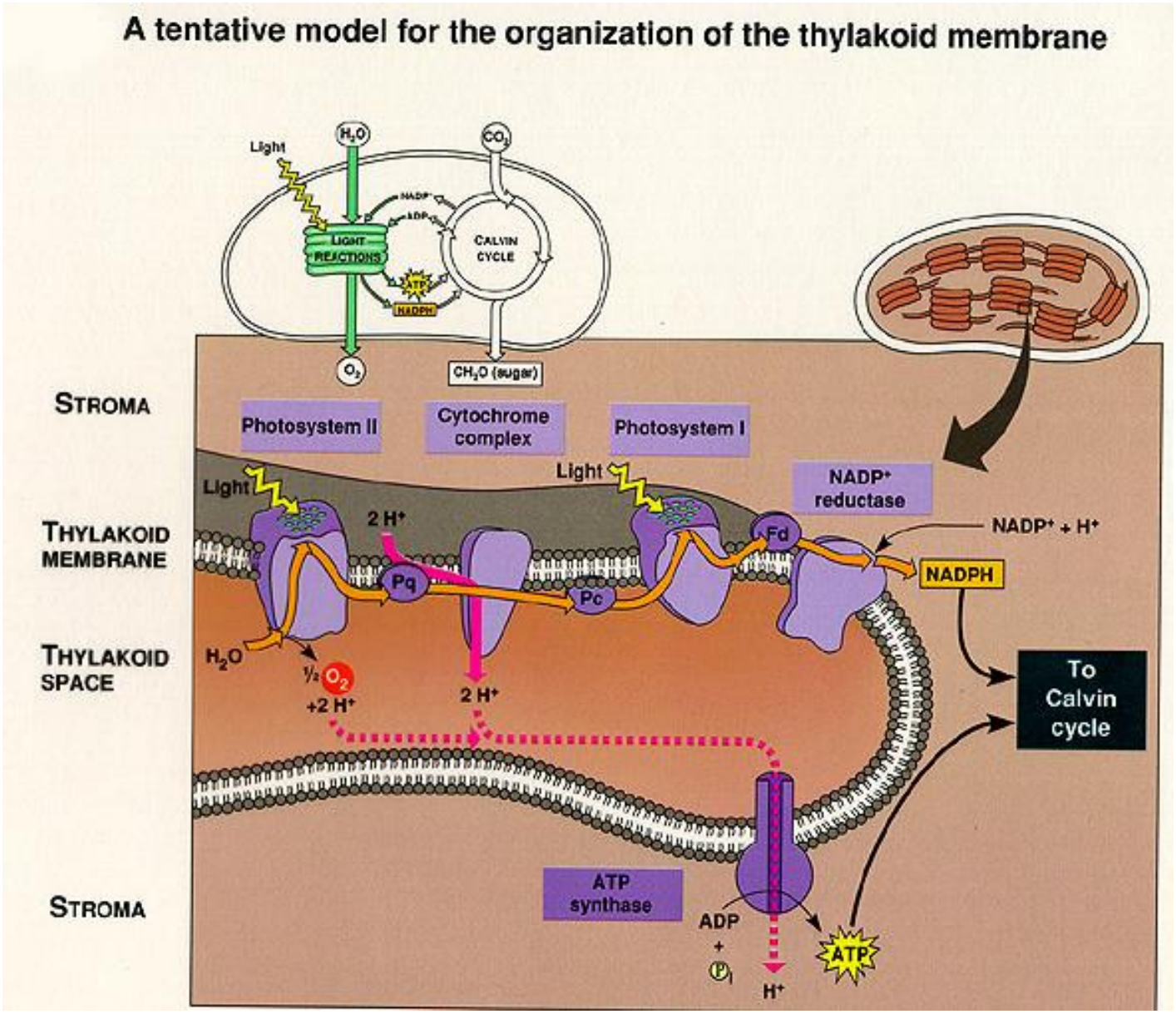

Plant Cell Chloroplast Structure
Outer Membrane
Inner Membrane
Stroma Lamellae
Thylakoid
Stroma
Intermembrane Space
Granum (Stack of Thylakoids)

Figure 1

Chloroplast showing thylakoids and grana (stacks of thylakoids)

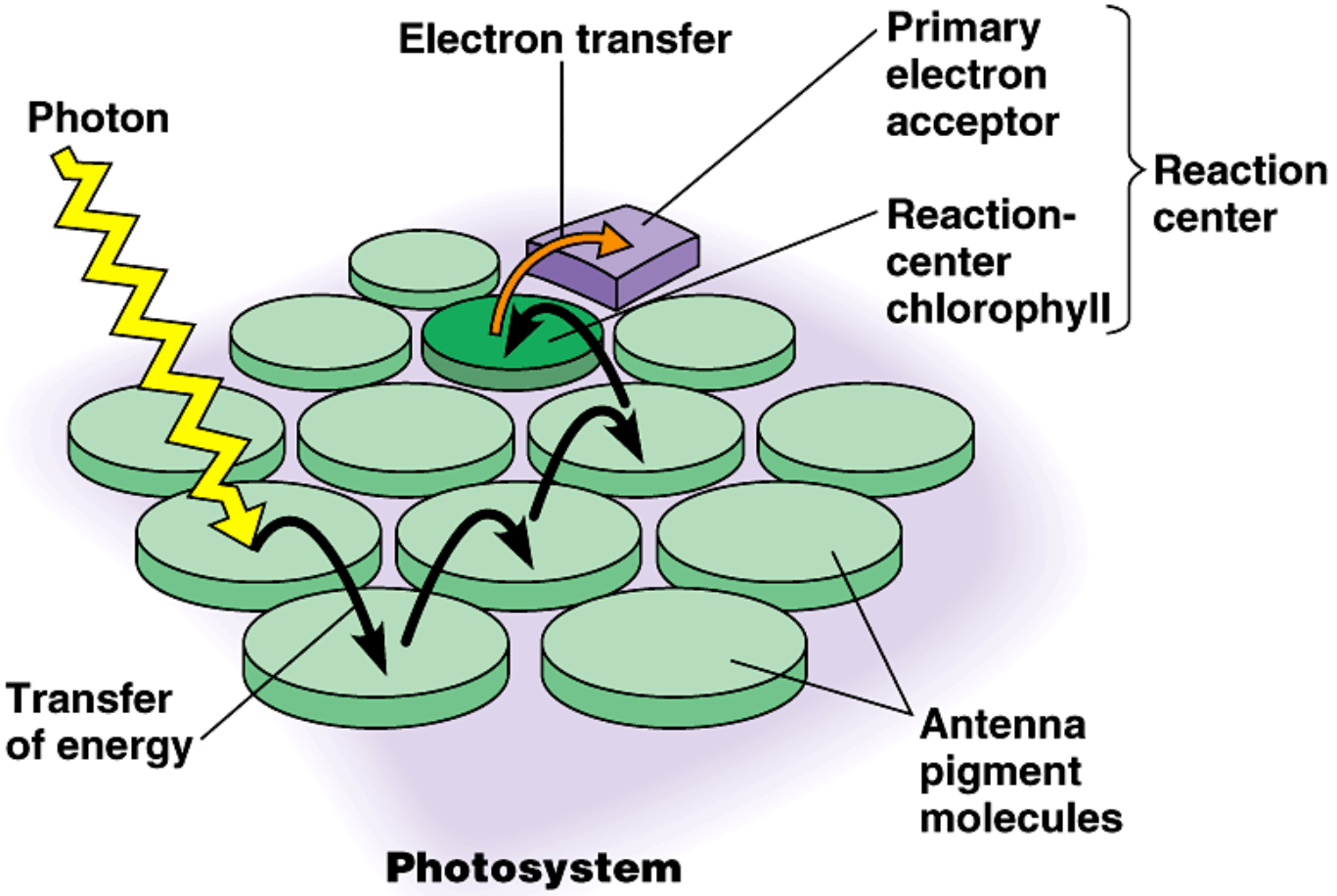


A tentative model for the organization of the thylakoid membrane



Chlorophyll is a **molecule** contained in the thylakoid membrane which traps sunlight

Sun excites electrons - bounce around chlorophyll molecules



Photosynthesis Happens in **Two** Phases

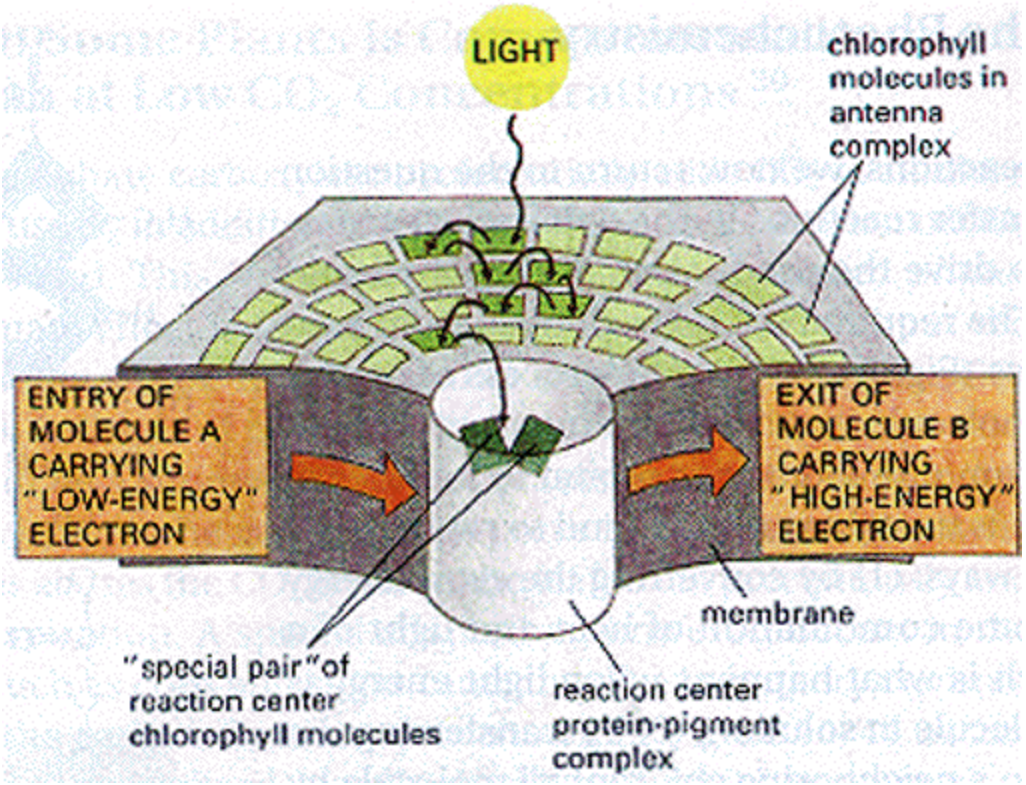
#1- Light-dependent reactions

#2 Light-independent Reactions

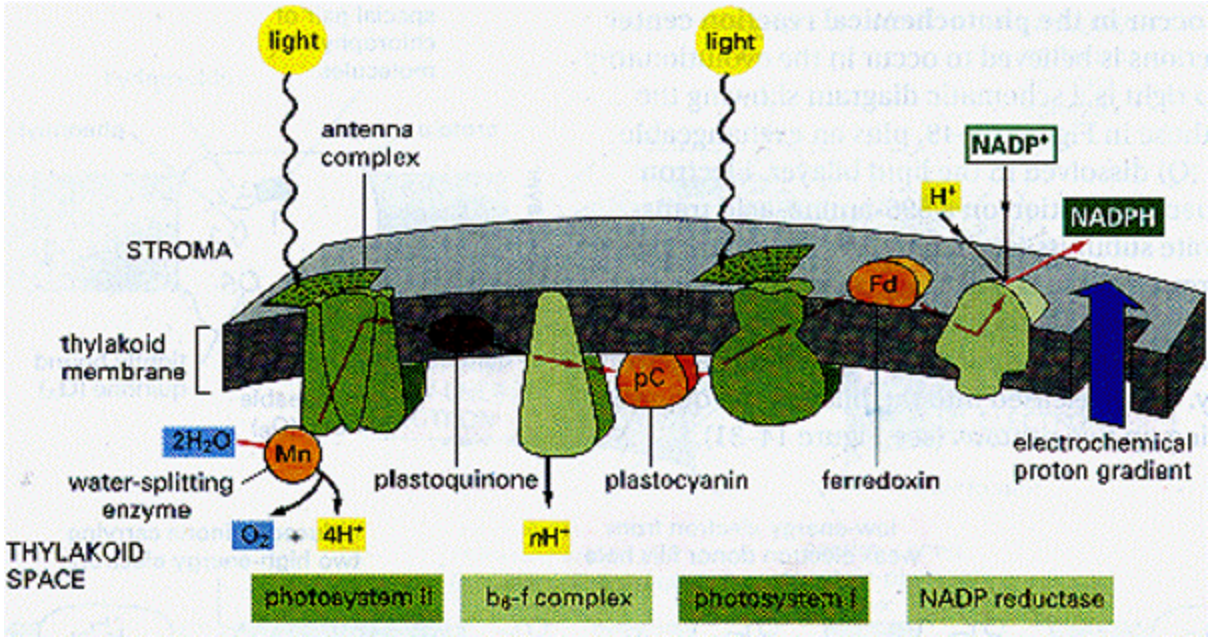
Light-dependent Reactions (the wind-up)

- Convert light energy into chemical energy
- Chemical energy is stored in the phosphate bonds of ATP
- Produce energy to power light-independent reactions
- Take place in the membranes of the thylakoids

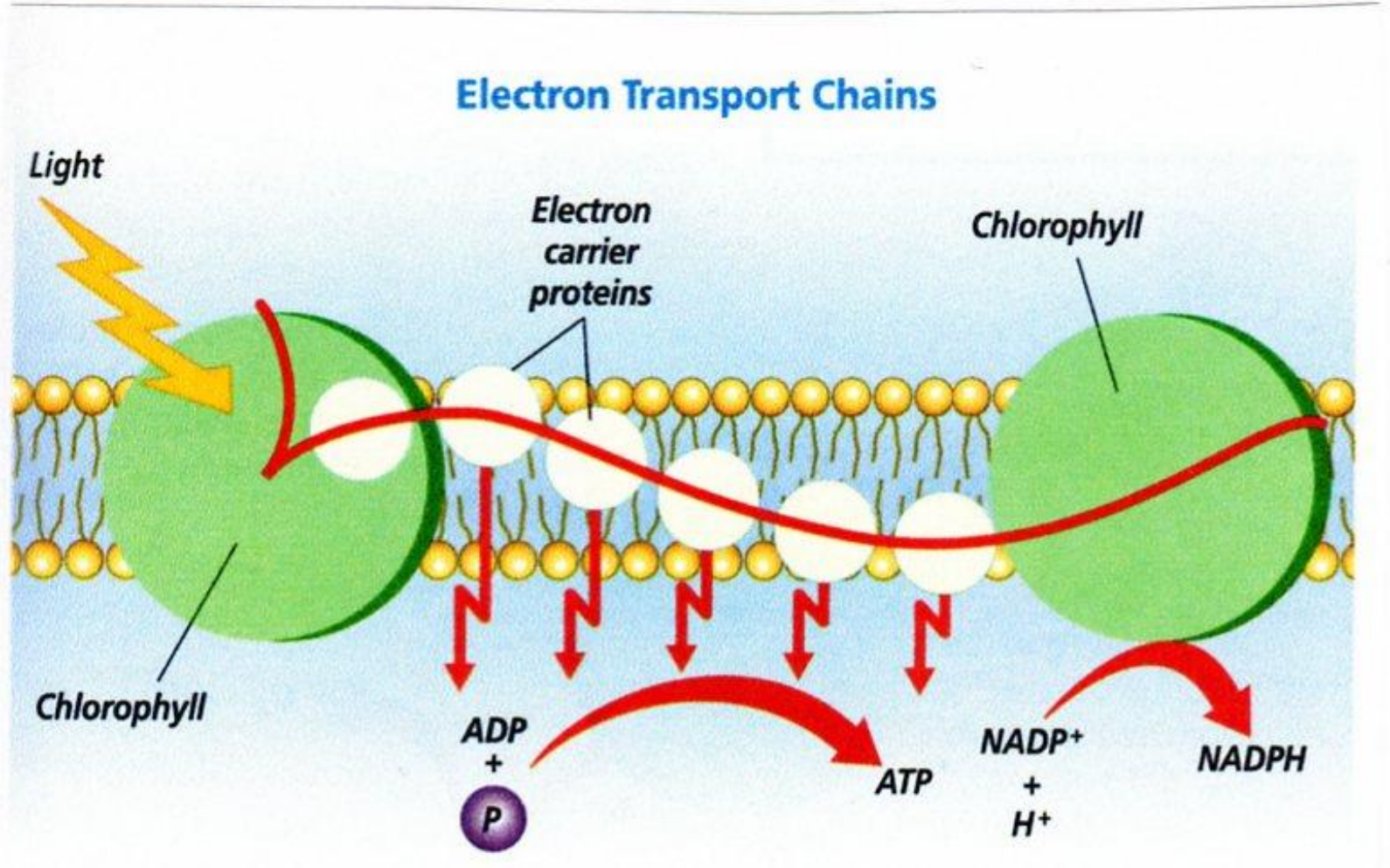
Chlorophyll molecules trap sunlight in the thylakoids



Light Reactions take place in the Thylakoid Membranes



Light Reactions



Steps of Light-dependent (Sun) Reactions

- Stage #1 – Chlorophyll captures energy from the sun and excites electrons
- Stage #2 - Excited electrons jump from molecule to molecule and store their energy in the chemical bonds of ATP and NADPH
- Water is split which:

1)replaces the excited electrons

2)makes oxygen and releases it

More Detail

- Stages #1 & #2 take place in the thylakoid membranes
- Some small energy packets are used to produce ATP by attaching a phosphate group to ADP
- Water is split into H+ (electrons) and oxygen
- Oxygen is released from plant for us to breathe
- Some small energy packets are used to pump hydrogen ions into the center of the thylakoid to store energy in NADPH

Light Reactions

yield

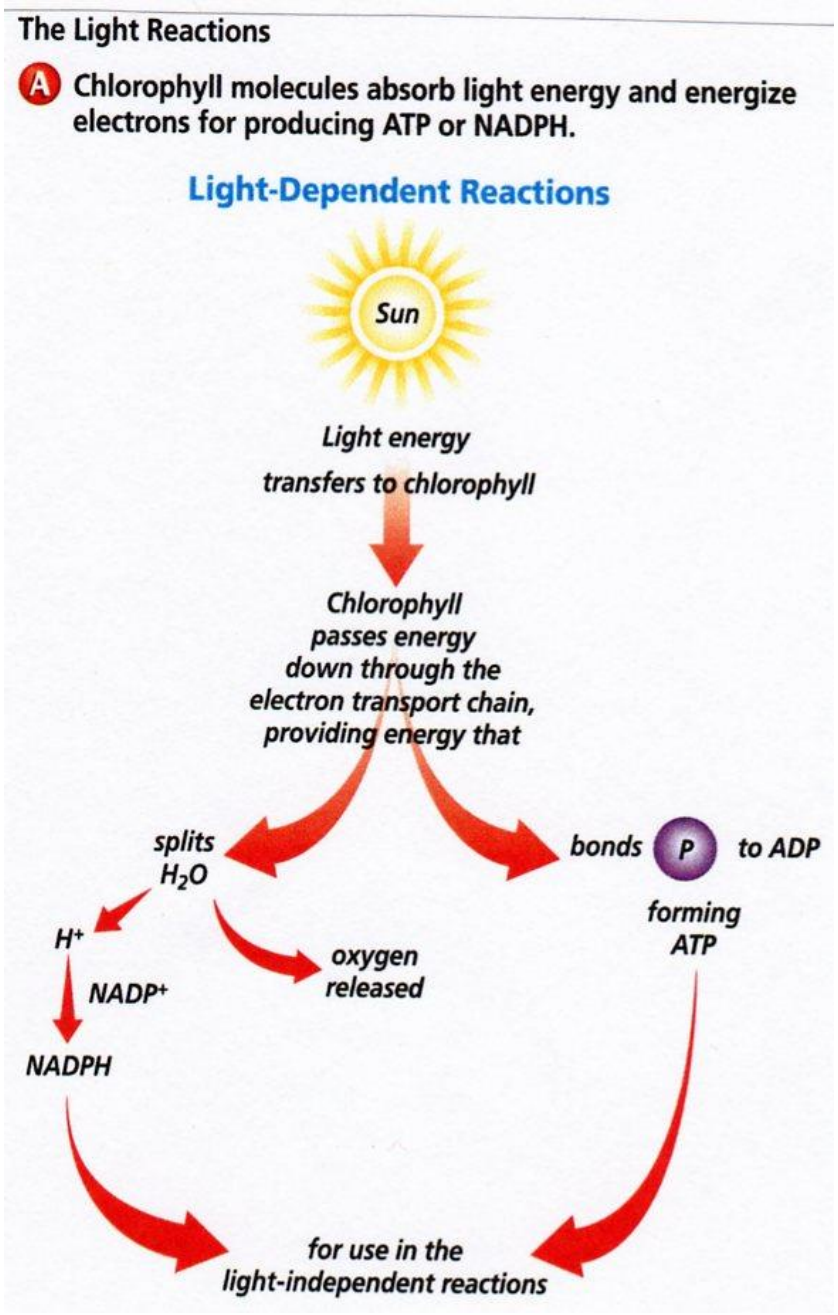
2 ATP

+

NADPH

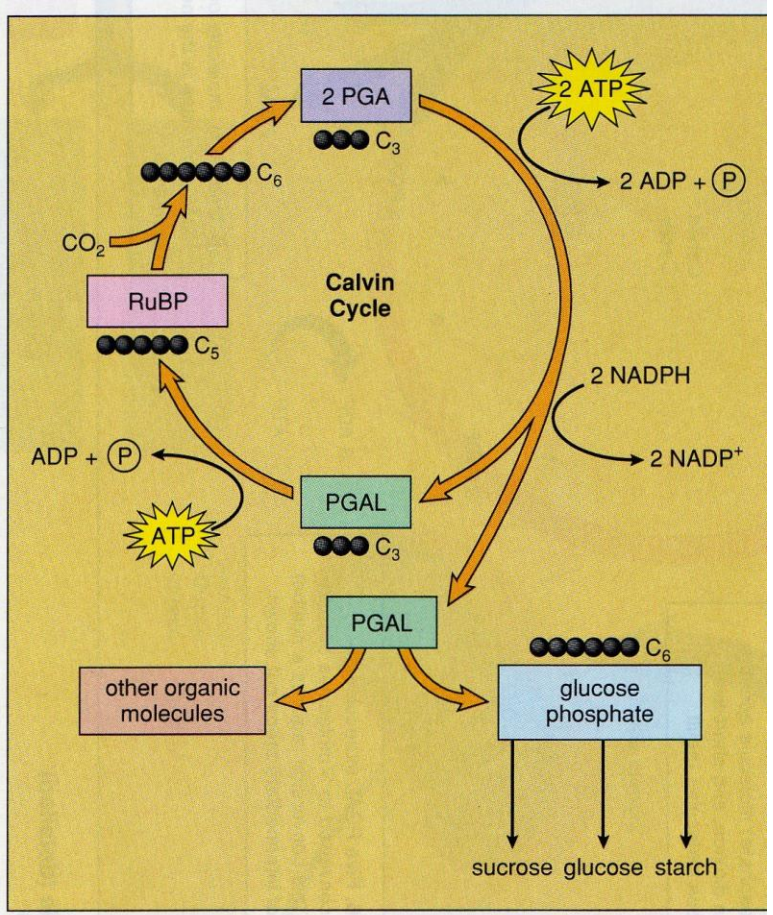
to power

Light-independent Reactions



Stage #3 Light-independent Reactions

Calvin Cycle



Calvin Cycle (simplified)
Figure 8.9

Light-Independent Reactions

- Produce glucose
- Does not require light
- Takes place in the **stroma** of chloroplasts
- Uses **carbon** from CO_2 to produce $C_6H_{12}O_6$
- Each time the Calvin Cycle makes a circle, one Carbon is added to form a glucose chain
- It takes six rounds of the cycle to form one glucose

Calvin Cycle

#1 CO_2 comes in from air and gets hooked to a 5-carbon compound (PGAL)

#2 This splits into two 3-carbon compounds. Phosphate groups from ATP and electrons from NADPH are hooked on. Now we have two 3-carbon sugars.

#3 One of these 3-carbon sugars is used to make glucose (then starch or sucrose)

#4 The other 3-carbon sugar gets recycled to begin the process over again

Factors Affecting Photosynthesis

- Amount of sunlight
- Carbon dioxide concentration
- Temperature
- Water availability

- Process is faster in summer

***Trees are captured carbon dioxide

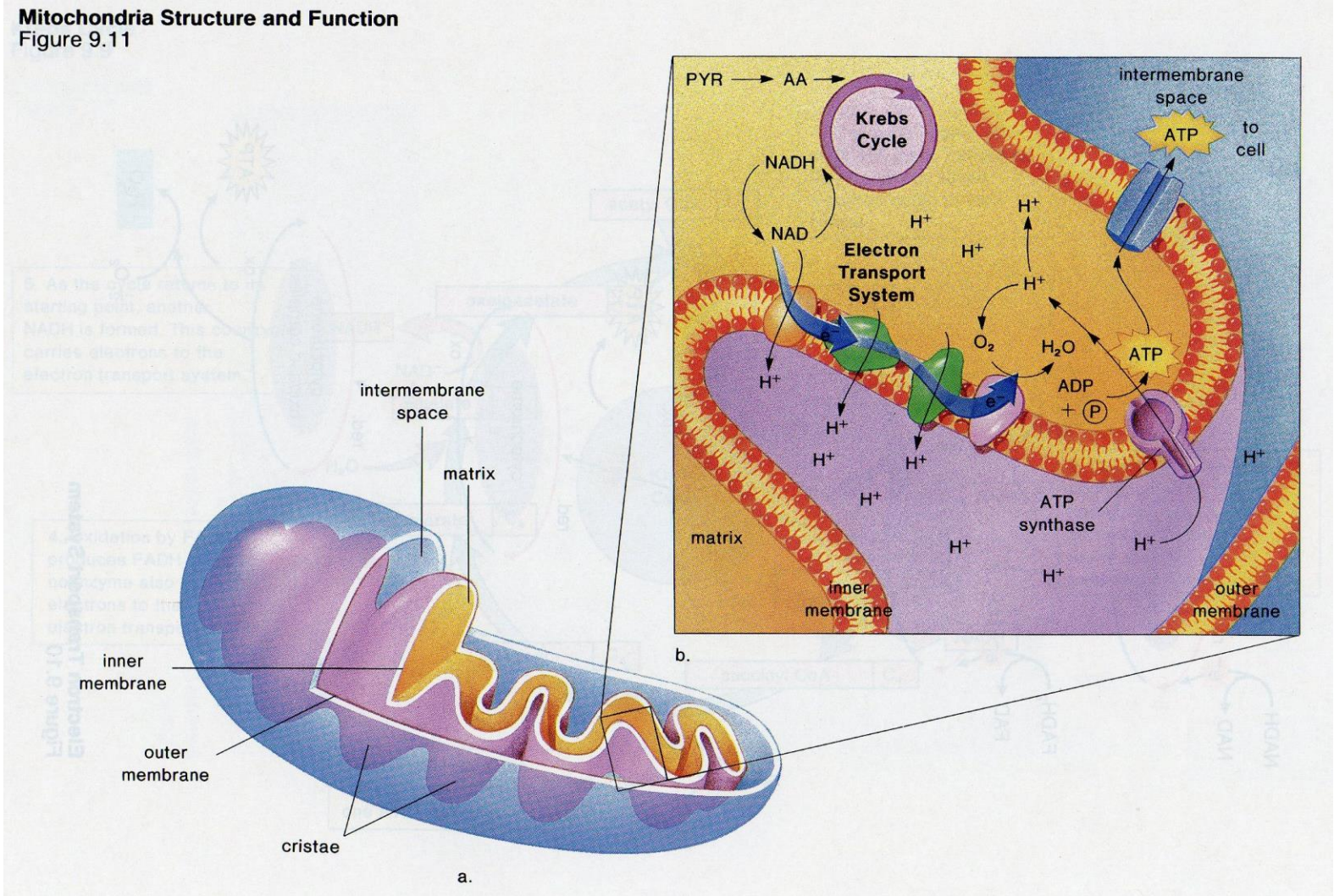
Cellular Respiration

- Charging & Using the battery
- Letting the spring loose so the coyote can fly

Cellular (Aerobic) Respiration

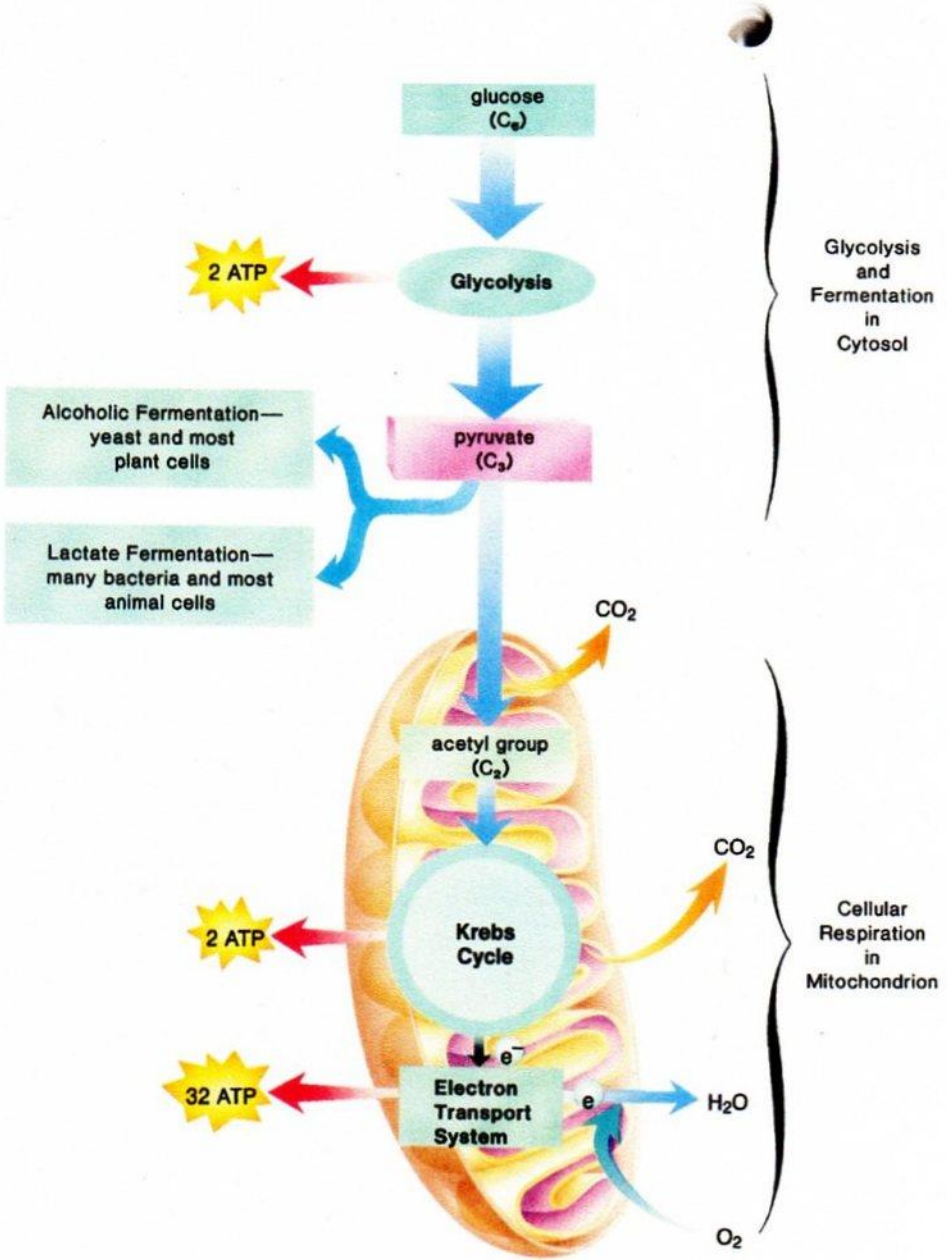
- Provides energy for cell processes
- Takes place in the mitochondria
- Breaks down glucose (food)($C_6H_{12}O_6$) to produce energy (ATP)
- Takes place in three phases
- Uses oxygen
- Does **not** require light to work

Mitochondria – site of Respiration



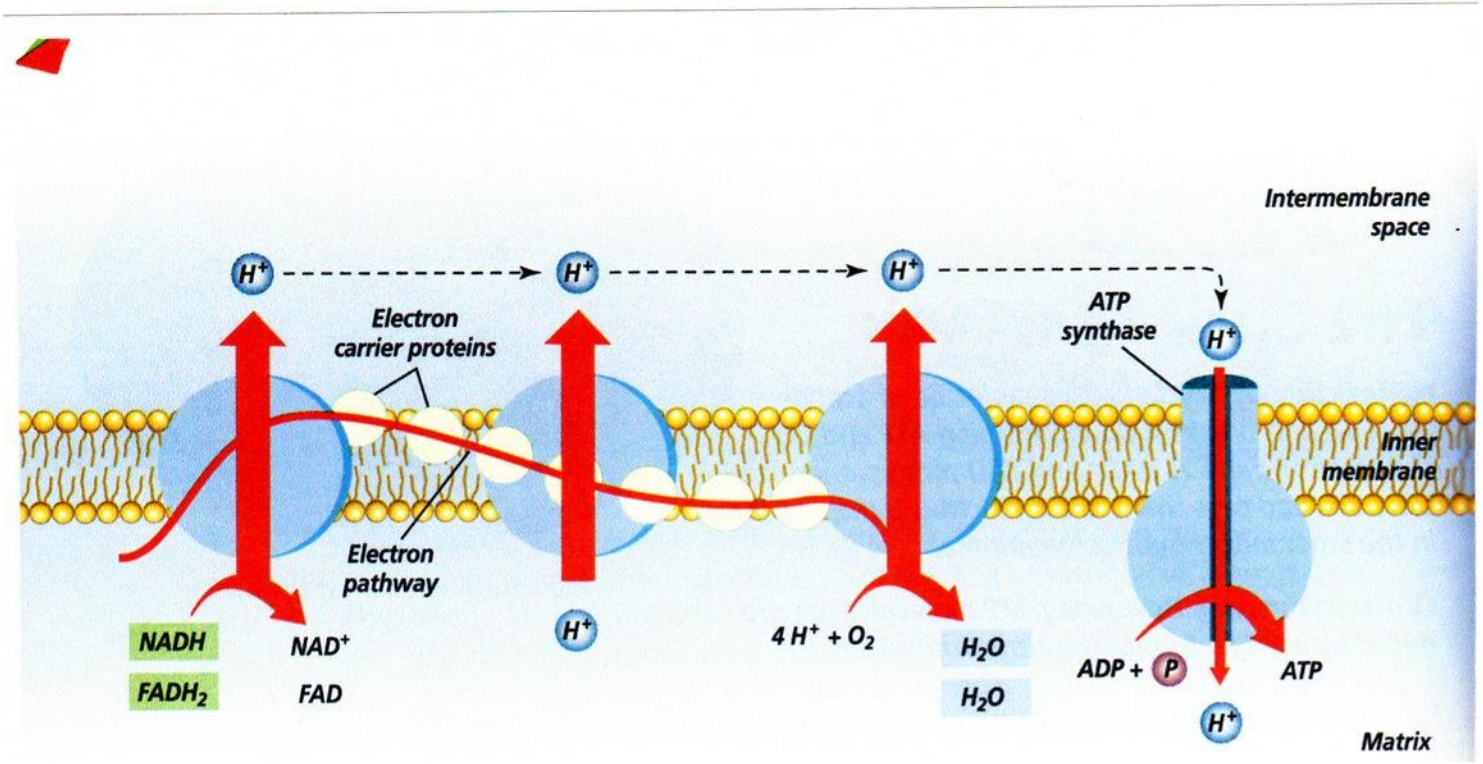
Three phases of Respiration

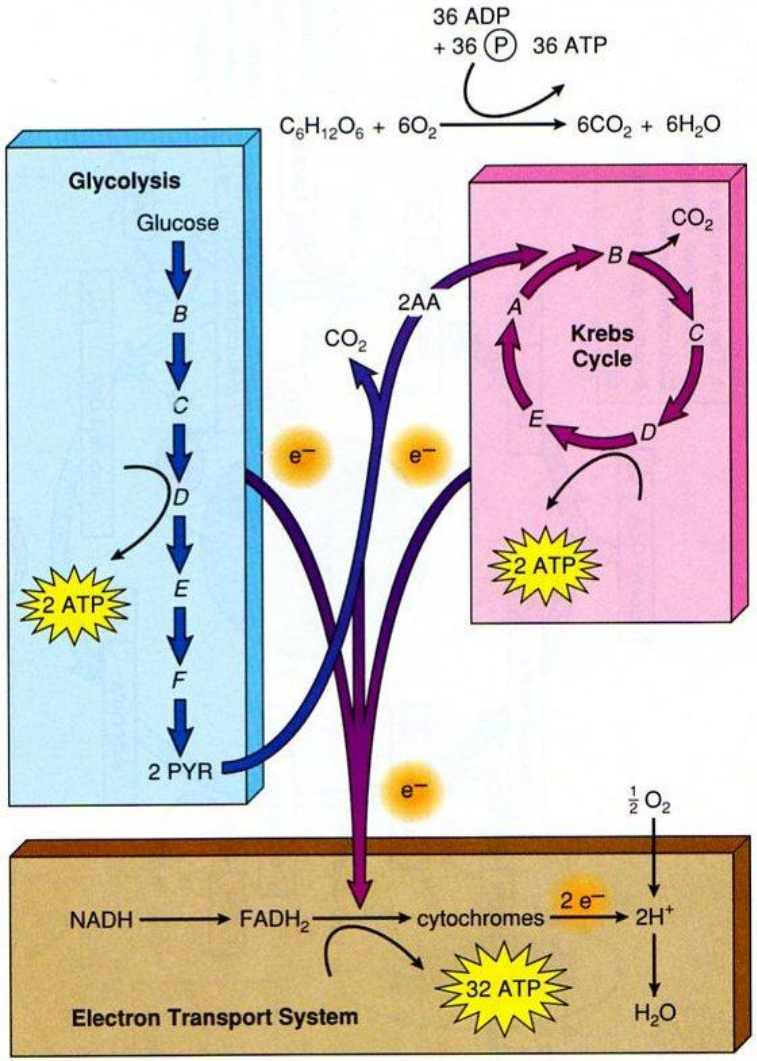
1. Glycolysis – breaks glucose into two pieces & makes two ATP
2. Citric Acid Cycle – like the Calvin Cycle except that instead of building glucose, glucose is broken down and one ATP is made for every turn of the cycle. CO_2 is produced & expelled
3. Electron Transport Chain – produces 32 ATP molecules + 2 H_2O molecules in the inner membrane of the mitochondrion



Overview of Glucose Metabolism
Figure 9.2

Electron Transport Chain – Respiration (Mitochondria)





Summary of Glucose Metabolism
Figure 9.7

Anaerobic Respiration

- Respiration without oxygen
- Two types
  1. Lactic acid fermentation
  2. Alcoholic fermentation

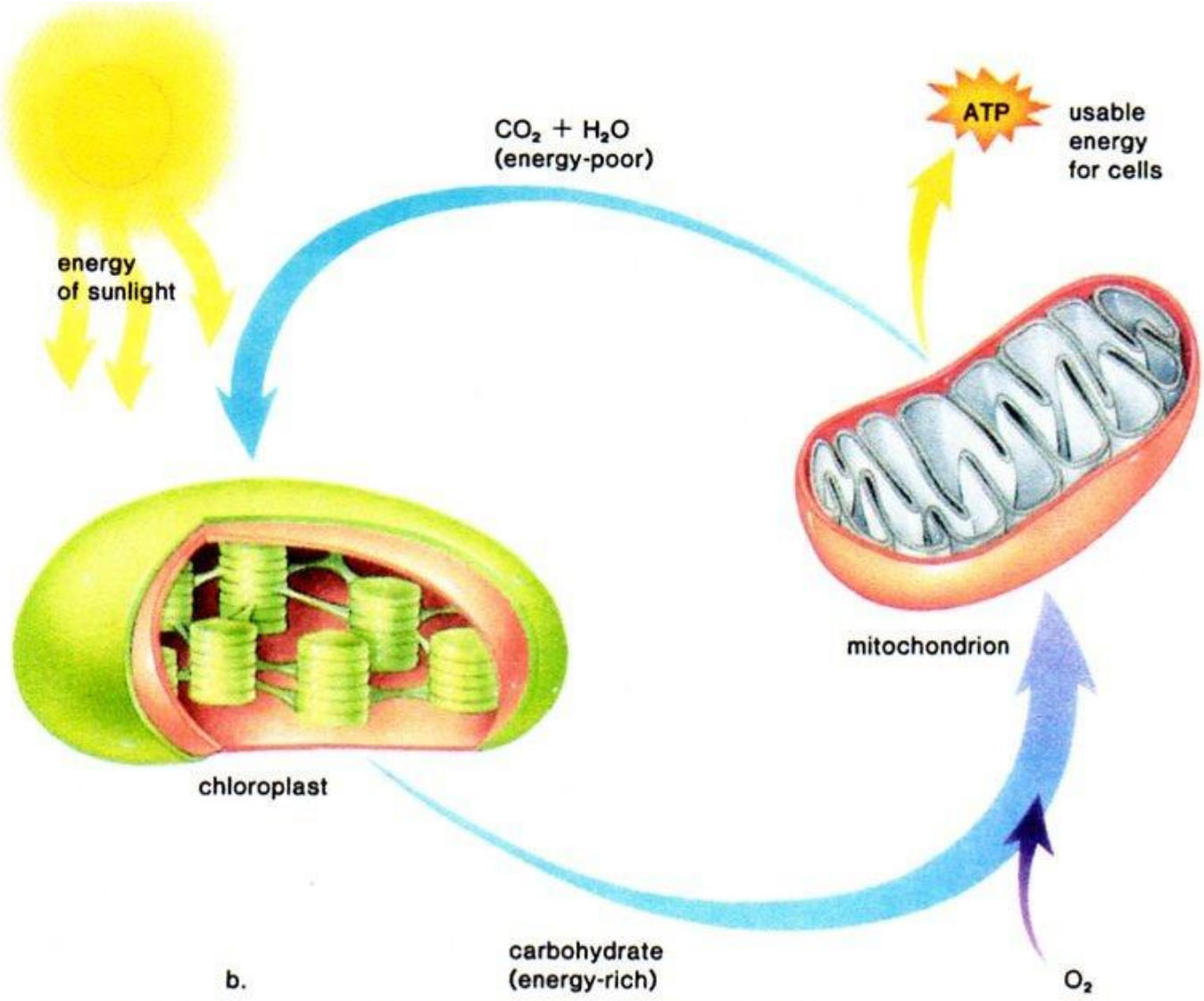
Lactic Acid Fermentation

- When you run out of oxygen, respiration can continue for a short time
- Glycolysis can continue to produce ATP as long as there is a glucose supply
- Process produces lactate
- Lactate can build up in muscle cells and cause pain

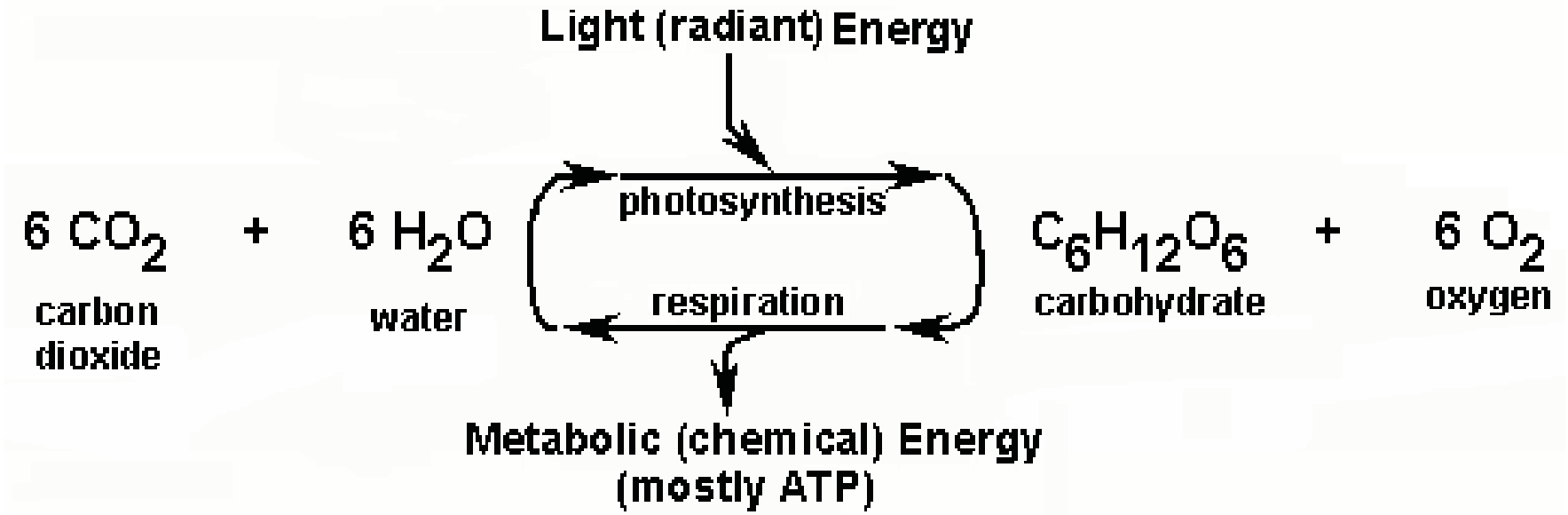
Alcohol Fermentation

- Other organisms can produce ethyl alcohol (ethanol) from sugar
- No oxygen is used – glycolysis only
- Yeast (fungus) produces wine & beer
- Yeast produces carbon dioxide which makes bread dough rise
- Ethanol is toxic to yeast and kills it at 12% concentration

Photosynthesis versus Cellular Respiration



Relationship between Respiration and Photosynthesis
Figure 9.1b


Light (radiant) Energy
6 CO_2
carbon dioxide
+
6 H_2O
water
photosynthesis
respiration
$C_6H_{12}O_6$
carbohydrate
+
6 O_2
oxygen
Metabolic (chemical) Energy
(mostly ATP)

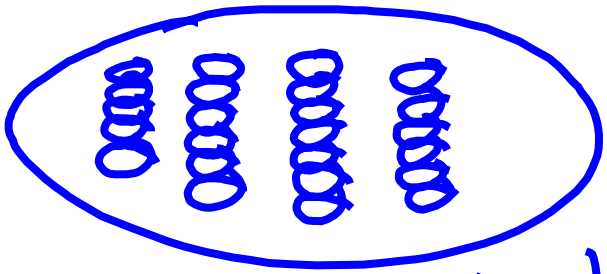
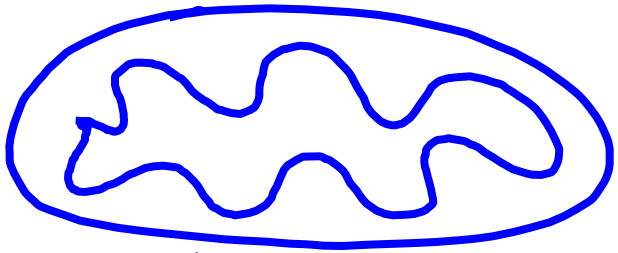
Photosynthesis

- Food accumulated
- Energy from sun stored in glucose
- Carbon dioxide taken in
- Oxygen given off
- Produces glucose from PGAL
- Goes on only in light
- Occurs only in presence of Chlorophyll
- (Formation of oxygen and sugars)

Cellular Respiration

- Food broken down
- Energy of glucose released
- Carbon dioxide given off
- Oxygen taken in
- Produces CO_2 and H_2O
- Goes on day and night
- Occurs in all living cells
- (Formation of carbon dioxide and water)

Photosynthesis	Respiration
Food is made	Food broken down
Energy from Sunlight is stored in glucose	Energy of glucose is released
Carbon dioxide (CO_2) taken in	Carbon dioxide (CO_2) given off
Oxygen (O_2) given off	Oxygen (O_2) taken in & used
Produces glucose ($C_6H_{12}O_6$) Oxygen (O_2) & ATP	Produces carbon dioxide and water
Must have sunlight to occur	Occurs day & night

occurs only in the presence of chlorophyll	occurs in ALL living cells
Takes place in chloroplast	Takes place in mitochondria
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
 Chloroplast	 mitochondria