Cellular Respiration

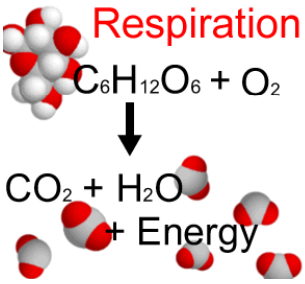
Keeping us alive.

ABCDE of Trauma

- Airway
- Breathing
- Circulation
- Disability
- Exposure

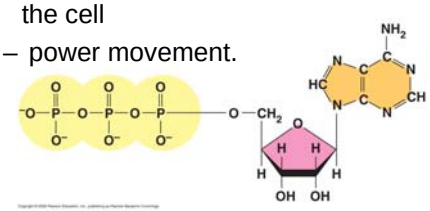
Why is oxygen so important?

- Cellular respiration is used by cells to produce usable energy.
  - Without this energy cells (especially neurons) rapidly die.
  - When the brain dies, the body dies.



Cellular Respiration Produces ATP

- ATP = adenosine triphosphate
- Used by cells to
  - carry out metabolic reactions
  - transport ions & molecules in/out of the cell
  - power movement.



Respiration: the overall reaction

Glucose + Oxygen + ADP + Phosphate yields Carbon dioxide + Water + ATP

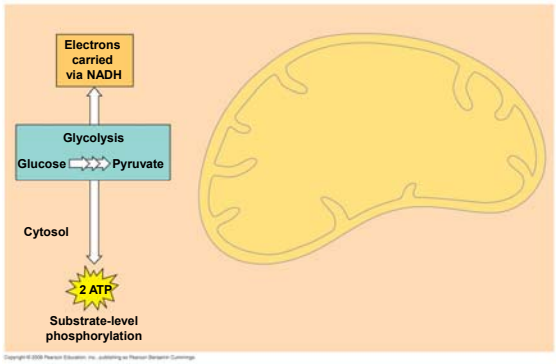
-- more precisely --

$C_6H_{12}O_6 + 6\ O_2 + 36\ ADP + 36\ Pi \longrightarrow 6\ CO_2 + 6\ H_2O + 36\ ATP$

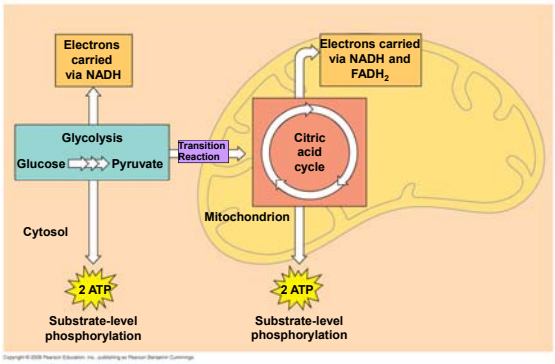
Cellular Respiration: Four Parts

- **Glycolysis**: occurs in the cytosol.
- **Transition Reaction**: occurs in the mitochondria (aka preparatory steps, formation of acetyl-CoA, oxidation of pyruvate).
- **Krebs Cycle**: occurs in the mitochondria. (aka **citric acid cycle**).
- **Electron Transport System**: occurs in the mitochondria.

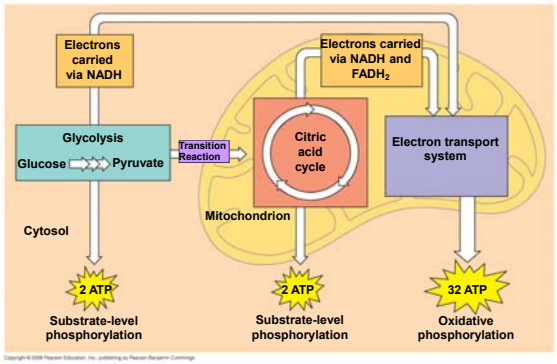
Connections between the four parts



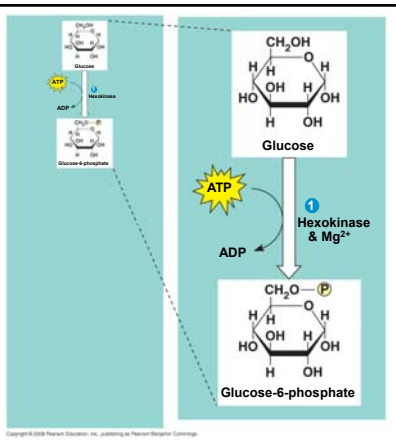
Connections between the four parts



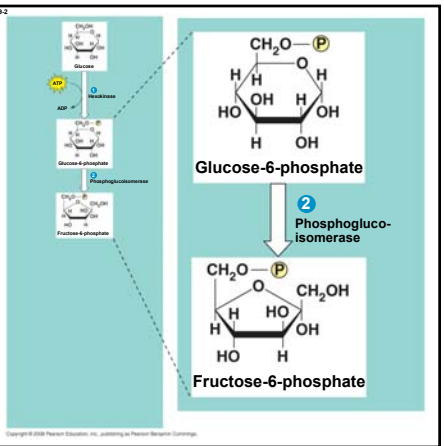
Connections between the four parts



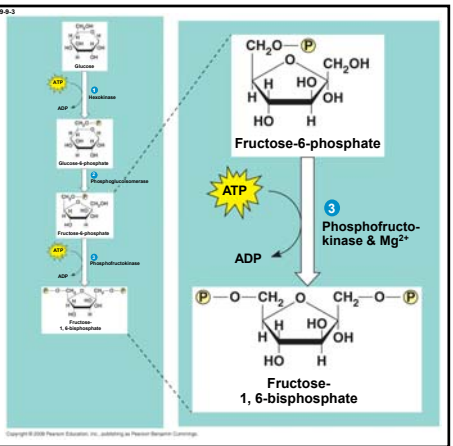
Glycolysis Step 1



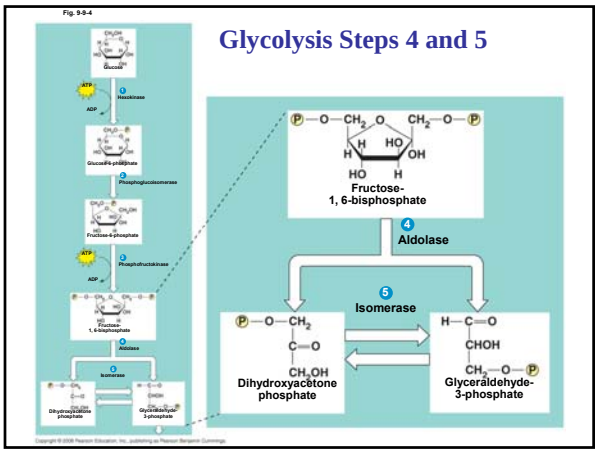
Glycolysis Step 2



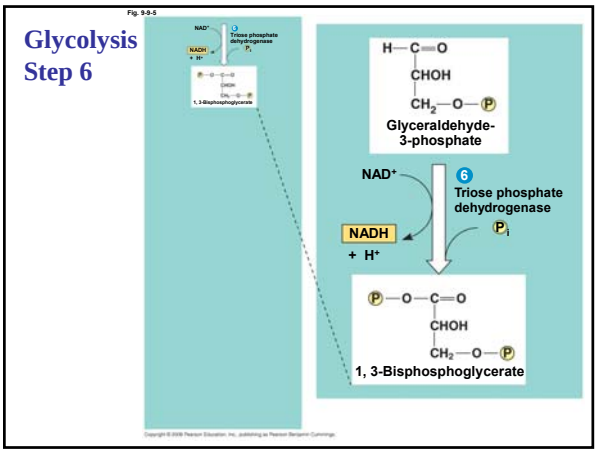
Glycolysis Step 3



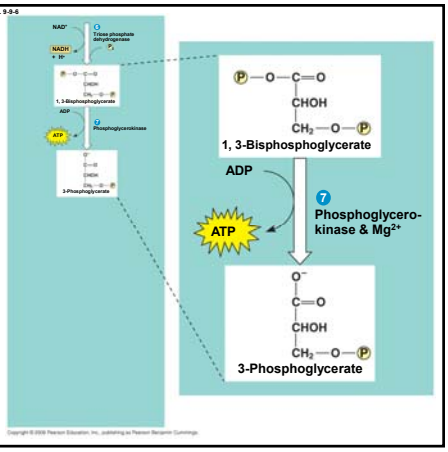
Glycolysis Steps 4 and 5



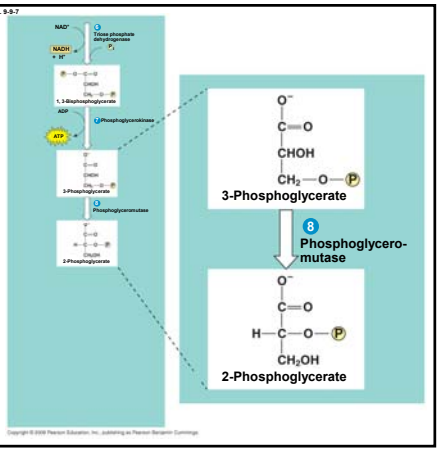
Glycolysis Step 6



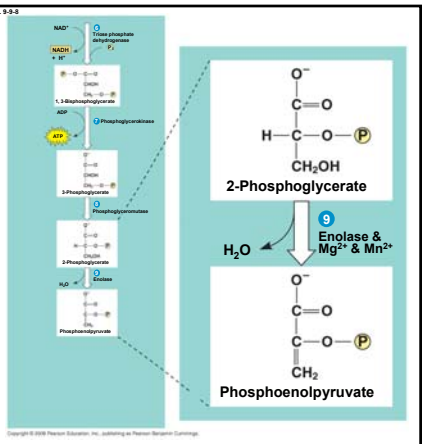
Glycolysis Step 7



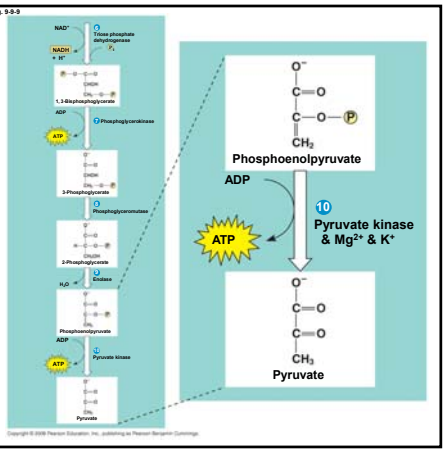
Glycolysis Step 8



Glycolysis Step 9

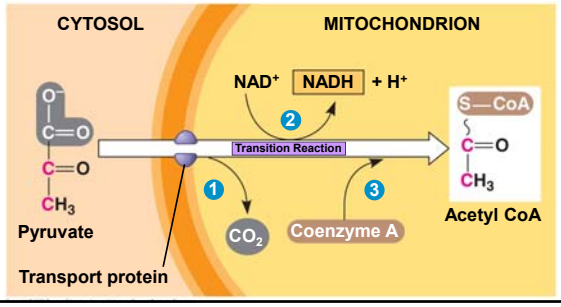


Glycolysis Step 10



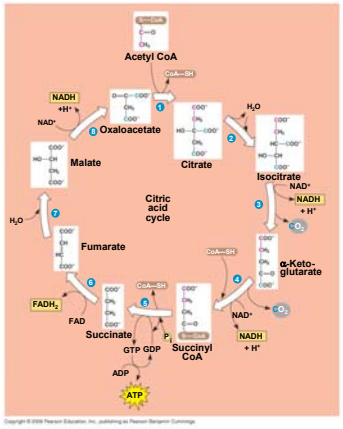
Transition Reaction

The transition reaction forms the first molecule of CO_2, converts another NAD^+ to NADH, and attaches what remains of pyruvate to coenzyme A making acetyl-CoA.

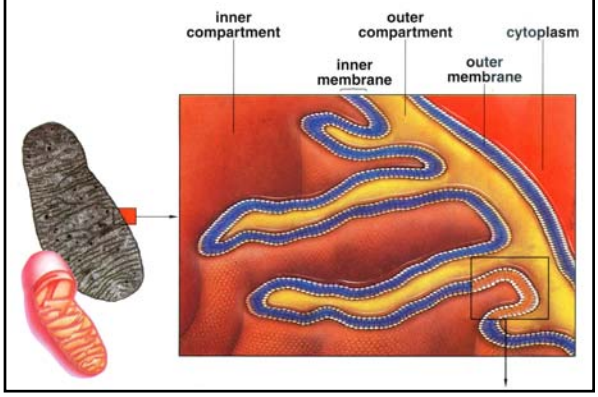


Krebs Cycle

The Krebs cycle takes the acetyl-CoA through a series of reactions that make two more molecules of CO_2, two more ATP, three more NADH, and a similar molecule $FADH_2$.

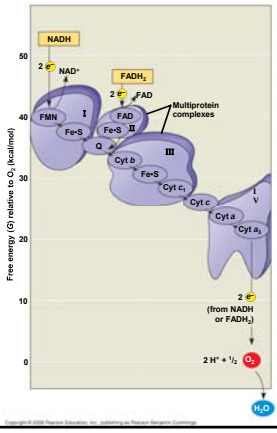


Mitochondrion Structure



The Electron Transport System

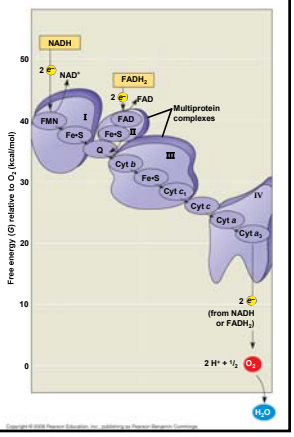
The electron transport system accepts the electrons carried by NADH and $FADH_2$ and passes them along a series of molecules embedded in the inner membrane of the mitochondrion.



The Electron Transport System

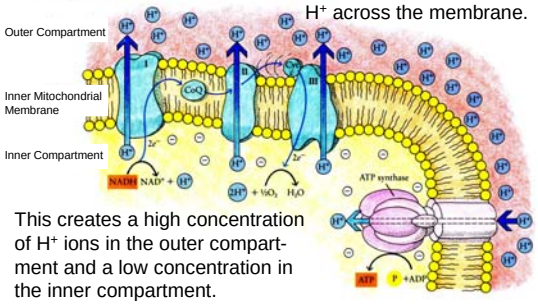
At each step the electrons go to a slightly lower energy state.

The final electron acceptor is oxygen; the electrons + hydrogen ions + oxygen form water.



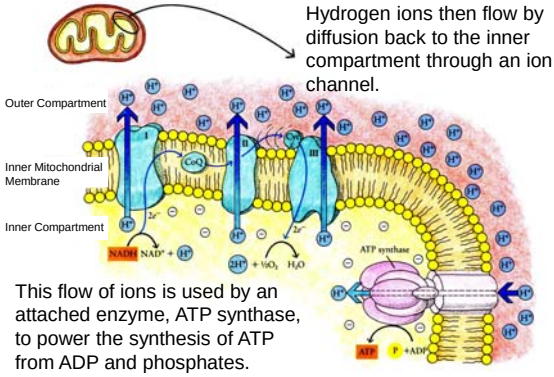
The Electron Transport System

As electrons are passed from one carrier to another, the energy drop is used to pump H^+ across the membrane.



This creates a high concentration of H^+ ions in the outer compartment and a low concentration in the inner compartment.

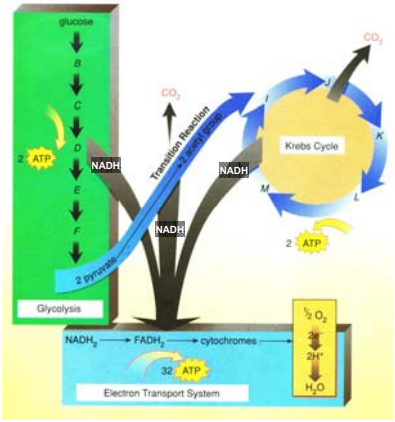
The Electron Transport System



Hydrogen ions then flow by diffusion back to the inner compartment through an ion channel.

This flow of ions is used by an attached enzyme, ATP synthase, to power the synthesis of ATP from ADP and phosphates.

Cellular respiration summary

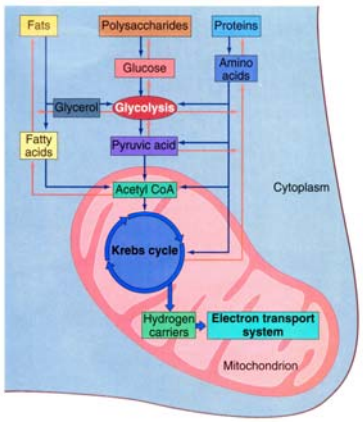


Metabolic Water

The kangaroo rat can survive on dry seeds - it does not need to drink or to eat moist food. It obtains all the water it needs through cellular respiration.

Many Energy Sources

Proteins and fats can also be metabolized in cellular respiration.



Fermentation

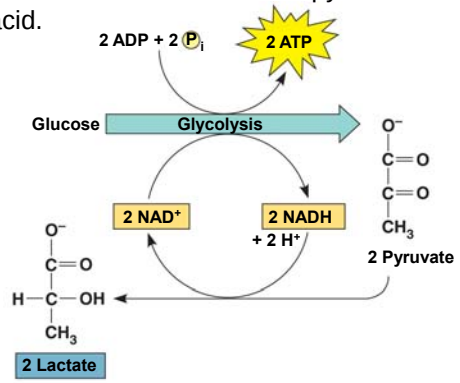
Aerobic cellular respiration requires O_2; without oxygen the electron transport system and Krebs cycle shut down.

Glycolysis can continue in the absence of O_2, but to do so it needs a supply of NAD^+.

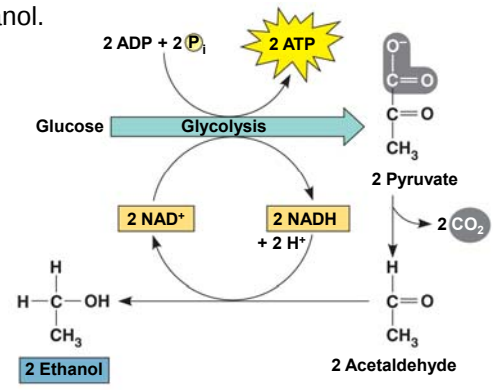
NAD^+ is usually regenerated from the electron transport system; without that glycolysis needs another source of NAD^+.

Fermentation provides NAD^+ from reactions with pyruvate.

Lactic acid fermentation converts pyruvate to lactic acid.



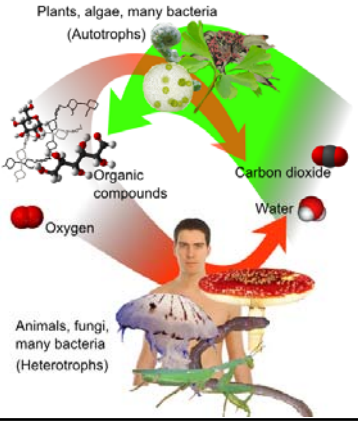
Alcohol fermentation converts pyruvate to ethanol.



Autotrophs and Heterotrophs

Autotrophs make their own food, usually by photosynthesis.

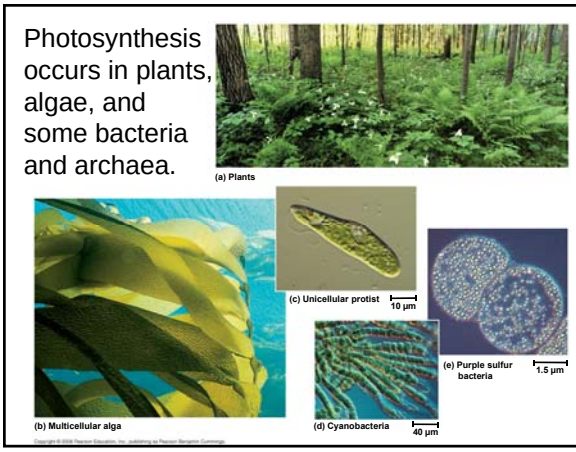
Heterotrophs rely on organic molecules made by autotrophs for their nutrition.



Photosynthesis is the process that converts solar energy into chemical energy.

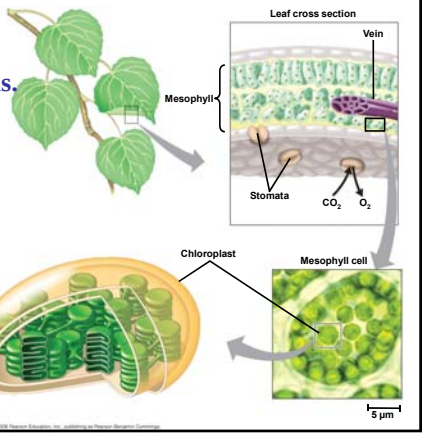
Directly or indirectly, photosynthesis nourishes almost the entire living world.

Photosynthesis occurs in plants, algae, and some bacteria and archaea.



Chloroplasts are the site of photosynthesis.

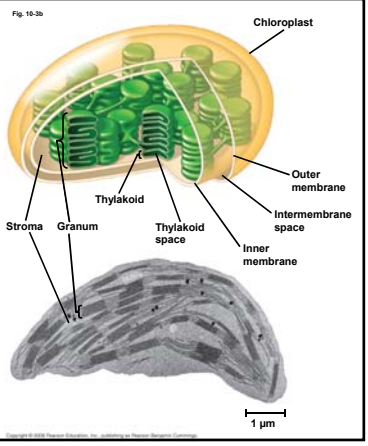
Chloroplasts are found mainly in the leaves of plants.



Chloroplast Structure

Chloroplasts have a double outer membrane and a complex inner membrane called the thylakoid.

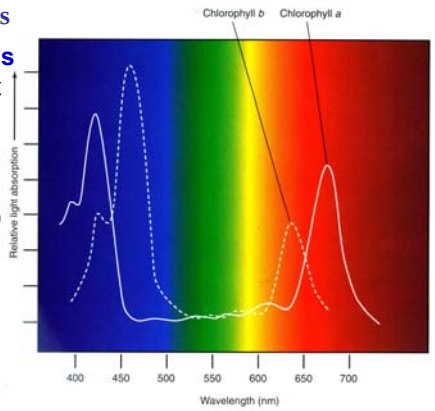
Pigment molecules are embedded in the thylakoid.



Chlorophylls

Chlorophylls are the most abundant pigments in plants.

They absorb primarily blue and red light, reflecting green.



Photosynthesis: the overall reaction

Carbon dioxide + Water + Sunlight yields Glucose + Oxygen

-- more precisely --

$6\ CO_2 + 6\ H_2O + \text{sunlight} \longrightarrow C_6H_{12}O_6 + 6\ O_2$

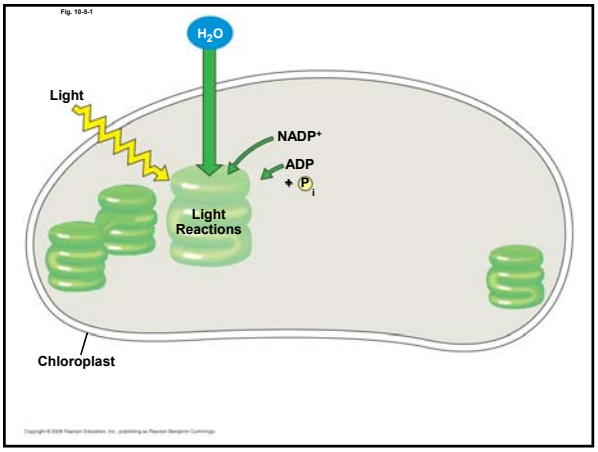
Note that this is the reverse of cellular respiration!

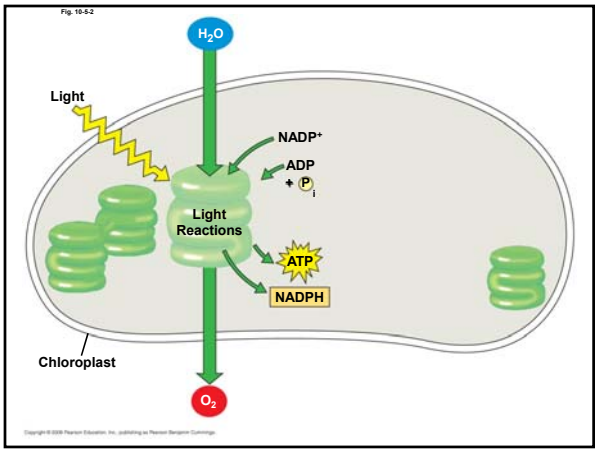
Photosynthesis occurs in two parts: the light reactions and the Calvin cycle.

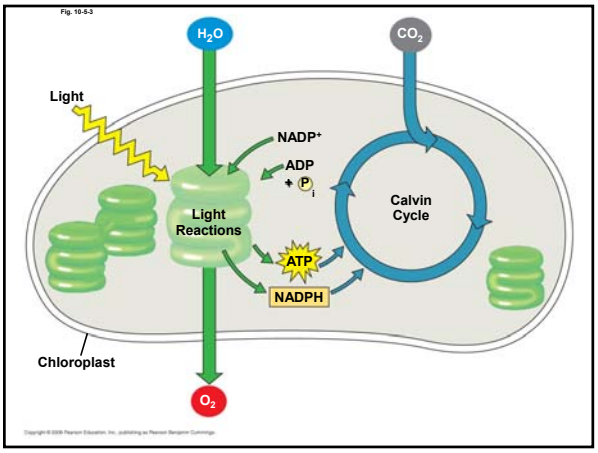
The **light reactions** (in the thylakoids):

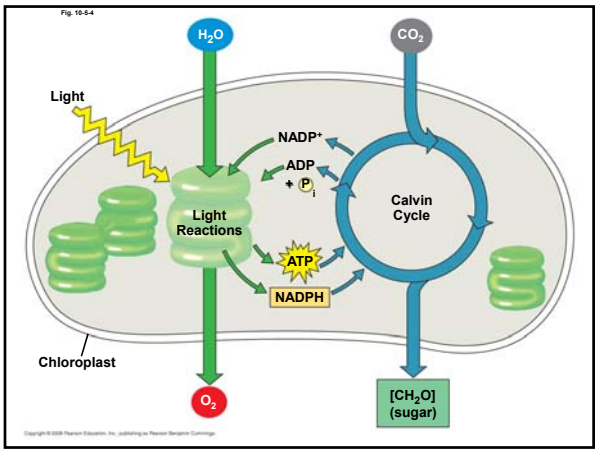
- Split H_2O
- Release O_2
- Convert **$NADP^+$** to NADPH
- Generate ATP from ADP.

The **Calvin cycle** (in the stroma) forms sugar from CO_2, using ATP and NADPH.

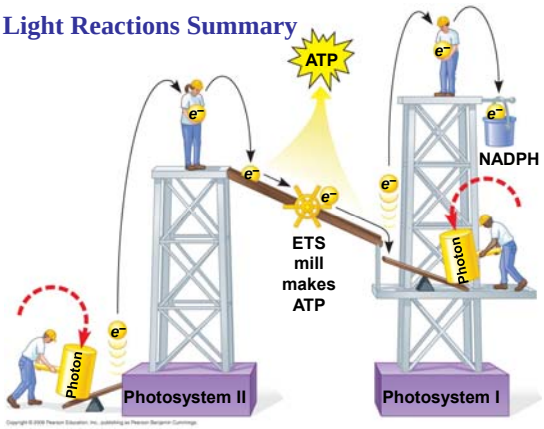








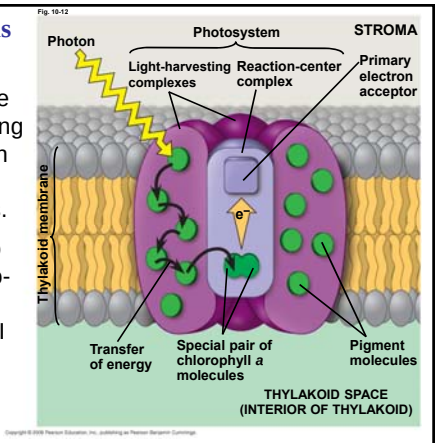
Light Reactions Summary



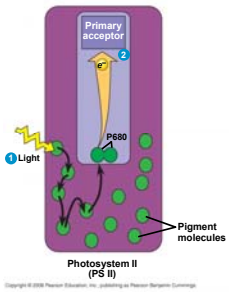
Photosystems

Pigment molecules are organized along with a reaction center into photosystems.

There are two kinds of photo-systems, Photosystem I and Photo-system II.



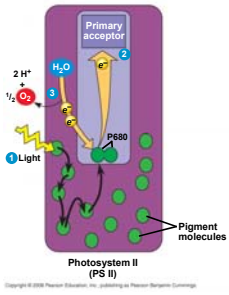
The light reactions begin in Photosystem II.



Light striking a pigment molecule cause electrons in it to become "excited": they jump from a lower energy level to a higher energy level.

They immediately jump back down to the more stable lower level, but transfer the energy to an acceptor molecule in the reaction center.

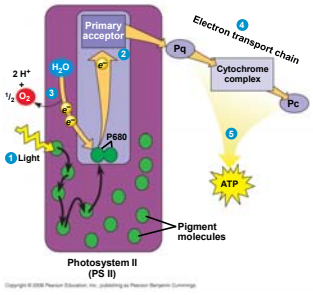
Photosystem II - splitting water



The energy absorbed by the acceptor molecule eventually causes one of its electrons to be passed to the first member of an electron transport chain.

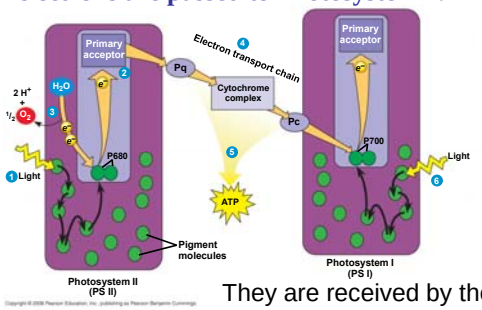
Electrons lost by the acceptor molecule are replaced by splitting water: a water molecule looses electrons, releasing hydrogen ions and oxygen gas.

The electron transport system makes ATP.



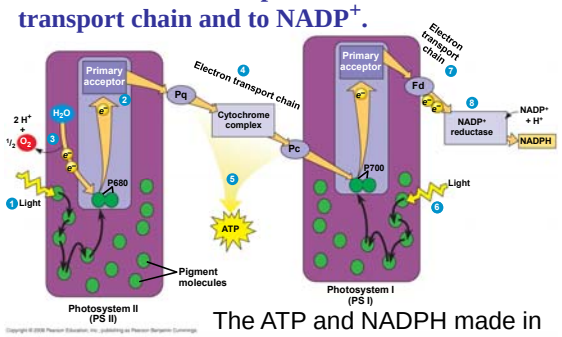
ATP are made by the electron transport system in a way similar to their manufacture in mitochondria.

At the end of the electron transport chain electrons are passed to Photosystem 1.



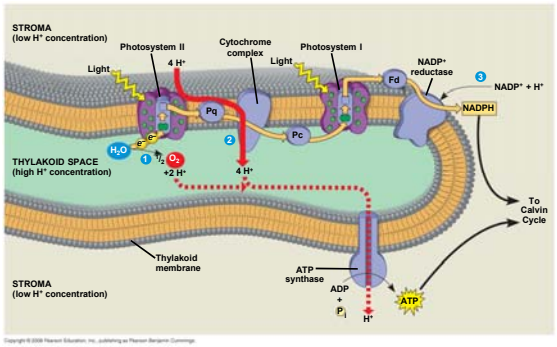
They are received by the Photosystem 1 acceptor and can be re-excited from it.

The excited electrons pass to another electron transport chain and to $NADP^+$.



The ATP and NADPH made in the light reactions go to the Calvin cycle.

Light Reactions Summary

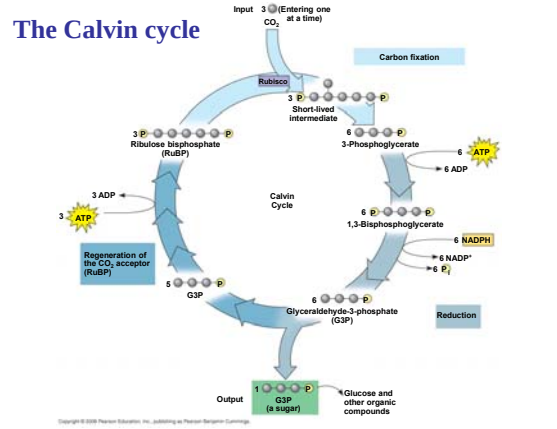


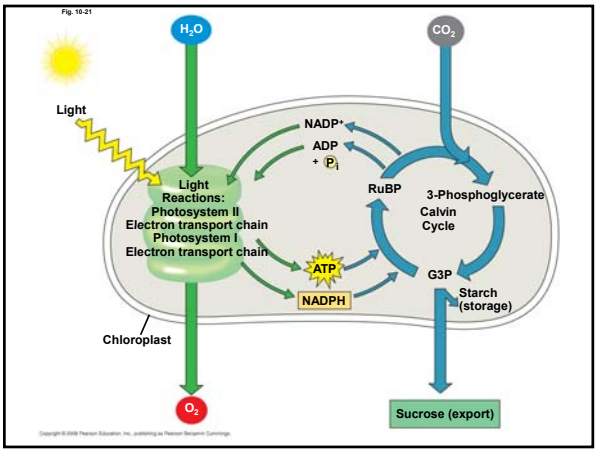
The Calvin cycle convert CO_2 to sugar

The Calvin cycle, like the Krebs cycle, regenerates its starting material after molecules enter and leave the cycle.

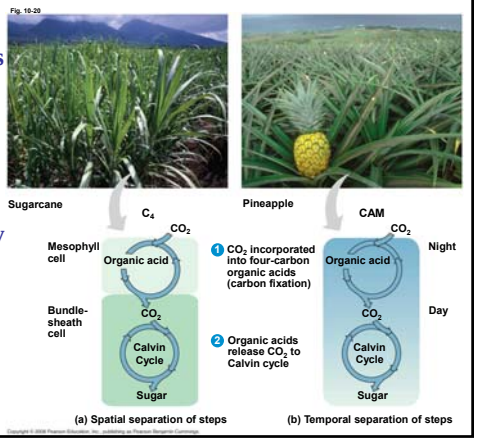
The cycle builds sugar from smaller molecules by using ATP and the reducing power of electrons carried by NADPH.

The Calvin cycle





Alternate variations of photo-synthesis occur in some plants in hot or dry climates.



The Importance of Photosynthesis: A Review

- The energy entering chloroplasts as sunlight gets stored as chemical energy in organic compounds.
- Sugar made in the chloroplasts supplies chemical energy and carbon skeletons to synthesize the organic molecules of cells.
- Plants store excess sugar as starch in structures such as roots, tubers, seeds, and fruits.
- In addition to food production, photosynthesis produces the O_2 in our atmosphere.