Cellular Energetics

Photosynthesis, Cellular Respiration and Fermentation

TEKS

B.4 Science concepts. The student knows that cells are the basic structures of all living things with specialized parts that perform specific functions and that viruses are different from cells. The student is expected to:

B.4B investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules

B.9 Science concepts. The student knows the significance of various molecules involved in metabolic processes and energy conversions that occur in living organisms. The student is expected to:

B.9B compare the reactants and products of photosynthesis and cellular respiration in terms of energy and matter;

Vocabulary

- Chemical Reaction
- Reactant
- Product
- Photosynthesis
- Autotroph
- Producer
- Chloroplast
- Light Dependent Reaction
- Calvin Cycle
- Cellular Respiration
- Heterotroph
- Consumer
- Adenosine Triphosphate (ATP)
- Mitochondria
- Glycolysis
- Krebs/Citric Acid cycle
- ETC (Oxydative Phosphorylation)
- Fermentation
- Endosymbiotic Theory

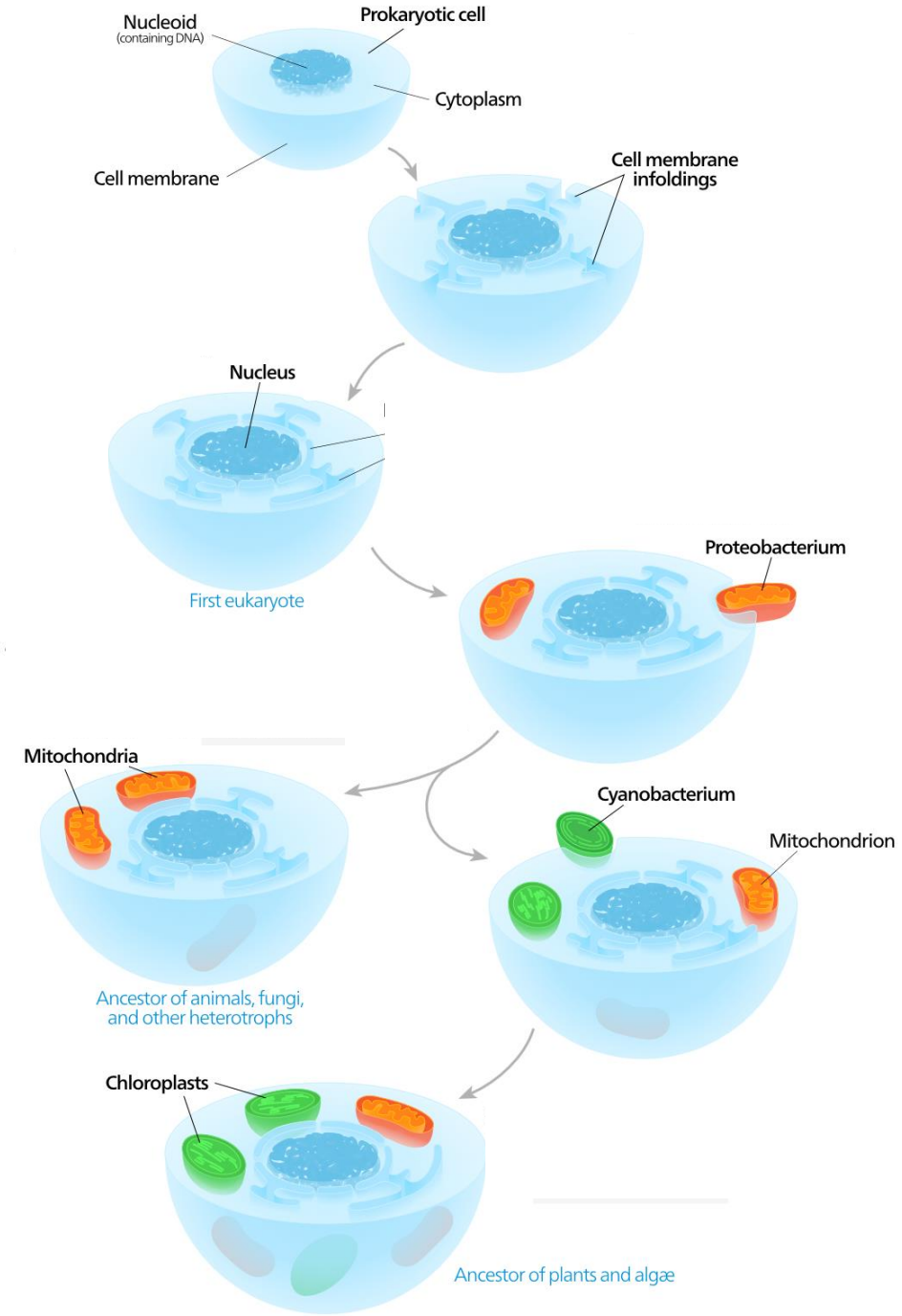
Essential Question

- How do energy and matter flow through the processes of photosynthesis and cellular respiration?

How organisms get energy

1. **Autotrophs**: able to produce own glucose
   - Ex: plants, algae, cyanobacteria
   - Also called: **producers**

2. **Heterotrophs**: must take in glucose from outside source
   - Ex: animals, fungus, most bacteria, protozoans
   - Also called: **consumers**



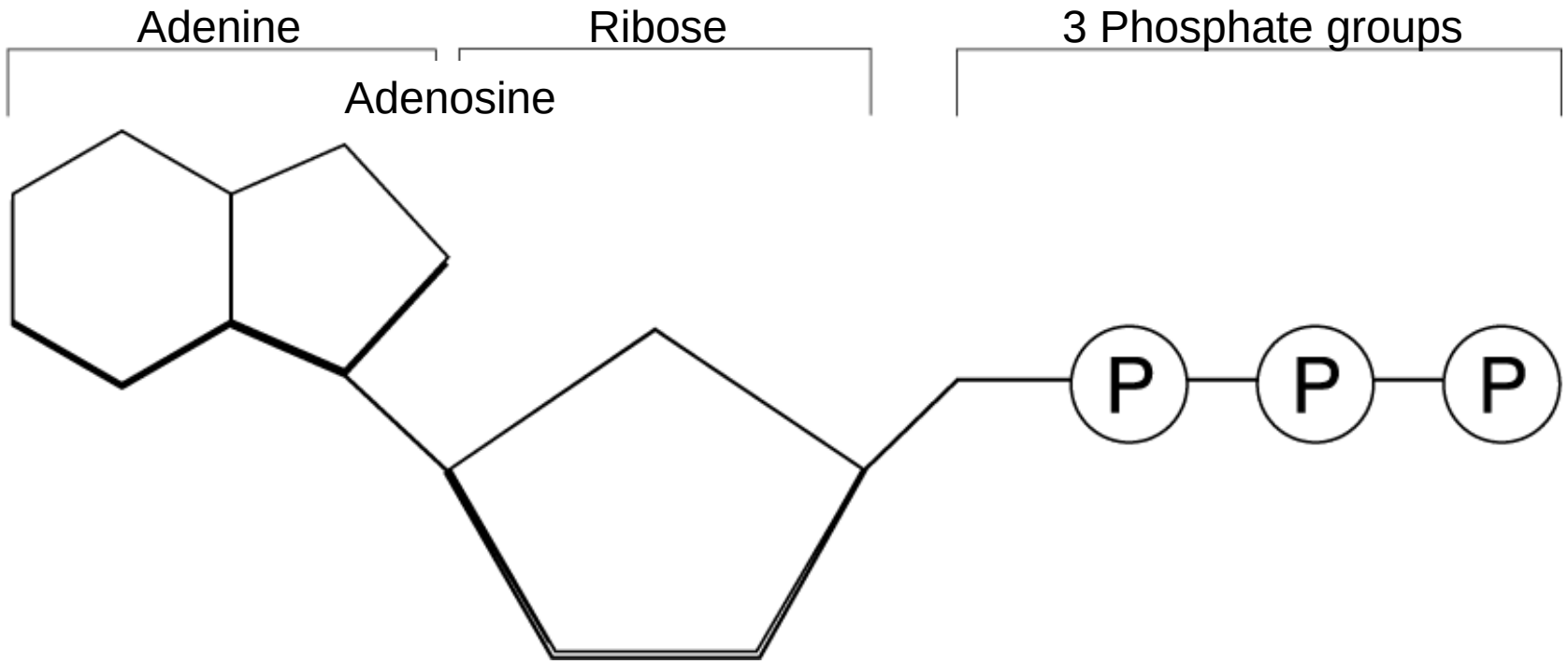
Endosymbiotic Theory

- **Lynn Margulis** proposed that certain organelles evolved from a symbiotic relationship between a host cell and early prokaryotes. This is supported by observation & data.
- **Mitochondria** were chemosynthetic aerobic prokaryotes
- **Chloroplasts** were photosynthetic prokaryotes

Why is food so important?

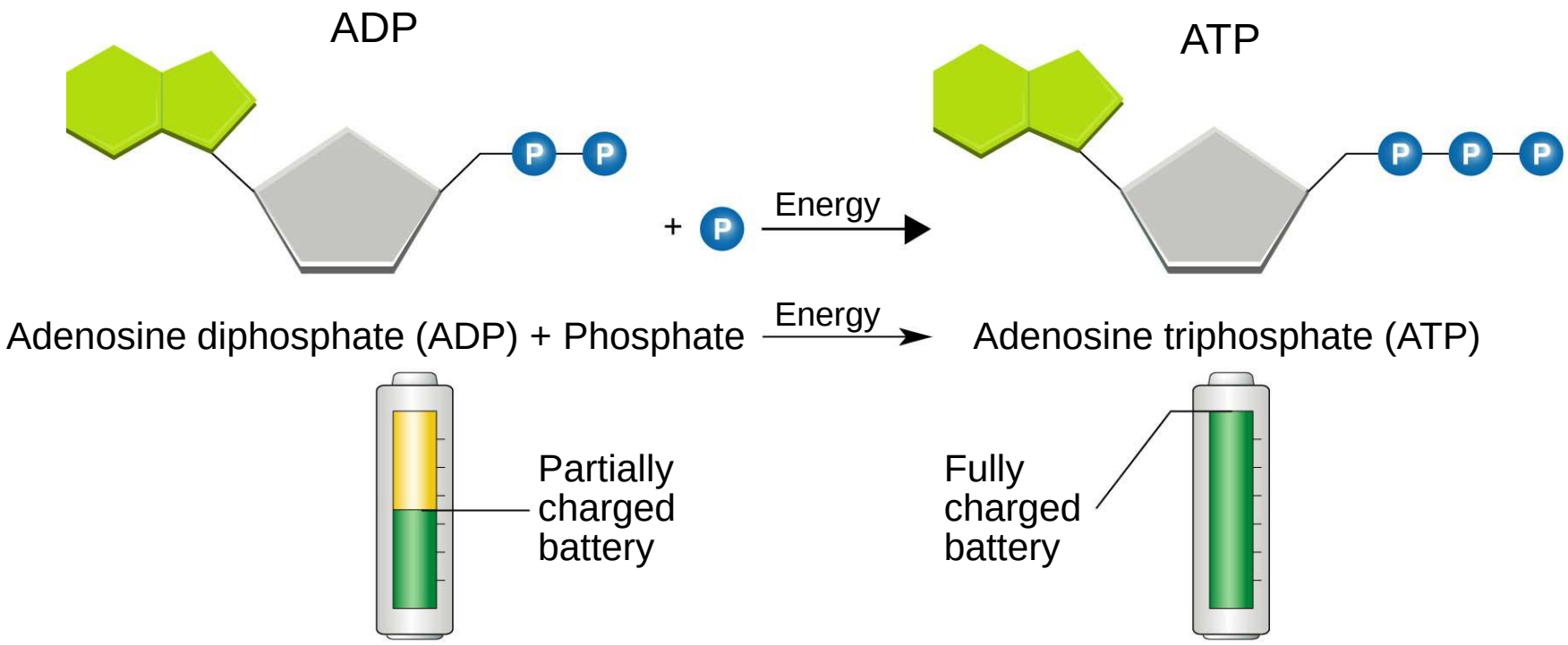
- The energy from carbon based molecules (food) is needed to re-charge **ADP** **(adenosine di-phosphate)** to **ATP** **(adenosine tri-phosphate)** molecules

- ATP provides energy for ***ALL*** metabolic reactions.



ADP and ATP

- To get energy out of ATP, the bond between the last two phosphate groups is broken.



Importance of energy

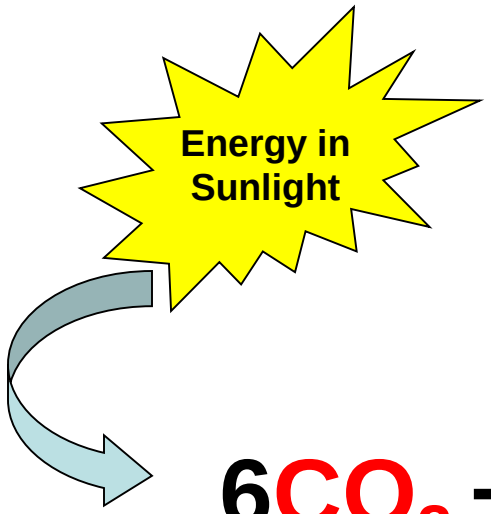
- Cells need **energy** to be able to carry out important metabolic functions to sustain life.

  - Ex: Active transport, cell division, movement of flagella or cilia, and the production, transport, and storage of proteins

Photosynthesis

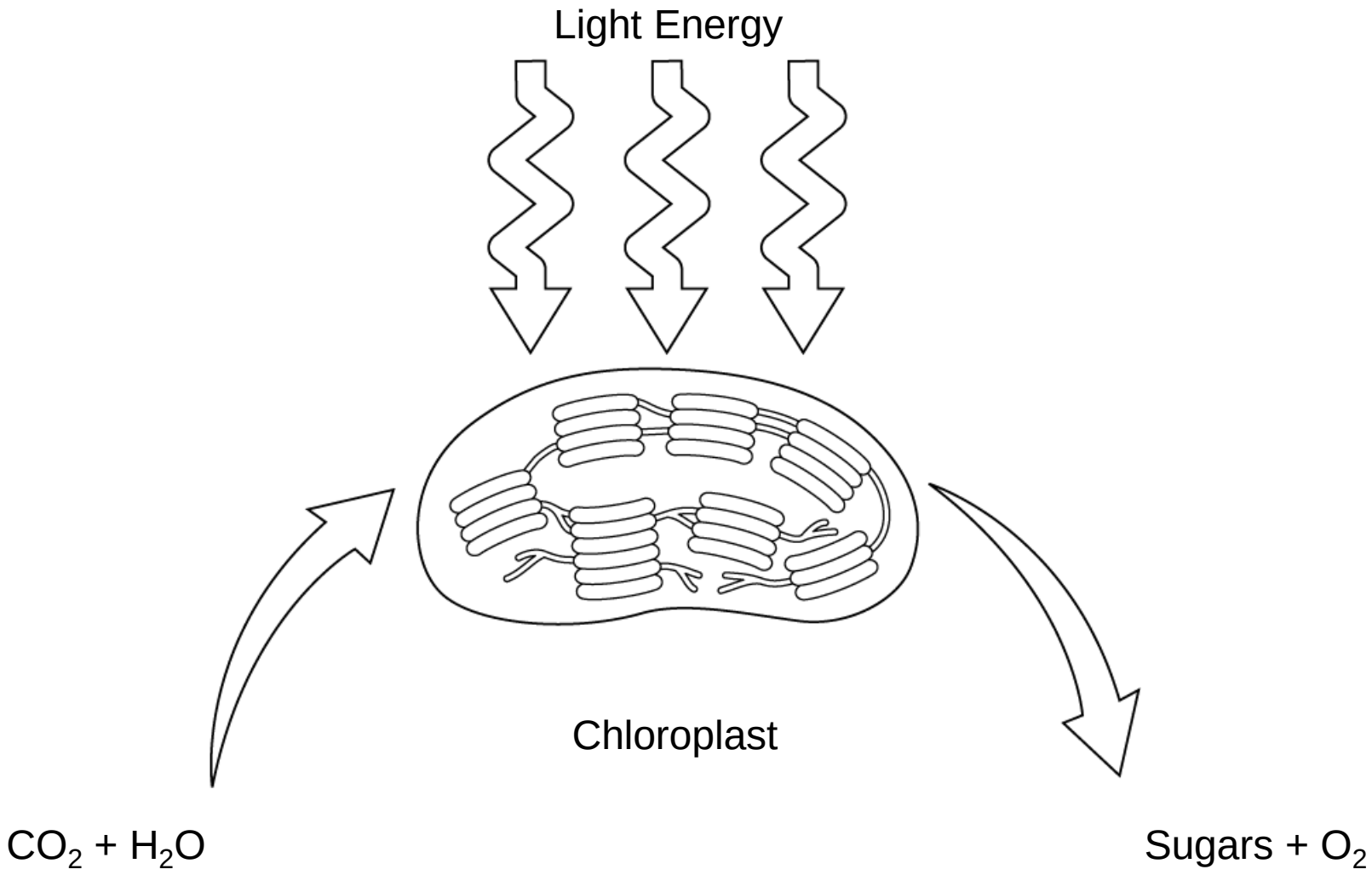
- The process autotrophs use to make glucose sugars from carbon dioxide, water, and light energy

Photosynthesis

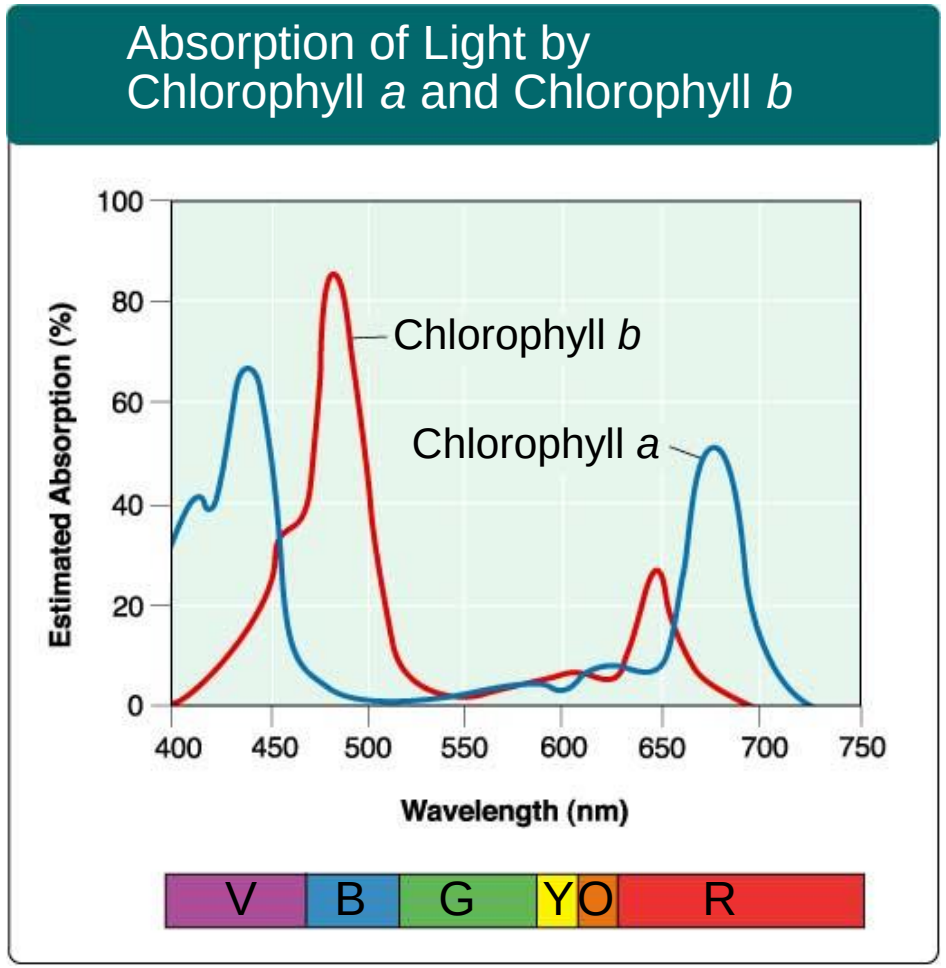


$$6CO_2 + 6H_2O \xrightarrow{\text{Enzymes}} C_6H_{12}O_6 + 6O_2$$

Where and how are sugars made?



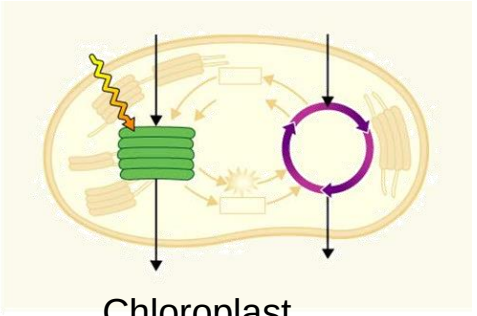
Pigments



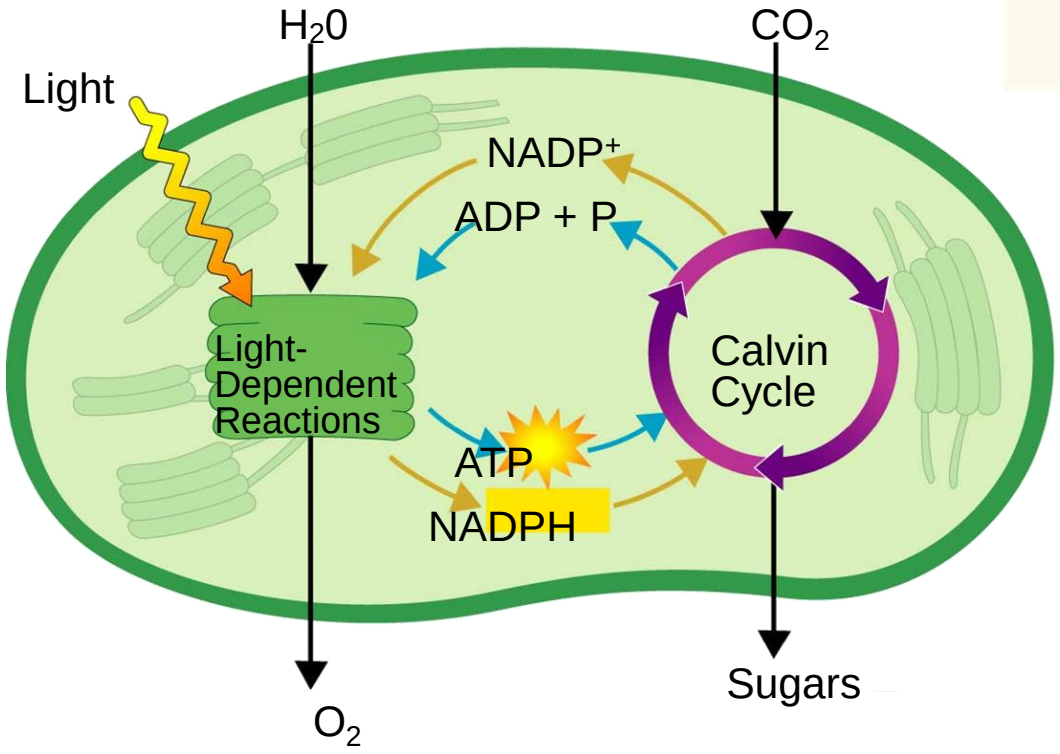
- Chlorophyll is a pigment, a molecule that can absorb light energy.
- Unused light is reflected.
- What is the color of the wavelength least used by chlorophyll?

Photosynthesis is an endergonic reaction…”energy in”

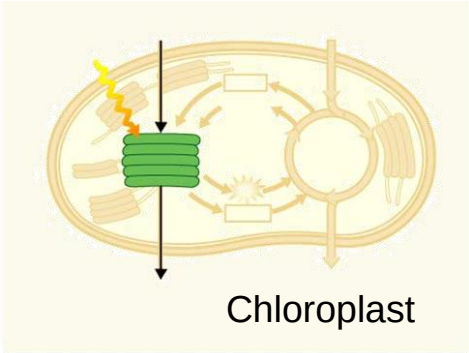
1. Light dependent reaction
2. Calvin cycle

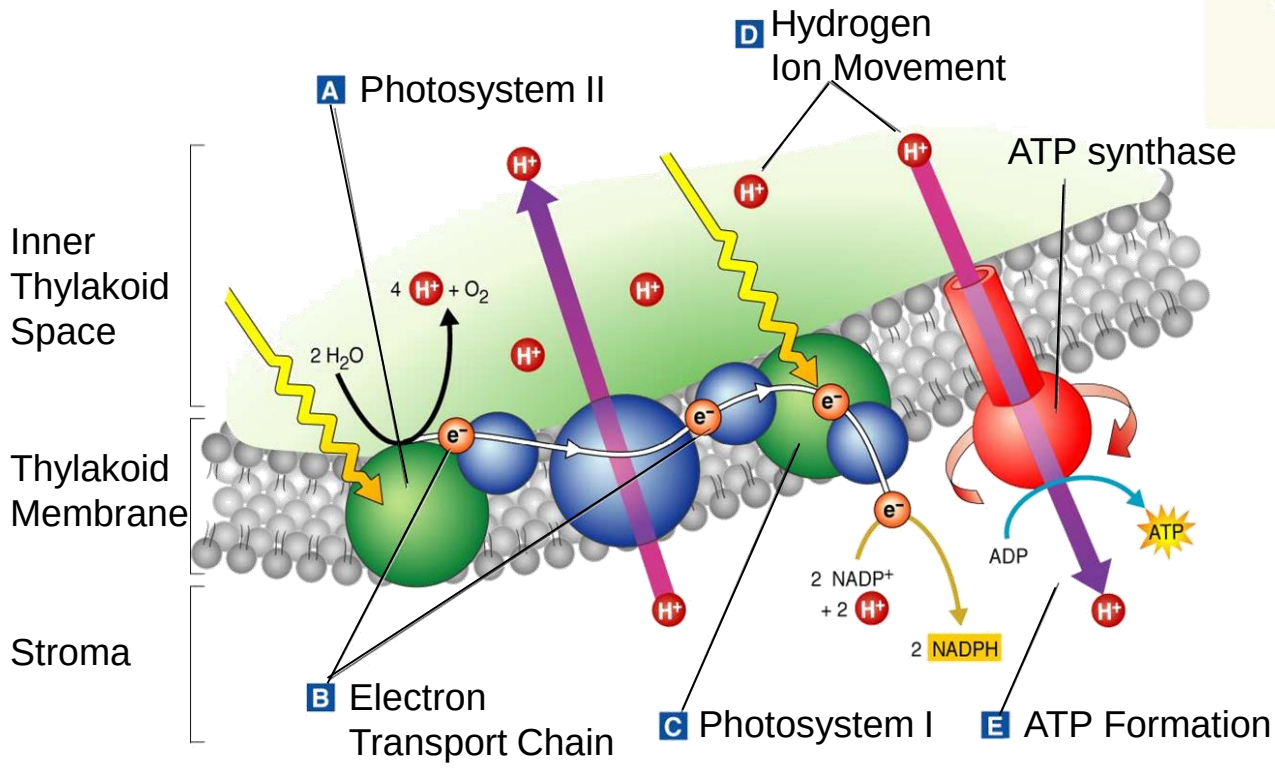


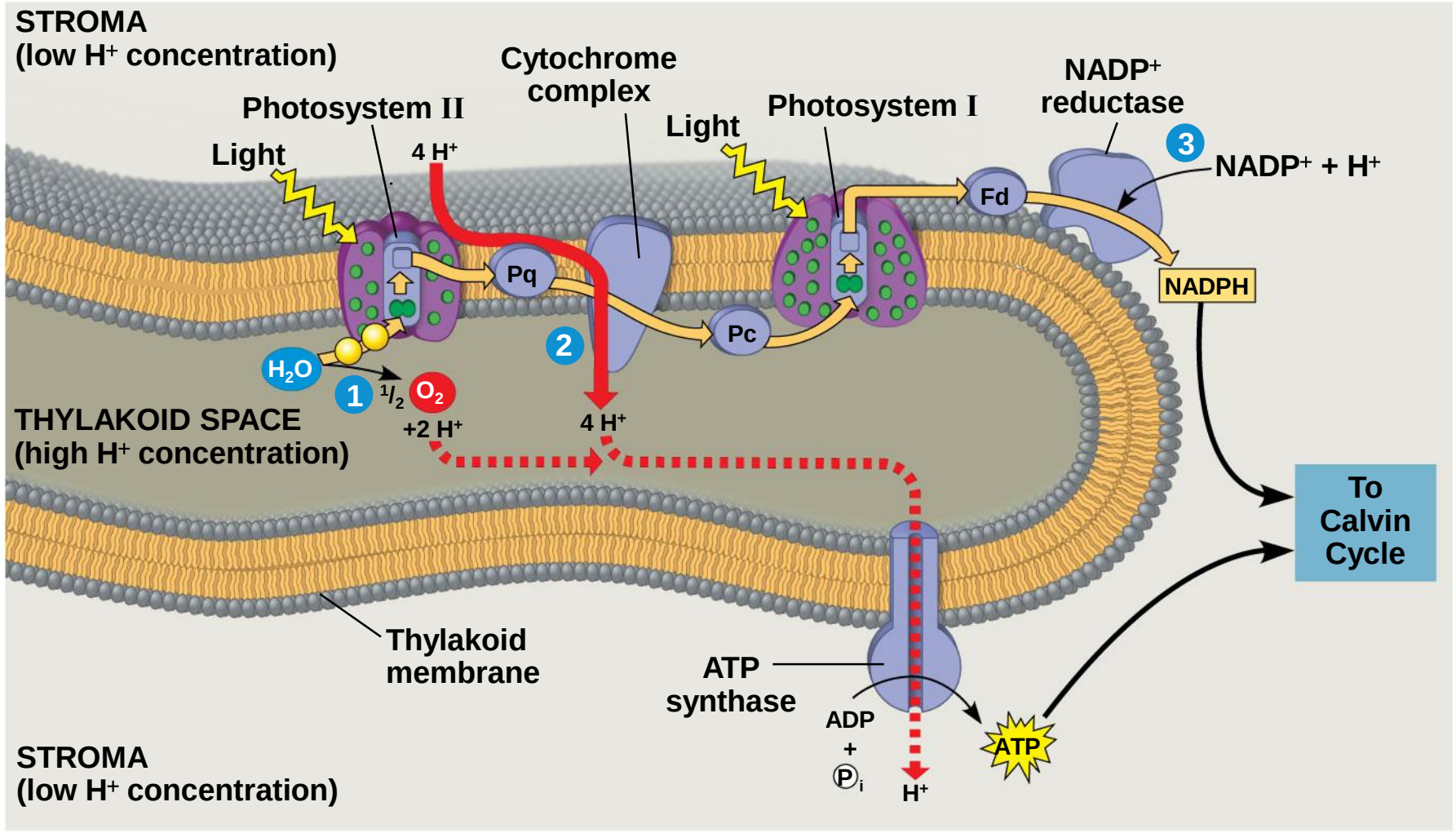
Chloroplast



Step 1: Light dependent reaction





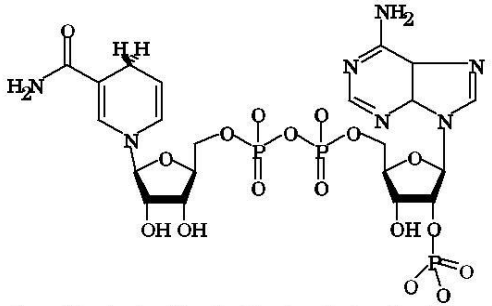


Light dependent reaction

- Pigments (chlorophyll) inside of the chloroplasts are arranged into **photosystems** (PS II and PS I).

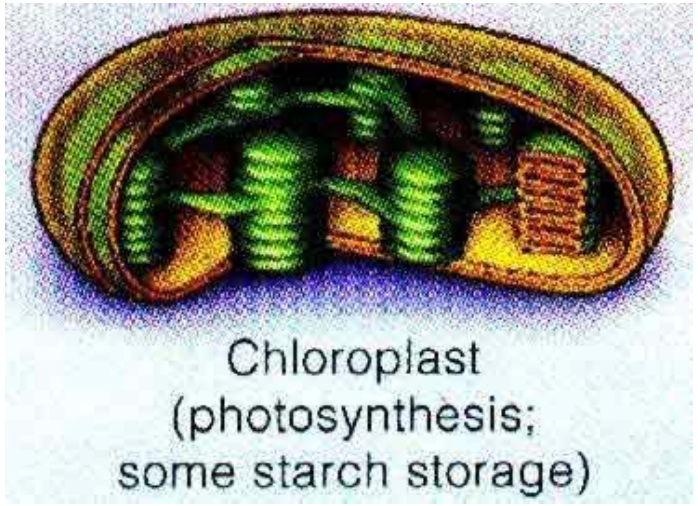
- Photosystems absorb sunlight.

- Electrons become energized and help to produce ATP & NADPH.



Nicotinamide adenine dinucleotide phosphate reduced form (NADPH)

Step 1: Light Dependent reactions

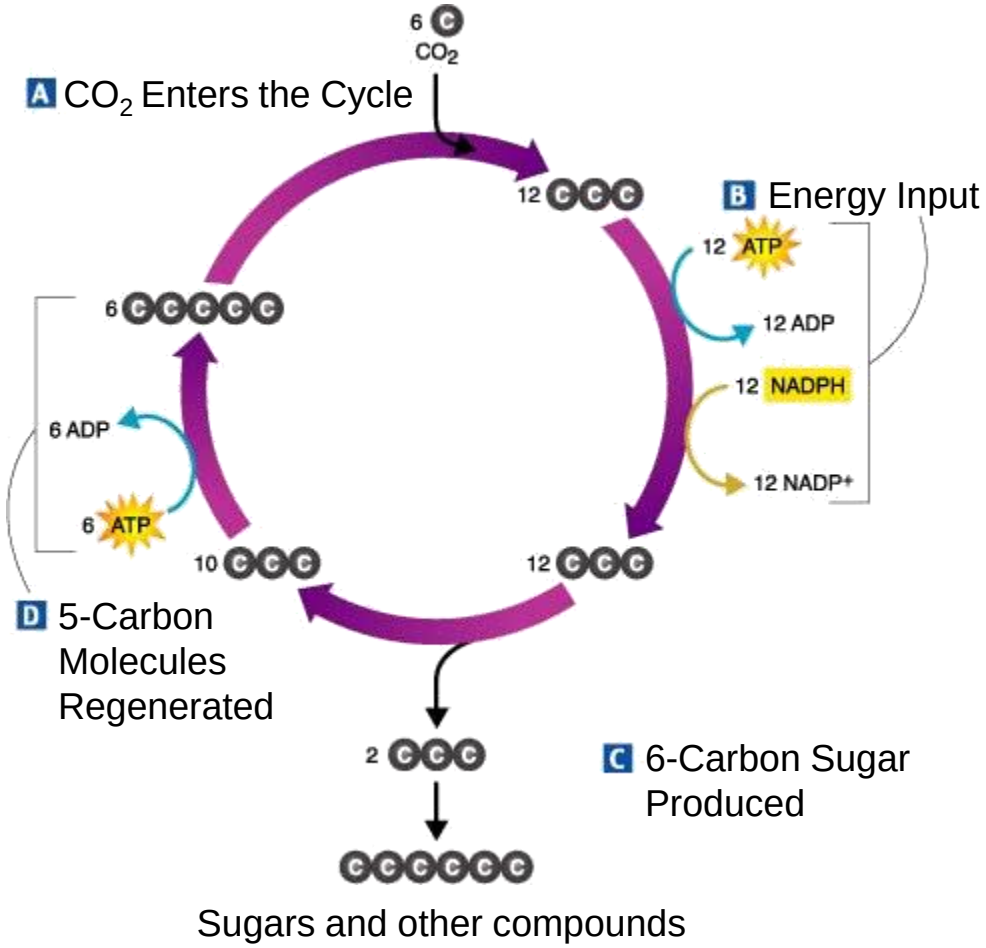


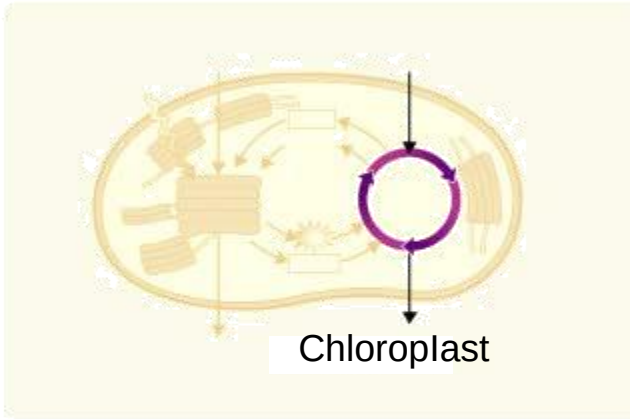
- **location:**
  grana of chloroplast
- **Photosystem II**:
  - energized chlorophyll splits water into Oxygen (released) and Hydrogen (carried by NADP to be used later)
- **Photosystem I**:
  - energized chlorophyll makes ATP (to be used later)

Light Dependent reactions

- The products of the light reactions will move on to the Calvin cycle:
    - ATP
    - NADPH

Step 2: Calvin cycle





Calvin Cycle

- **Location: stroma** (fluid) of chloroplast

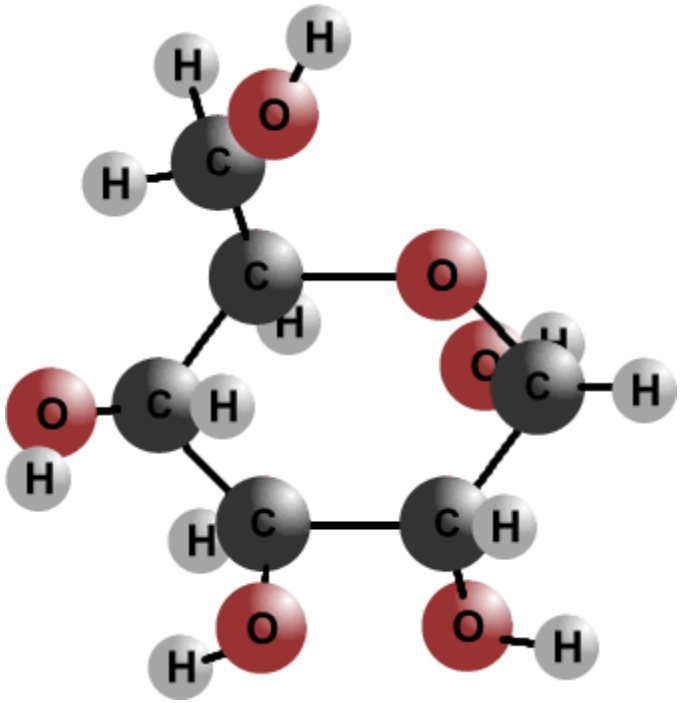
- **CO_2 is "fixed"** meaning it is attached to other molecules in the stroma. Eventually sugar molecules are released from the cycle.

- Products**: Glucose** (sugar/food) is made (from 6 turns of cycle)

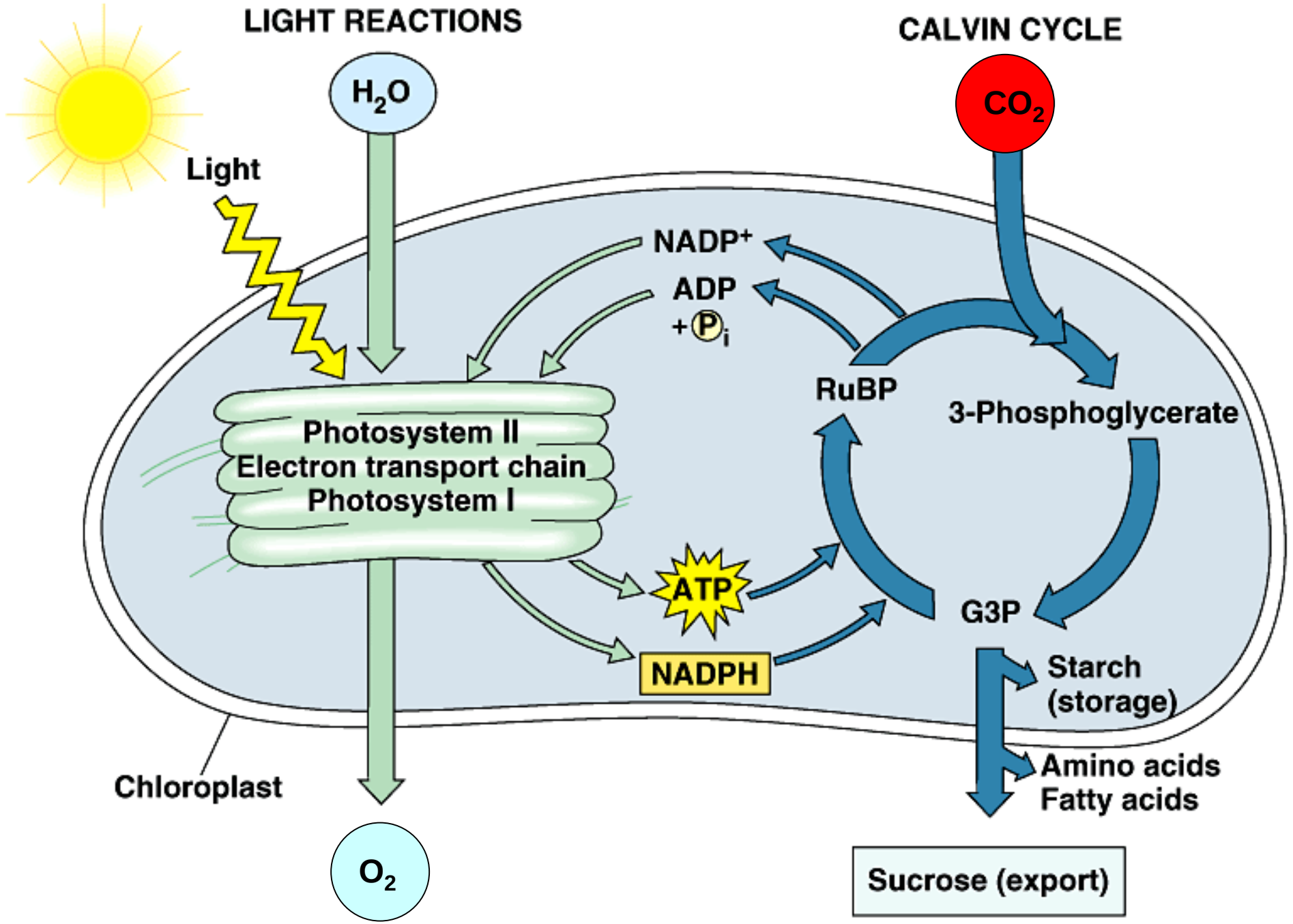
$$\mathbf{6CO_2} + 6H_2O \rightarrow \mathbf{C_6H_{12}O_6} + 6O_2$$

Calvin cycle

- ATP and NADPH supply the energy needed to change the CO_2 taken in by plants into a 6 carbon sugar molecule.



glucose



What happens to the sugar?

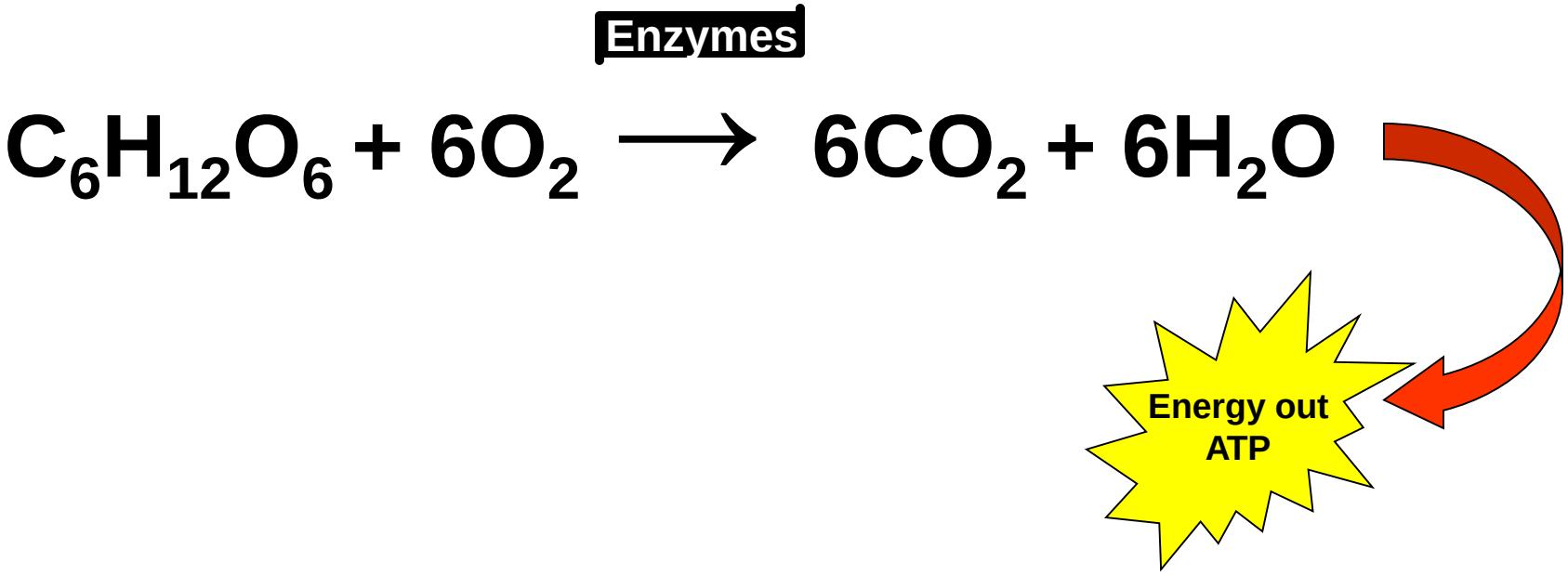
- Plants can store the sugar in roots or stems (ex: potatoes, turnips, carrots, sugar cane)
- Heterotrophs such as humans must eat or consume foods (ex. Carrots, potatoes, etc.) in order to make ATP by cellular respiration.
- Sugars & starches are used to make ATP by cellular respiration as needed.

- ALL living organisms need and use energy.
- Therefore ALL organisms need ATP
- ALL organisms (plants and animals, fungi, bacteria and protists) re-charge their ADP into ATP through respiration

Cellular Respiration

- The process autotrophs and heterotrophs use to break down glucose (energetic molecules) to make ATP

Photosynthesis and Respiration are complementary cycles



Two types of respiration

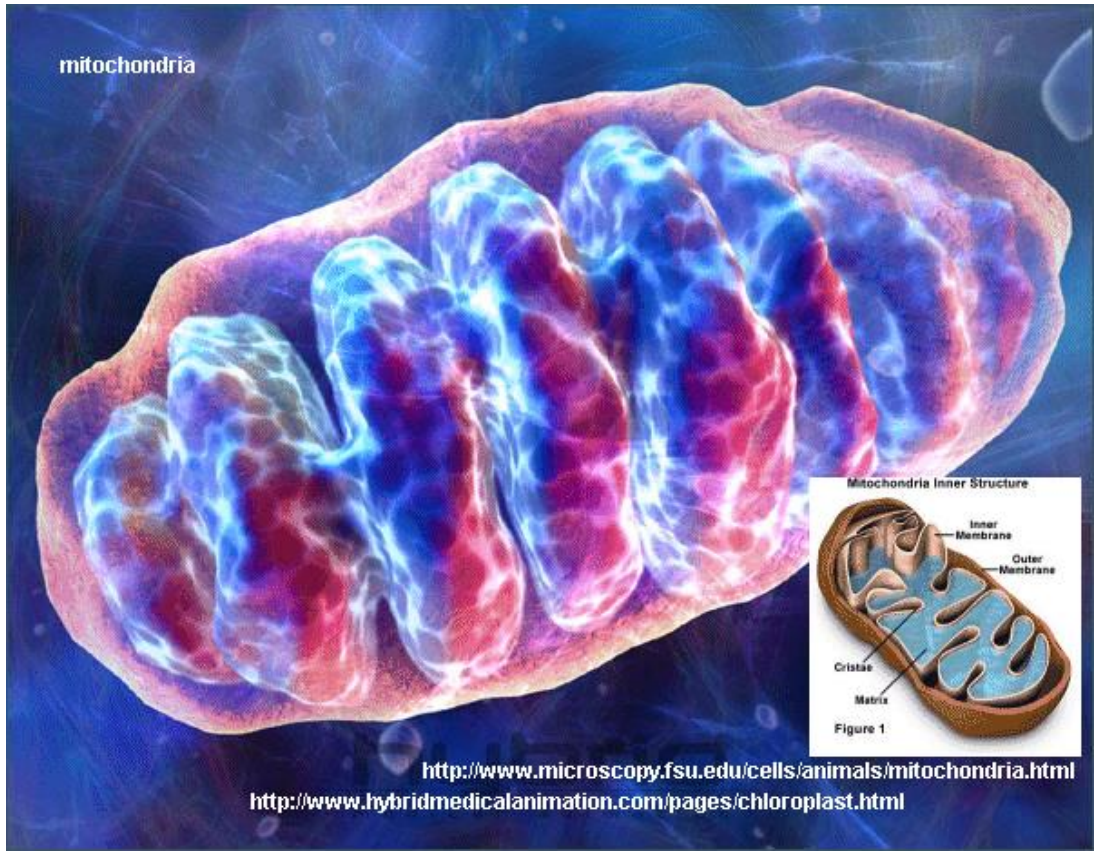
- **Aerobic respiration**: Organisms that require oxygen use aerobic respiration to make ATP but switch to **fermentation** when oxygen is not available.

- **Anaerobic respiration**: Organisms that live without oxygen use anaerobic respiration to make ATP and die in the presence of oxygen.

Where cell respiration takes place

- **<u>Prokaryotes</u>**: cell membrane
  (don't have mitochondria)

- **<u>Eukaryotes</u>**: mitochondria organelle

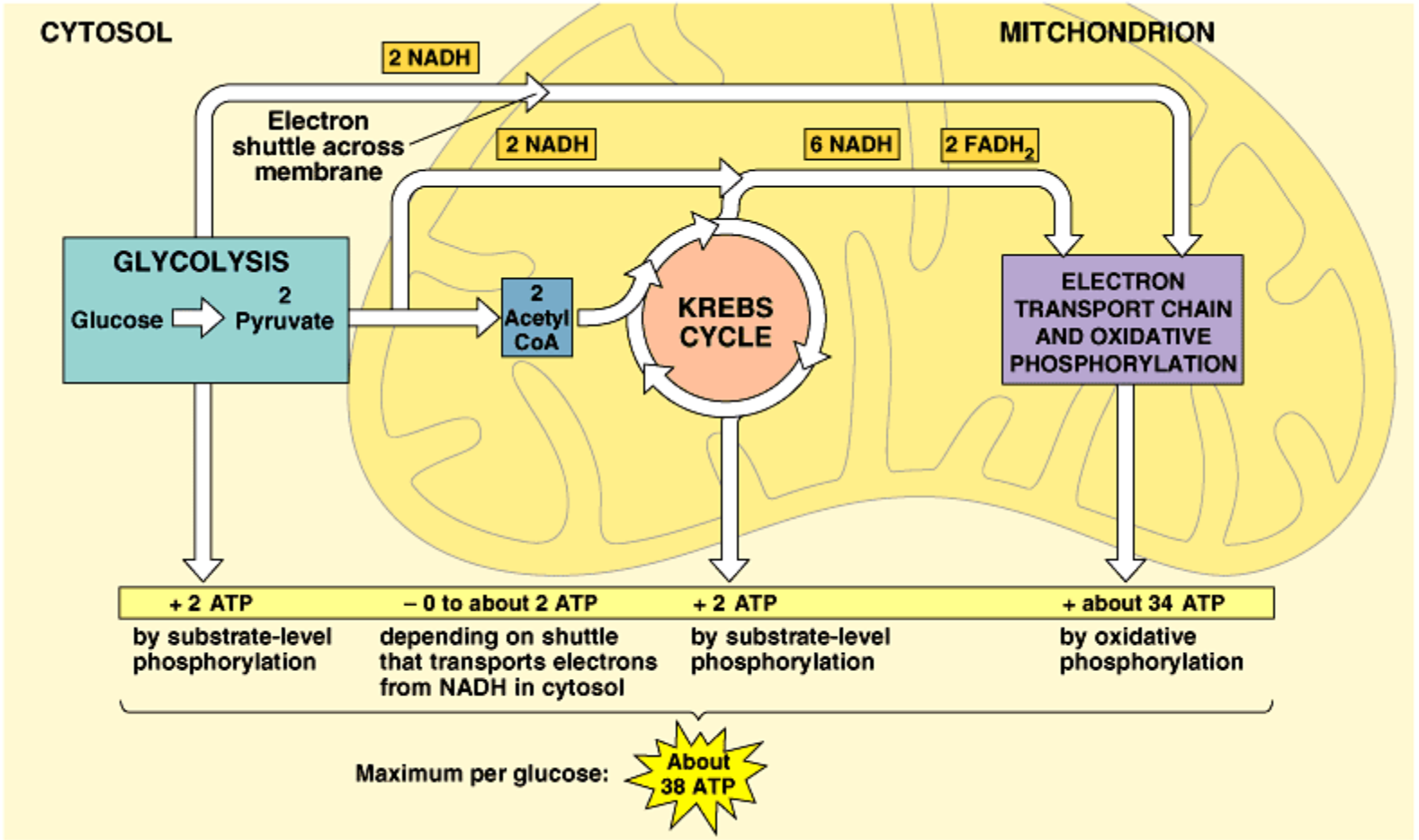


Steps of aerobic respiration

1. **Glycolysis**
2. **Krebs cycle**

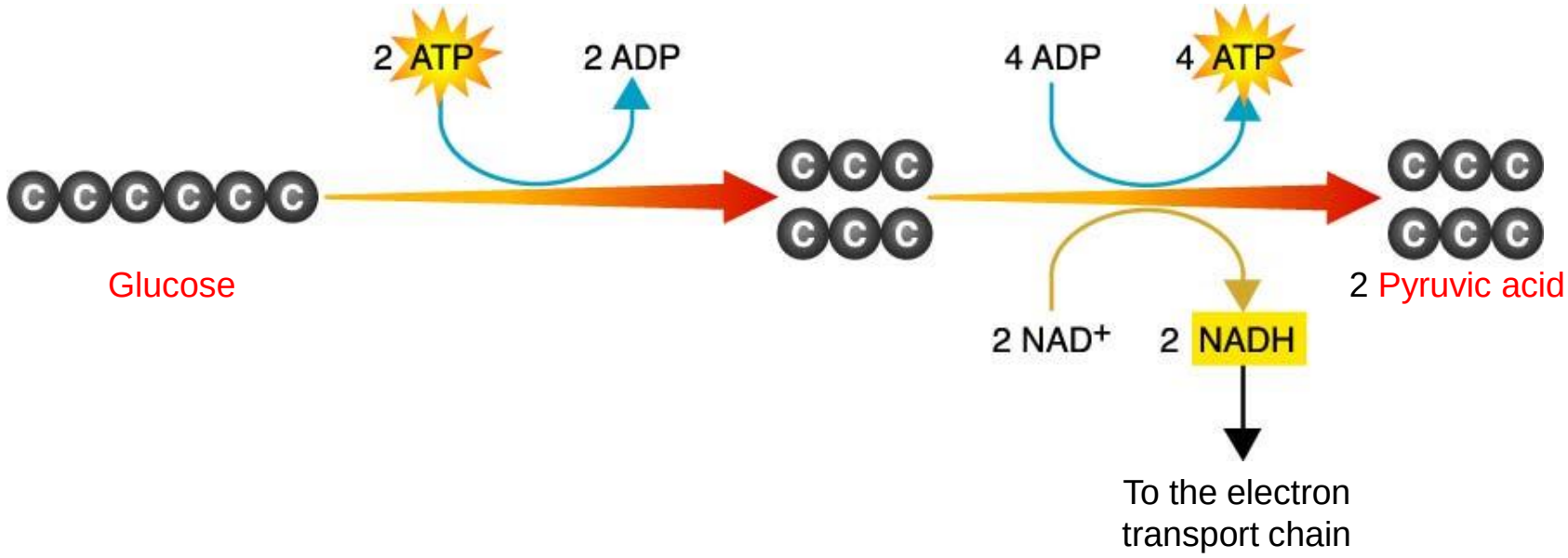
3.1 Electron transport chain

3.2 ATP synthase (Oxidative Phosphorylation)



Step 1: Glycolysis

- Glucose molecules are broken down into two molecules of pyruvic acid.



GLYCOLYSIS

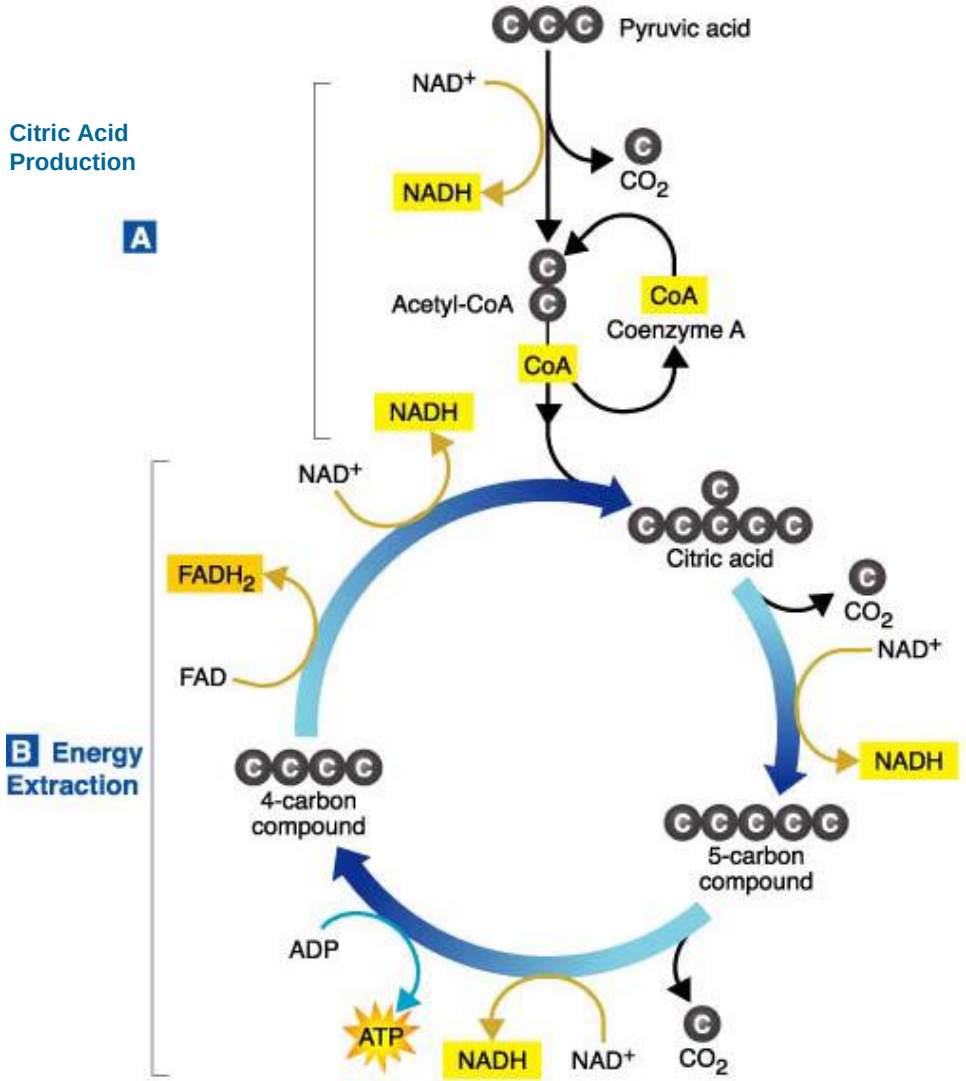
- **Location**: cytoplasm (outside mitochondria)
  - Anaerobic stage (occurs without oxygen)

- Glucose (6C) is split into two Pyruvates (3C) by the force of 2 ATP molecules

- **Products**: Hydrogen is saved by NAD^+ to be used later & 4 ATP (net gain of 2) are produced

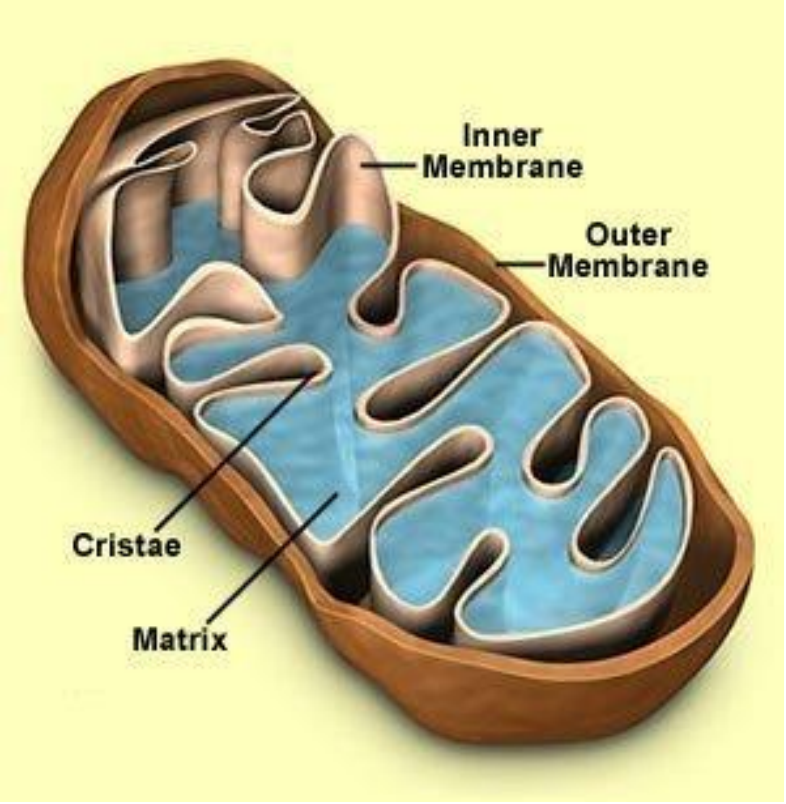
Step 2: Krebs or Citric Acid cycle

- Pyruvates are altered to produce NADH and $FADH_2$, electron carriers.
- CO_2 is created here

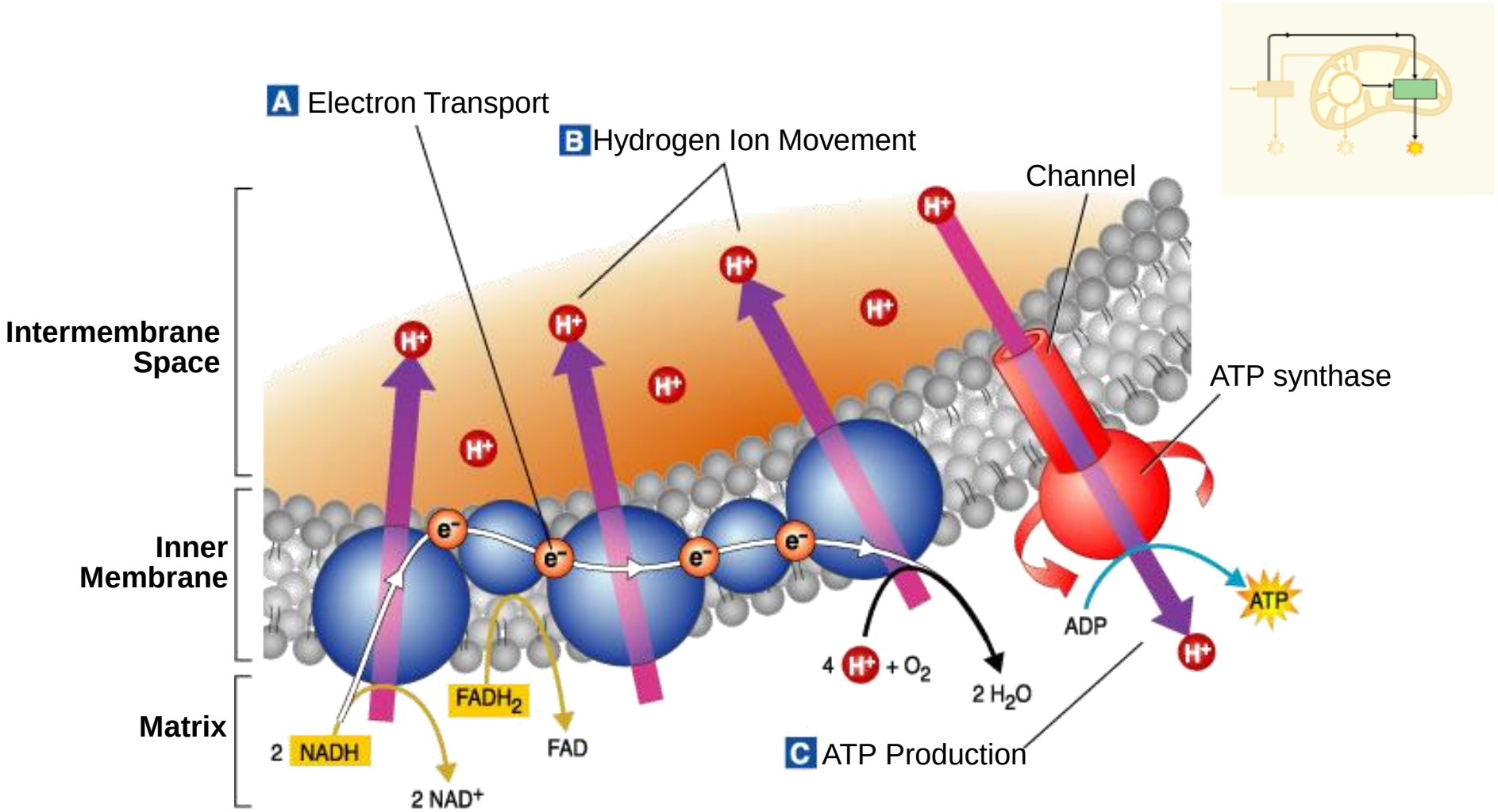


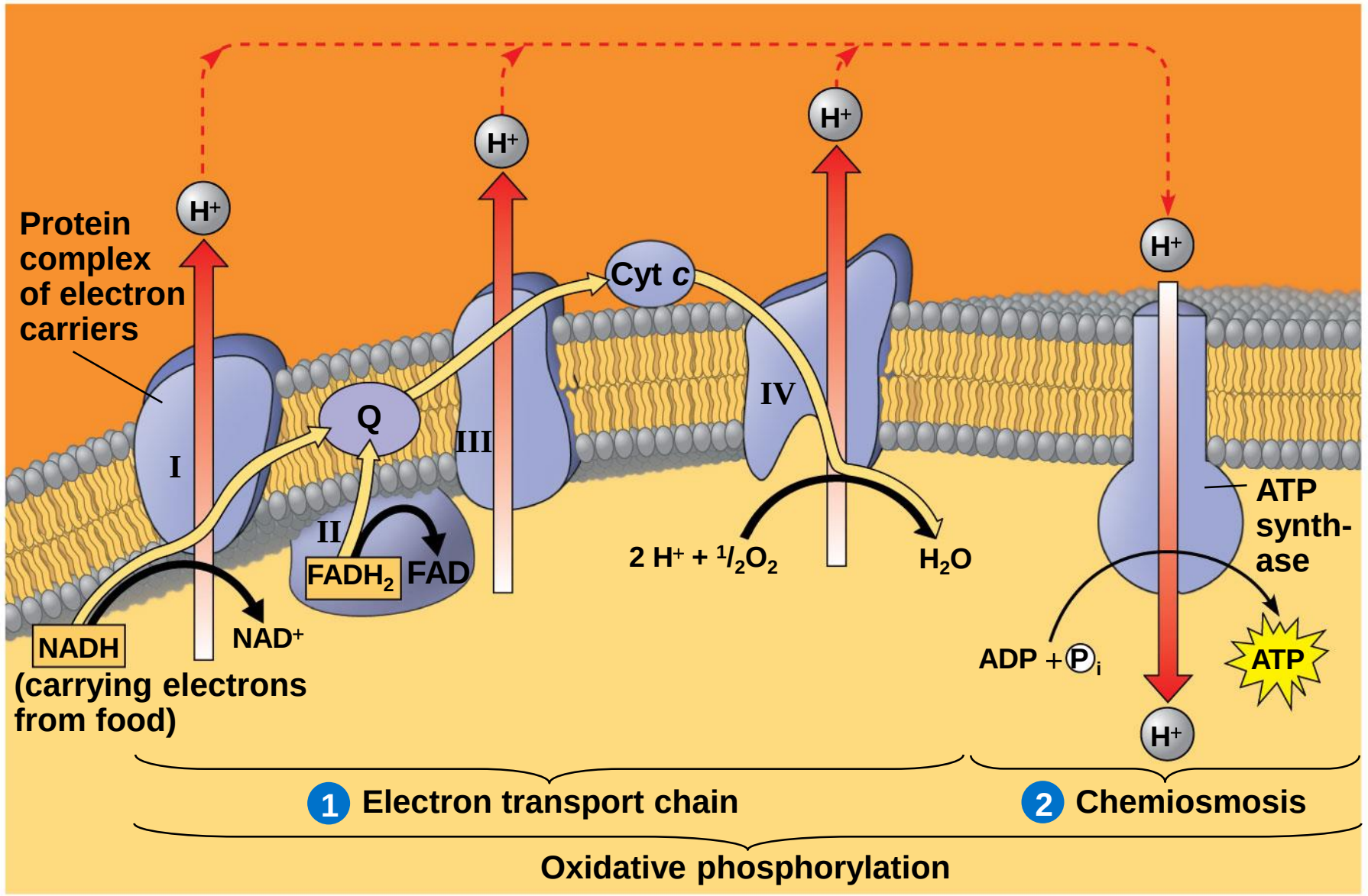
Krebs Cycle

- **Location:** mitochondria (fluid matrix)
- Carbon compounds join & break apart several times during the cycle, releasing lots of CO_2
- **Products:** small amount of ATP & large amount of NADH and $FADH_2$ (used later)



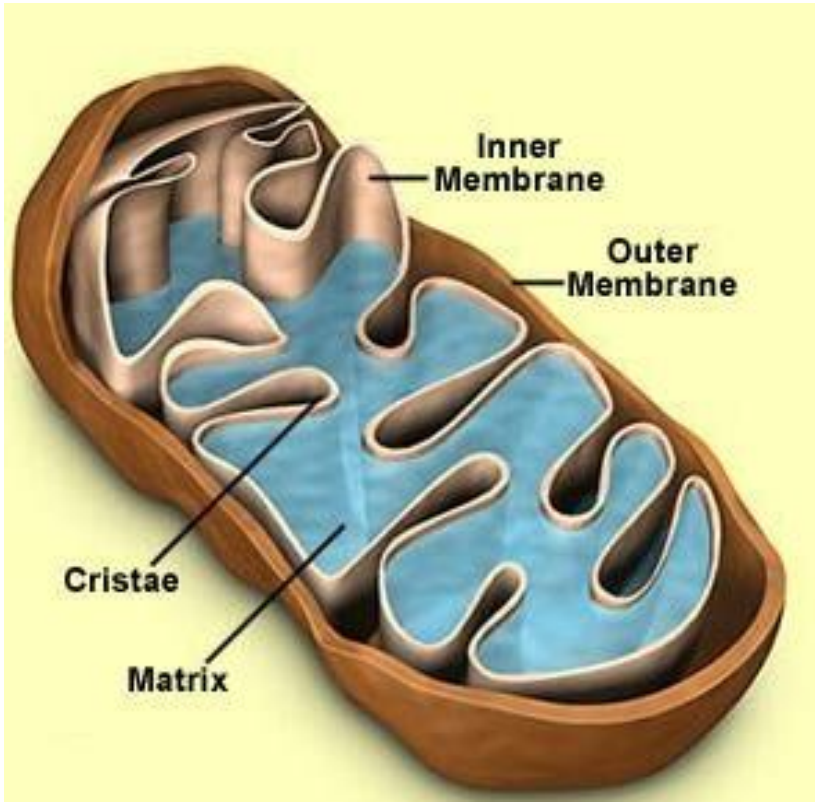
Step 3: **Oxidative Phosphorylation**





Electron transport chain (ETC) & Oxidative Phosphorylation

- **Location**: mitochondria (cristae, inner membrane)
- Energy from Hydrogen atom's electrons is utilized to change ADP into ATP
- Hydrogen ions (H^+) ultimately joins oxygen (O_2) to make water (H_2O) as a waste product

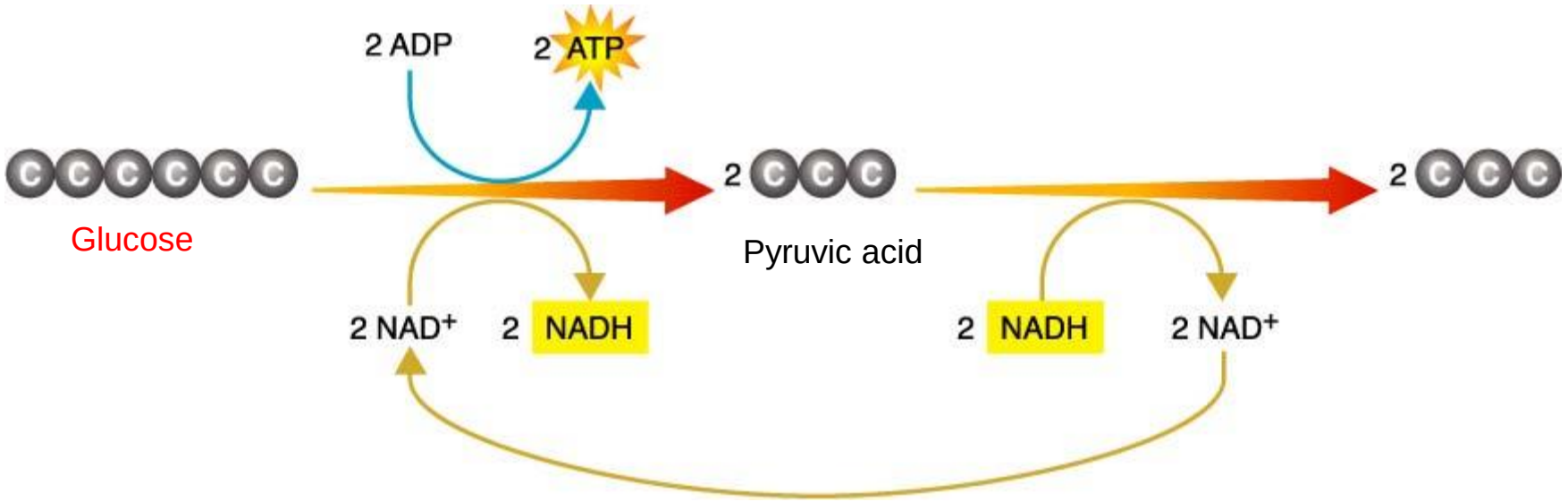


Electron transport chain

- NADH and $FADH_2$ supplies the electron needed to start the ETC.
- Hydrogen ions (protons) are pumped into the inner membrane space.
- The protons flow through the ATP-making enzyme (**ATP synthase**), activating the enzyme to add a phosphate group to ADP to make ATP.
- The electrons from the chain end up on Oxygen (O_2) and turn into Water (H_2O)

What happens if there is no oxygen available and the organism is aerobic?

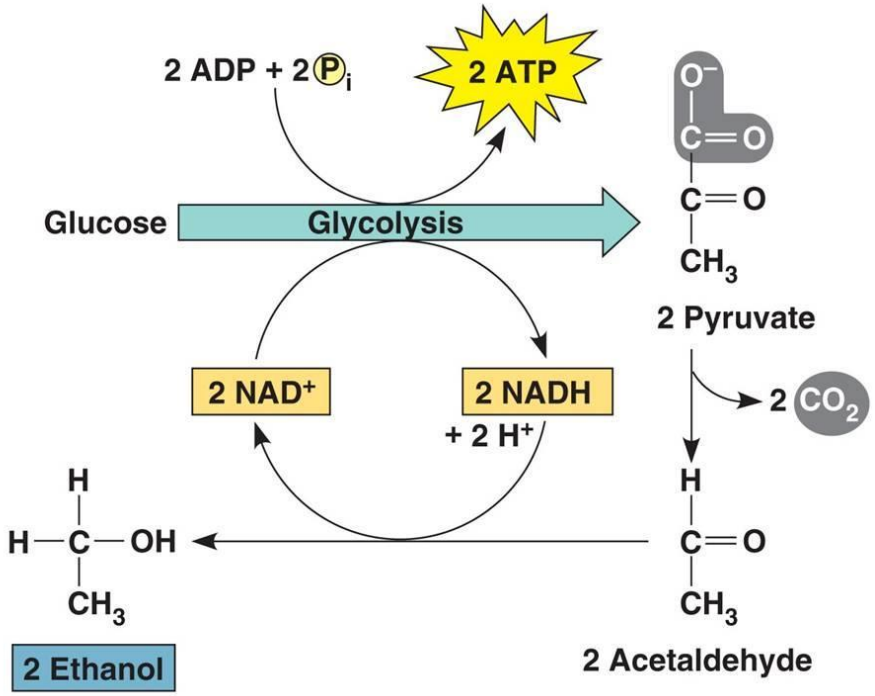
1. Glycolysis
2. Fermentation: lactic acid or alcohol



Fermentation

- The process of making a little ATP without the presence of Oxygen.

Alcoholic Fermentation
(anaerobic respiration)



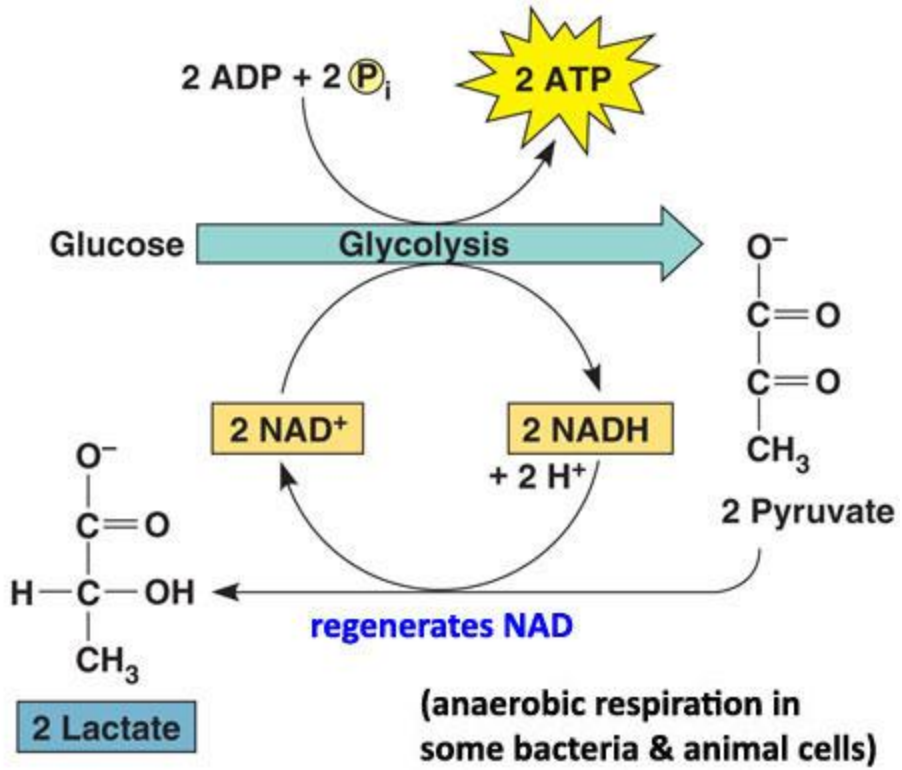
- Without enough oxygen present, an “alternate route” is taken, producing other products & ***much less*** ATP

- **In yeast: Alcohol and CO_2 are produced**
- Ex: in bread-making & the alcohol industry

Alcohol industry

- Yeast undergo alcohol fermentation when they do not have oxygen to make ATP.
- The alcohol industry uses specific yeast to convert fruit sugars into alcohol.

Lactic Acid Fermentation
(anaerobic respiration)



- Without enough oxygen present, an “alternate route” is taken, producing other products & ***much less*** ATP

- **In muscles: lactate is produced**

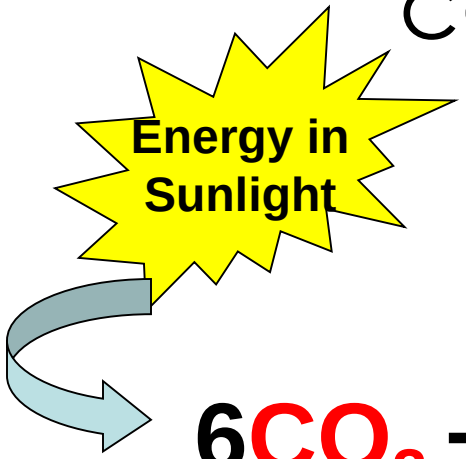
- Causes sore muscles

Sore muscles

- When a person exercises, the muscle cells use up oxygen faster than a person can breathe in.
- The muscle cells need O_2 to make ATP.
- The cells perform lactic acid fermentation instead producing lactic acid in the cells and when in higher concentrations, makes muscles feel sore.

US Swim Team members 2004

Photosynthesis and Respiration are complementary cycles



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

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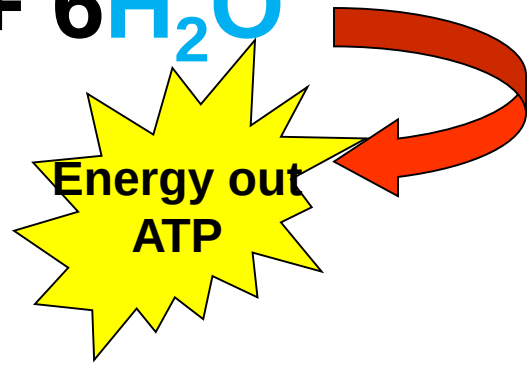
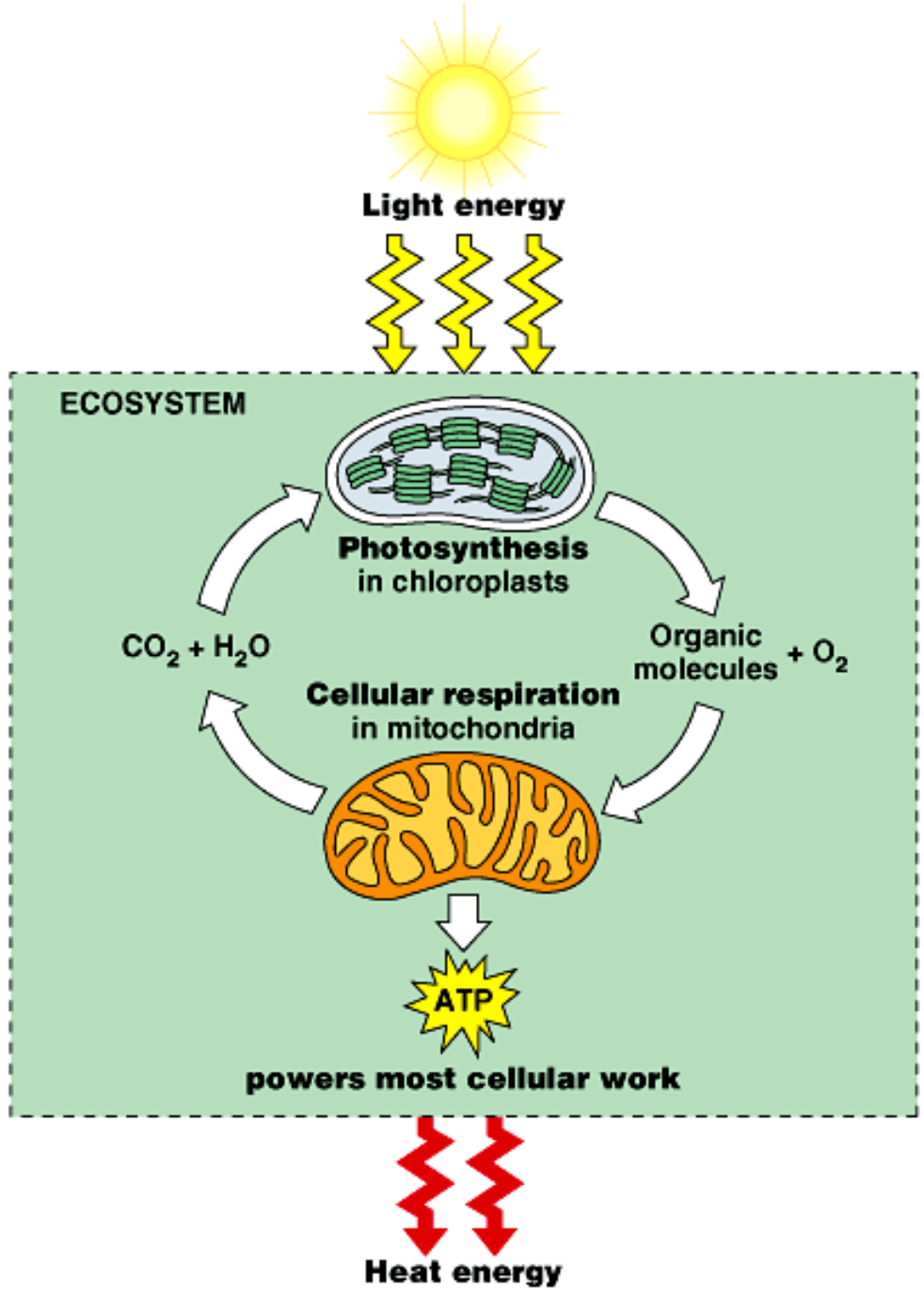




ATP and HEAT

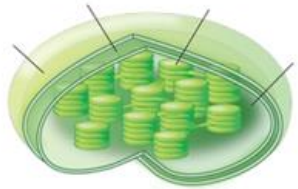
Solar Energy

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

Photosynthesis

Cellular Respiration

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



1. Glycolysis

- Takes place in the cytosol, $C_6H_{12}O_6$ broke into 2 pyruvates (makes some NADH and ATP)
- Pyruvates sent into mitochondria matrix

2. Krebs/Citric Acid cycle

- Pyruvates broken down further to make more NADH and some $FADH_2$
- CO_2 given off as a waste product from breaking pyruvates

3. Electron Transport Chain (ETC)

- NADH and $FADH_2$ from Glycolysis and Krebs used to power the enzymes to make A LOT of ATP
- O_2 broken by adding e^-, attracts H^+ and H_2O is created

1. Light Dependant Reaction

- Takes place in the thylakoid membrane
- H_2O converted to O_2 (e^- taken from Hydrogens)
- ATP and NADPH created (sent to Calvin Cycle)

2. Calvin Cycle

- ATP and NADPH (from LDR) use to power chemical reactions
- CO_2 converted to $C_6H_{12}O_6$ in chemical reactions (**carbon fixation**)