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

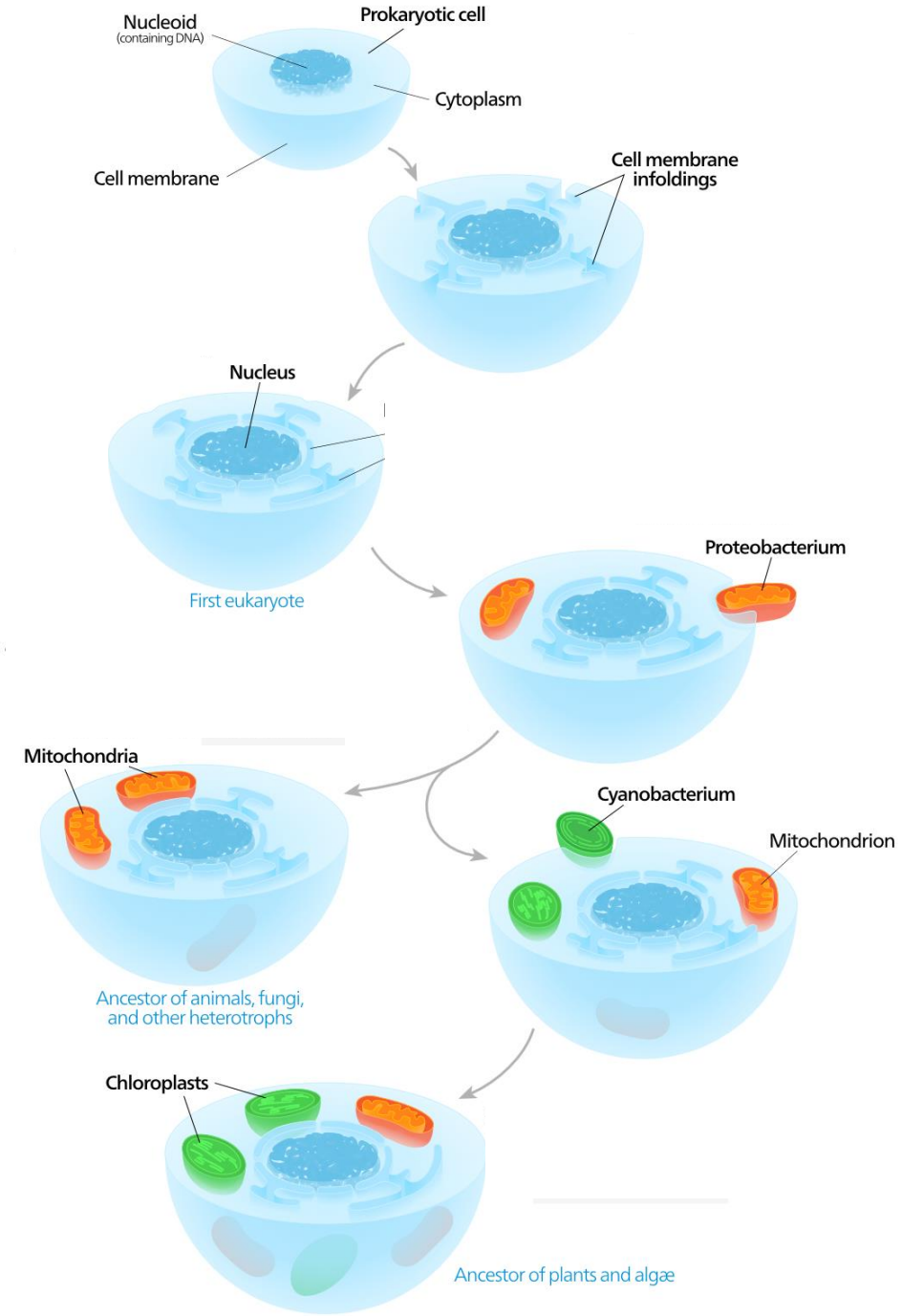
Essential Question

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

How organisms get energy

1. **Autotrophs**: able to produce their 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**



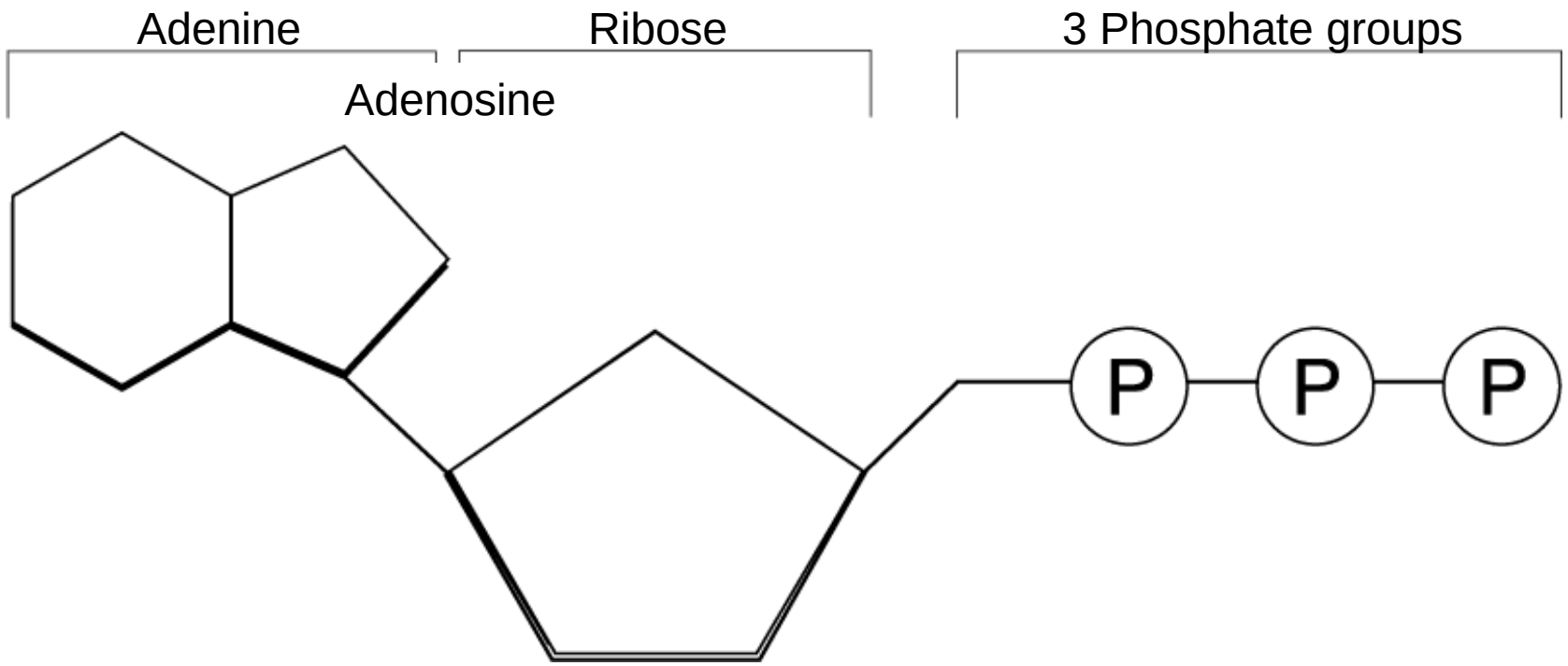
Endosymbiotic Theory

- **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?

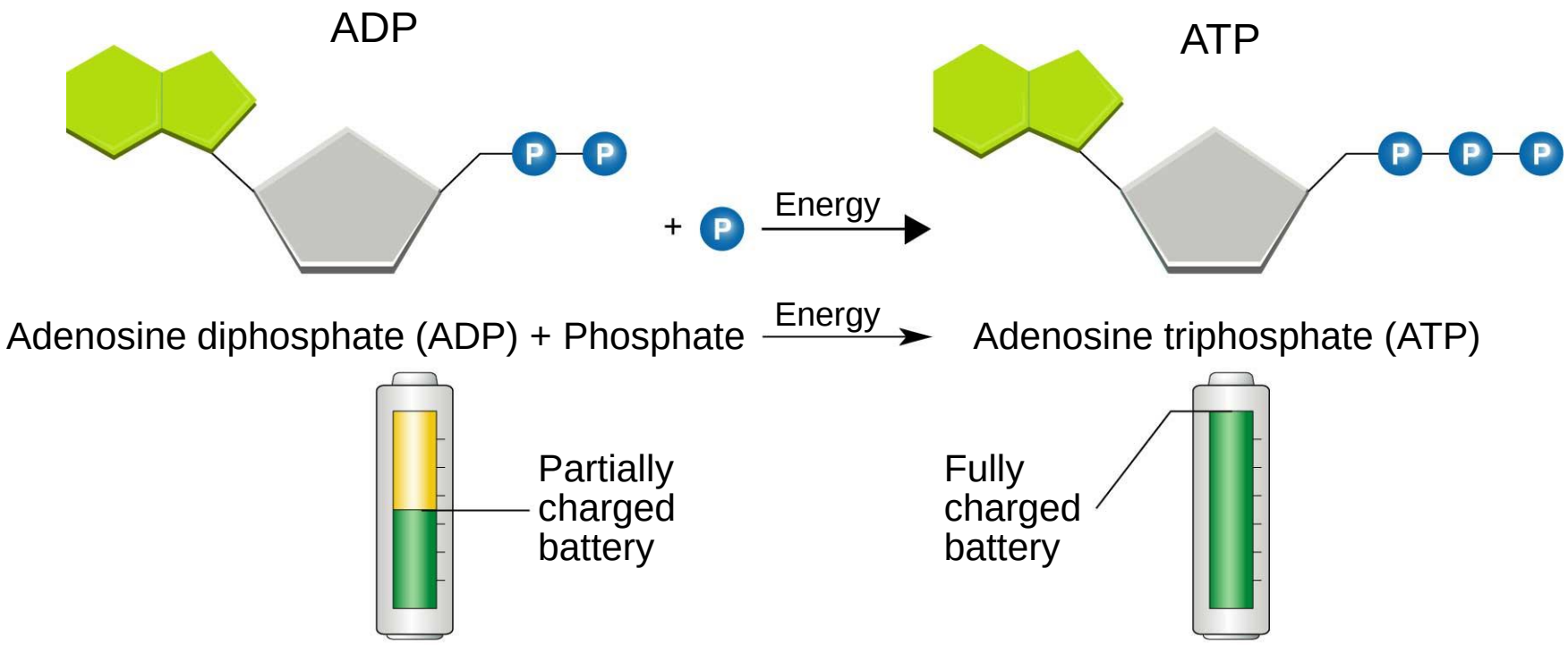
- The energy from carbon based molecules (food) is needed to re-charge **ADP** **(adenosine di-phosphate)** to **ATP** **(adenosine tri-phosphate)** molecules

- **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

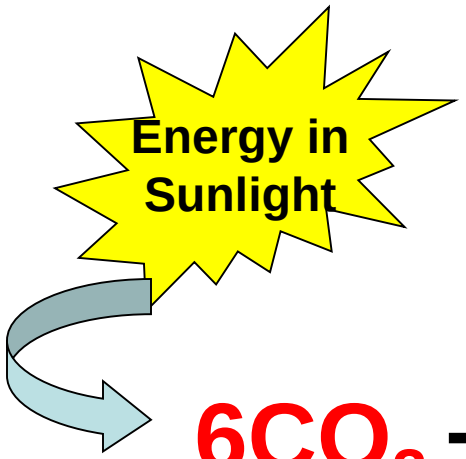
- Cells need **energy** to be able to carry out important metabolic functions to sustain life.

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

Photosynthesis

- The process autotrophs use to make sugars (ex: Glucose) from carbon dioxide (CO_2), water (H_2O), and light energy

Photosynthesis

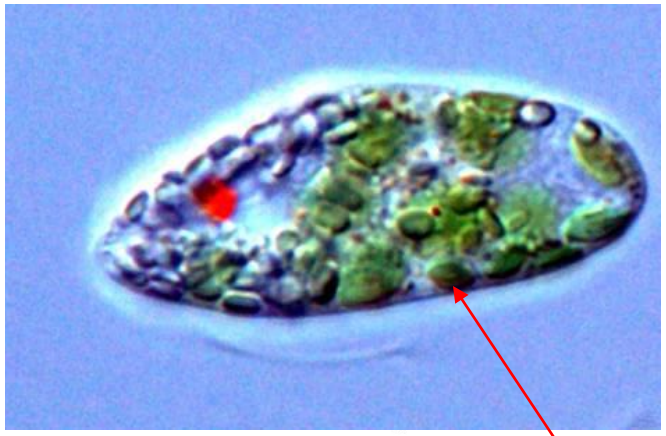


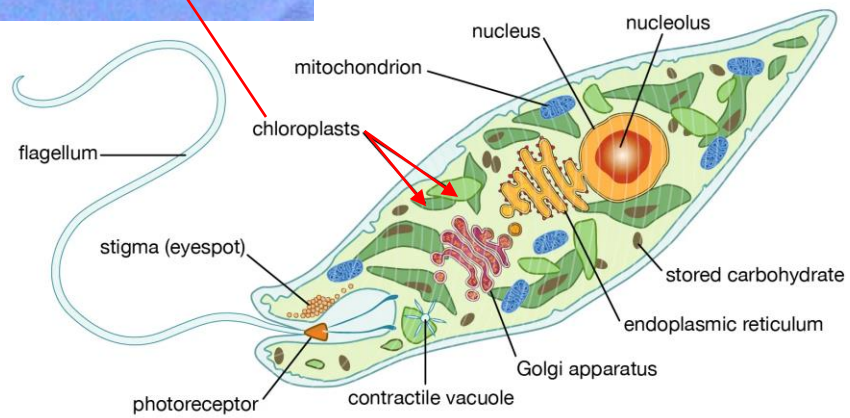
$$6CO_2 + 6H_2O \xrightarrow{\text{Enzymes}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide and **water** are used in chemical reactions to make sugars (glucose) and oxygen gas

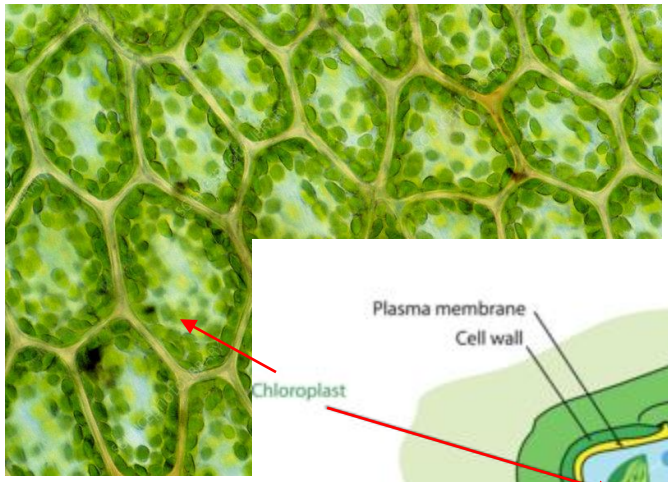
Photosynthetic Organelle

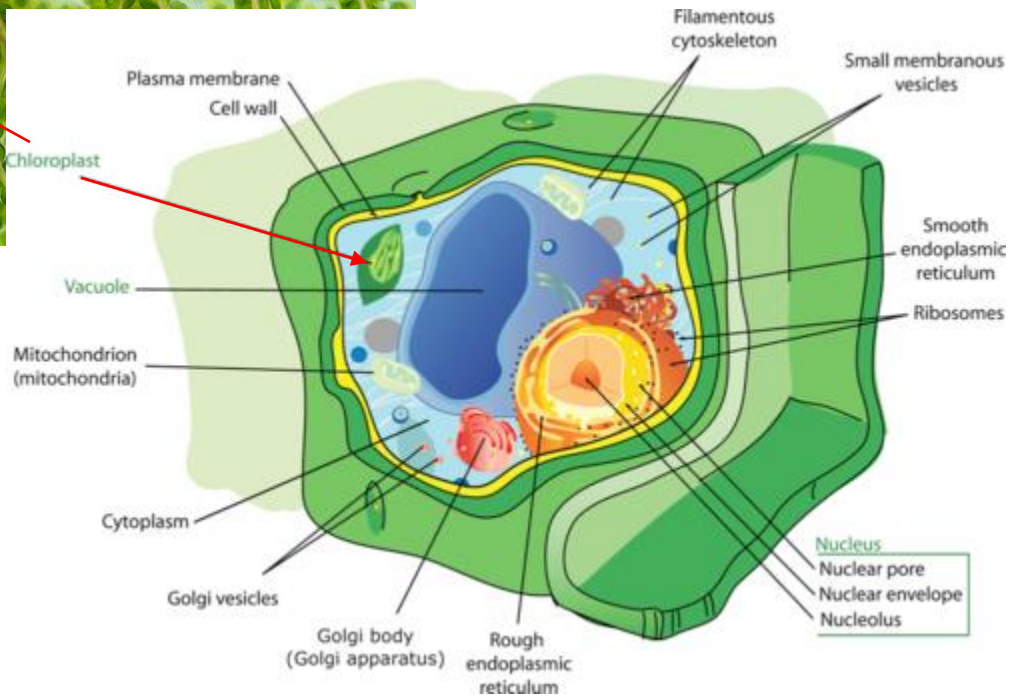
- In Eukaryotes, photosynthesis takes place in the **Chloroplast**.





Euglena



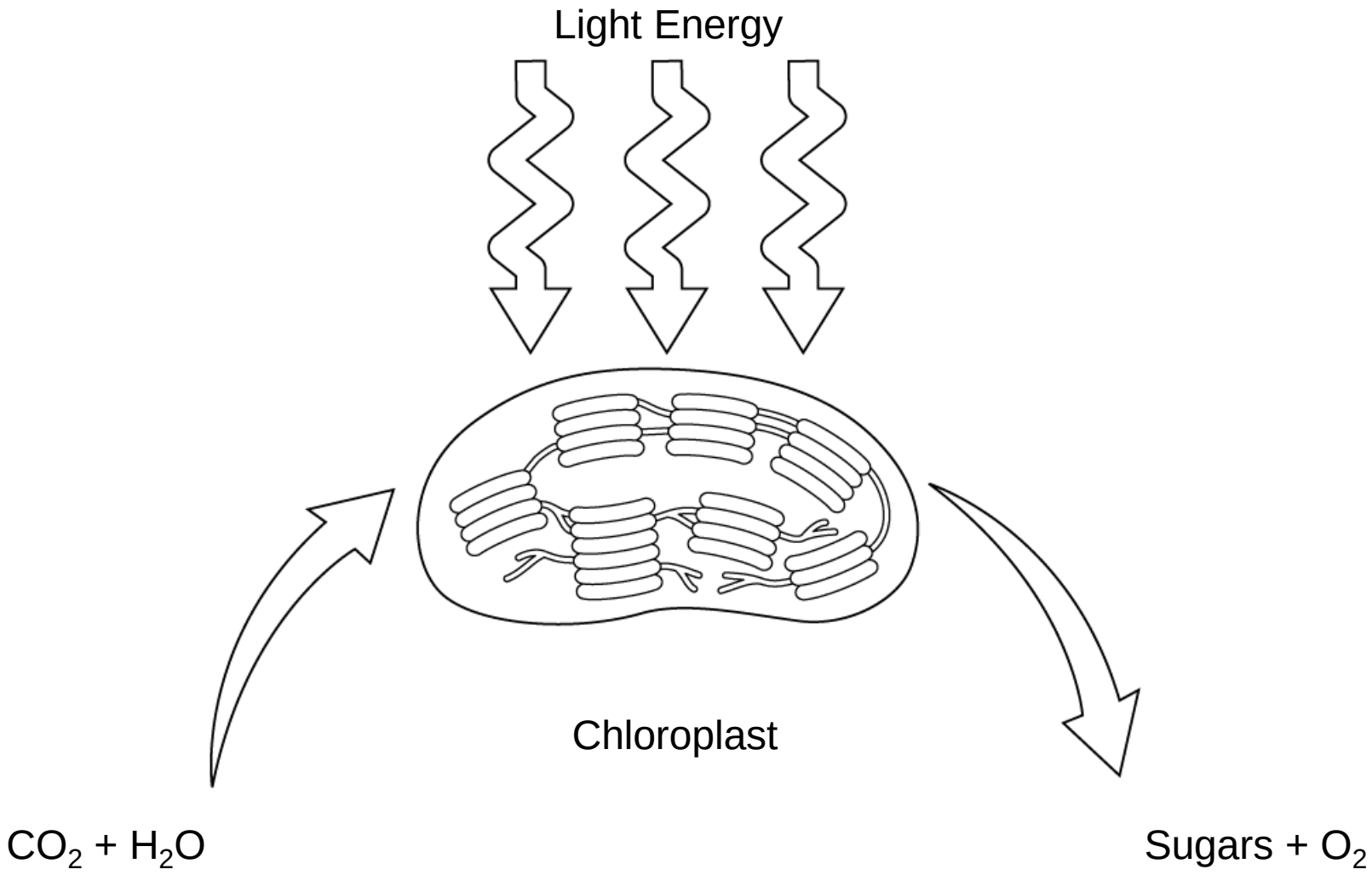


Who has a Chloroplast?

Not all eukaryotes have a chloroplast.

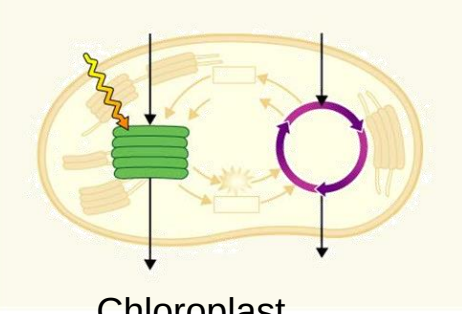
- All plants
- Some protists (ex: Euglena)

Where and how are sugars made?

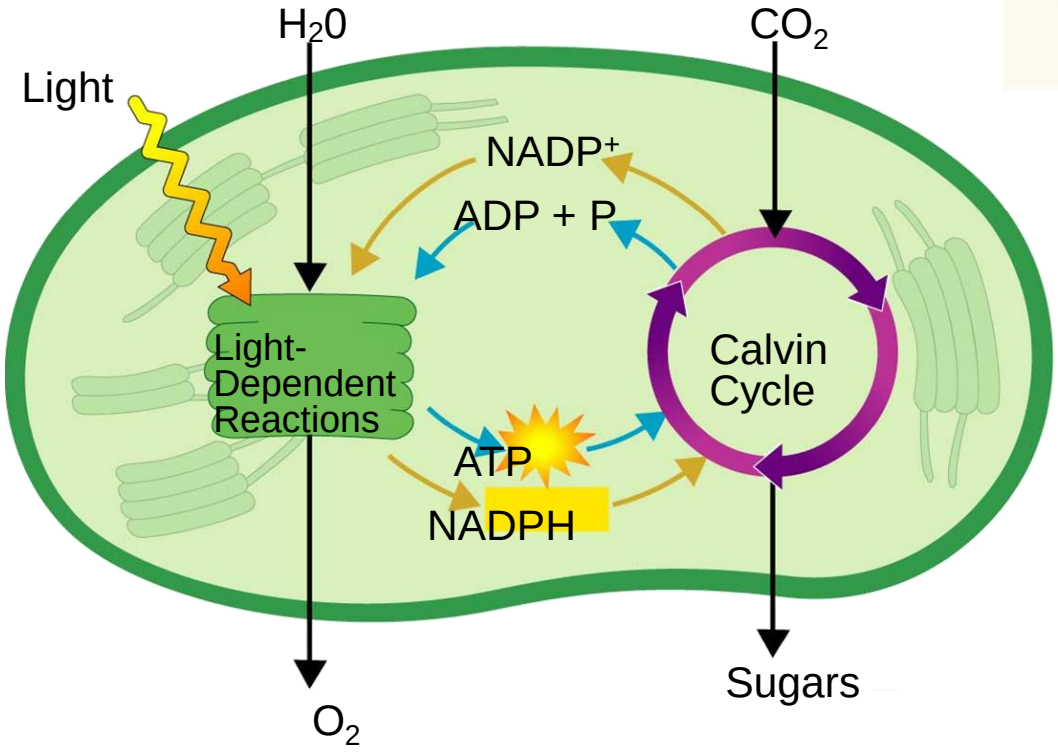


Photosynthesis is an endergonic reaction … ”energy in”

1. Light dependent reaction
2. Calvin cycle

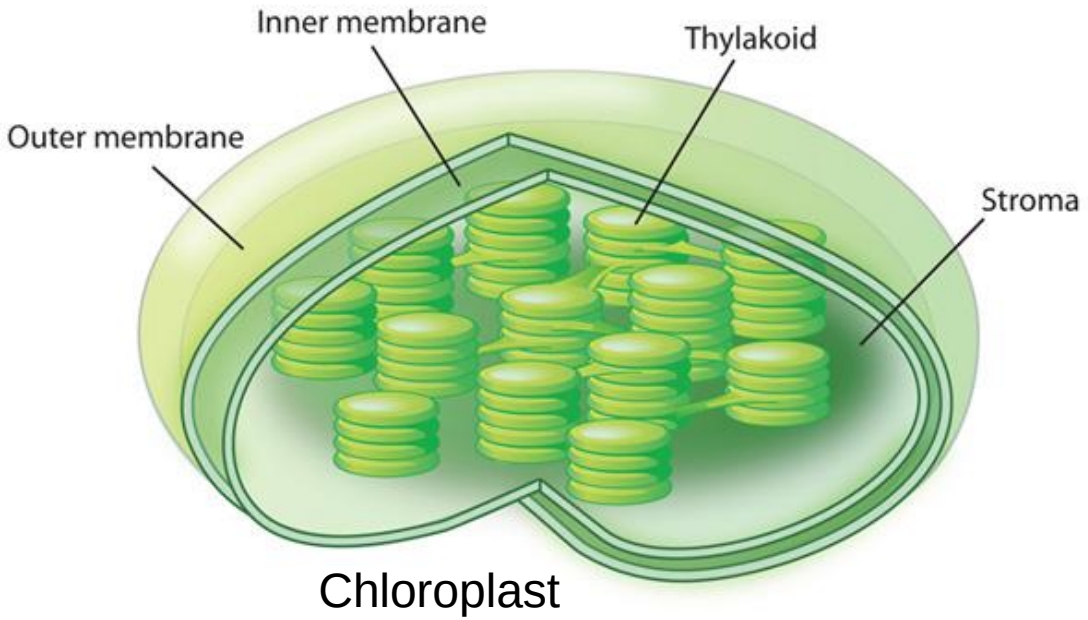


Chloroplast



Step 1: **L**ight **D**ependent **R**eaction -- LDR

- Pigments (**chlorophyll**) inside of the **Chloroplasts** are in the membranes of the **Thylakoids**

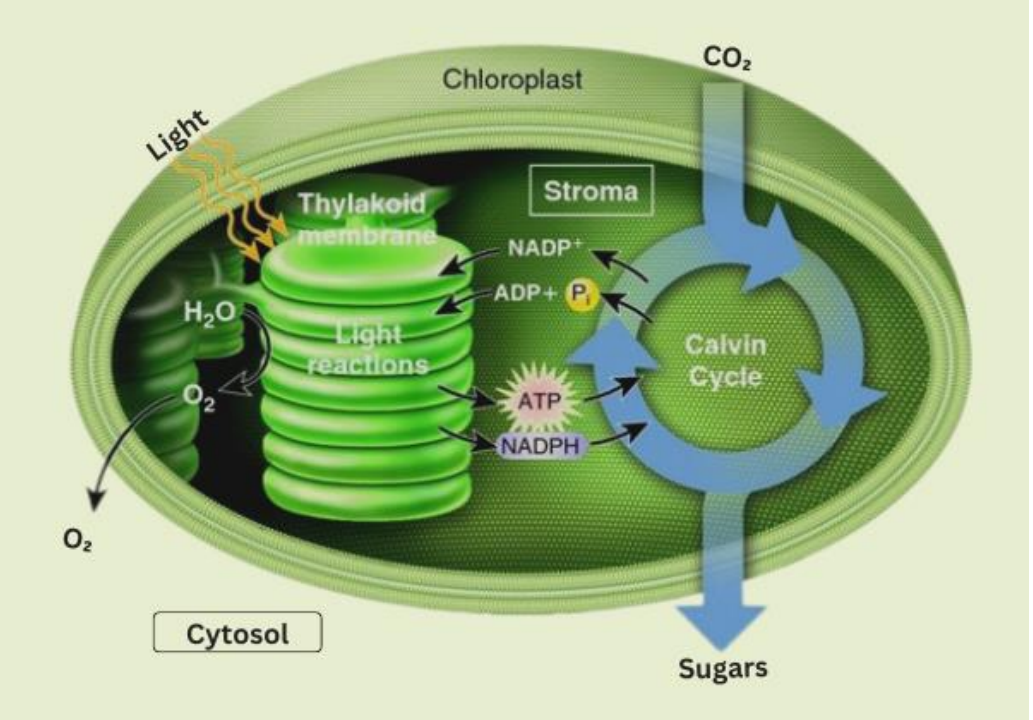


- Chlorophyll absorb sunlight.
- Light Dependent Reactions makes energy molecules (ATP) to power the Calvin Cycle
- Turns Water (H_2O) into Oxygen gas (O_2)

Step 2: Calvin cycle

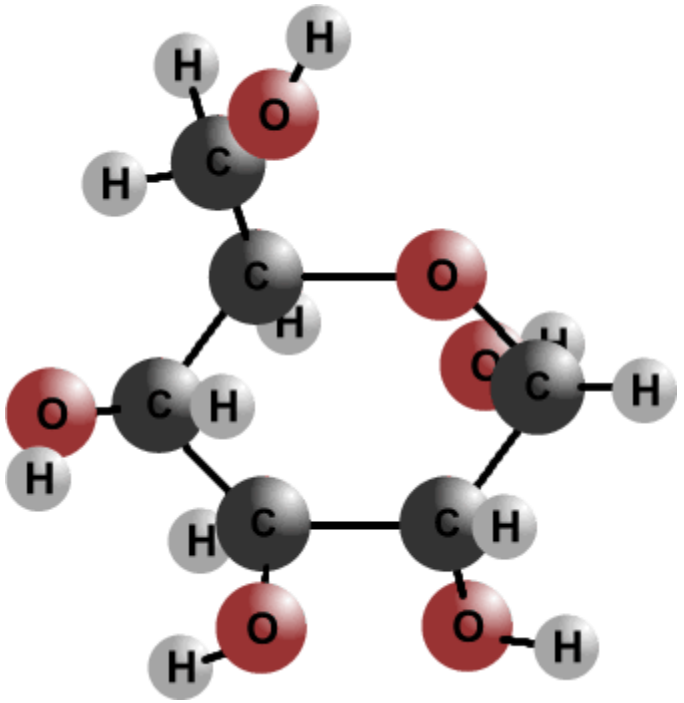
- Energy from LDR is moved to the **Stroma** (it is like cytosol in the Chloroplast)

- Chemical reactions in the Stroma use the energy to convert CO_2 (carbon dioxide) into sugars (Glucose)

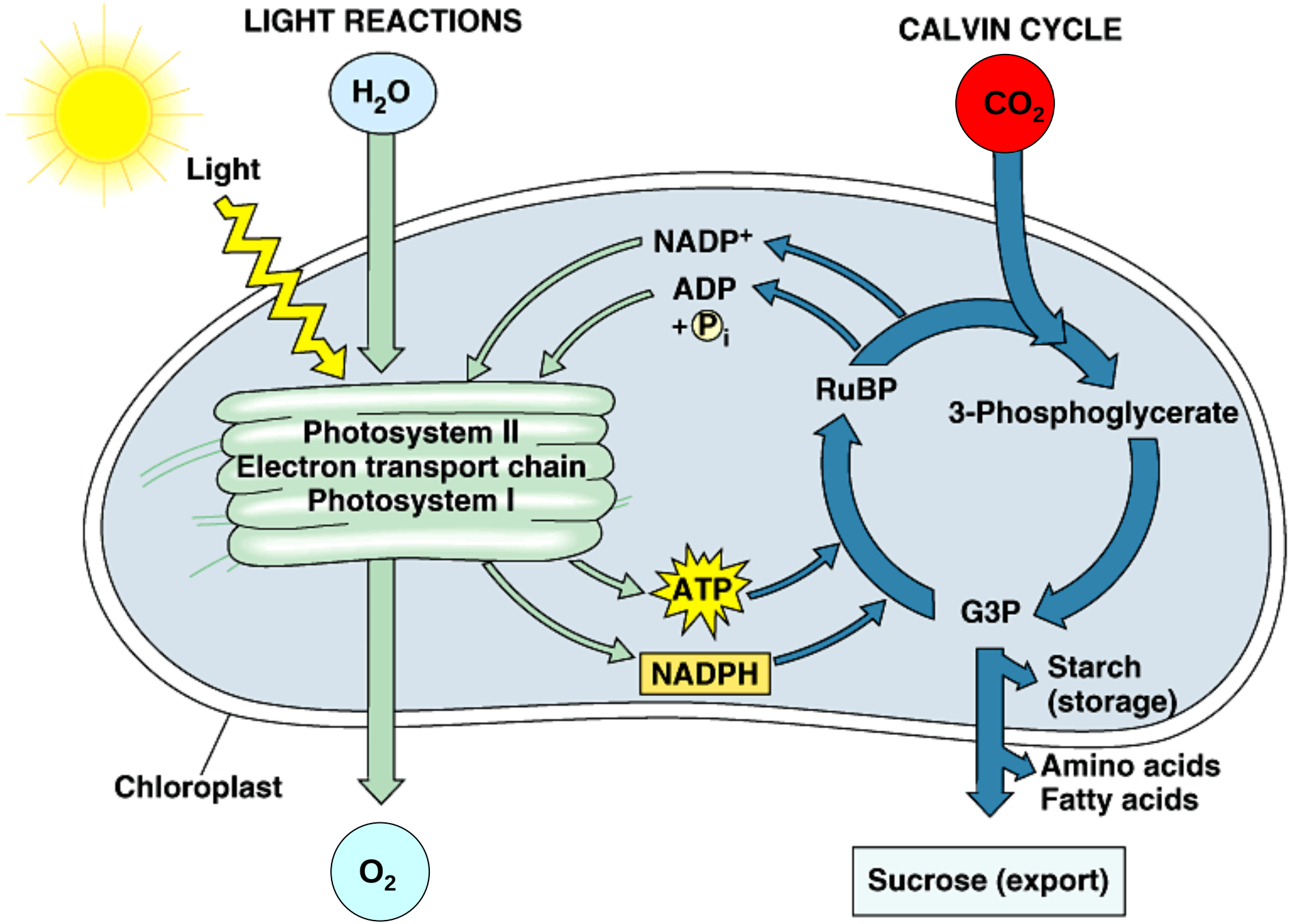


Sugars are produced in Photosynthesis

- Energy molecules (like ATP) are created on the Thylakoid membranes to power the Calvin Cycle which turns CO_2 into Glucose.
- The autotroph used the Glucose for food.



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.

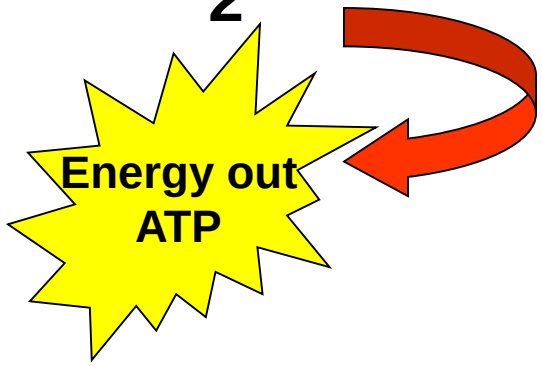
- ALL living organisms need and use energy.
- Therefore ALL organisms need ATP
- ALL organisms (plants and animals, fungi, bacteria and protists) re-charge their ADP into ATP through respiration

Cellular Respiration

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

Photosynthesis and Respiration are complementary cycles

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



Two types of respiration

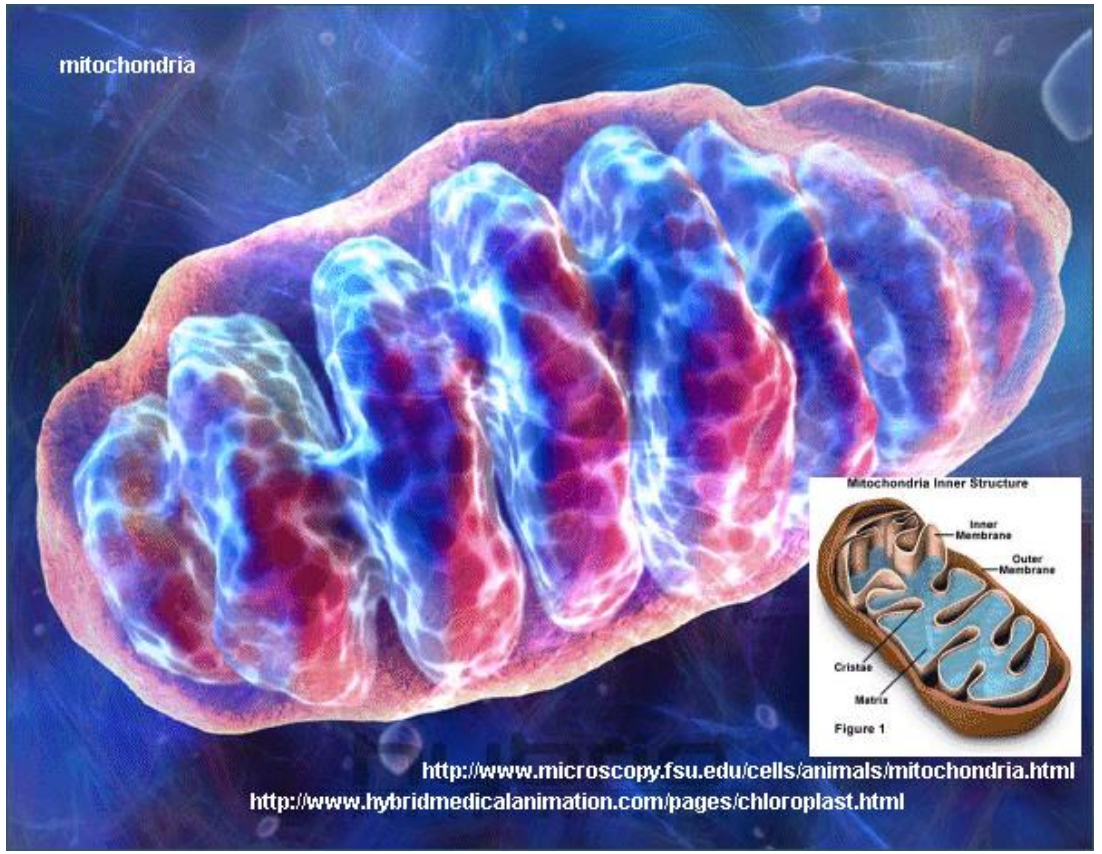
- **Aerobic respiration**: Organisms that require oxygen use aerobic respiration to make ATP but switch to **fermentation** when oxygen is not available.

- **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



Who has a Mitochondria?

ALL eukaryotes have a mitochondria:

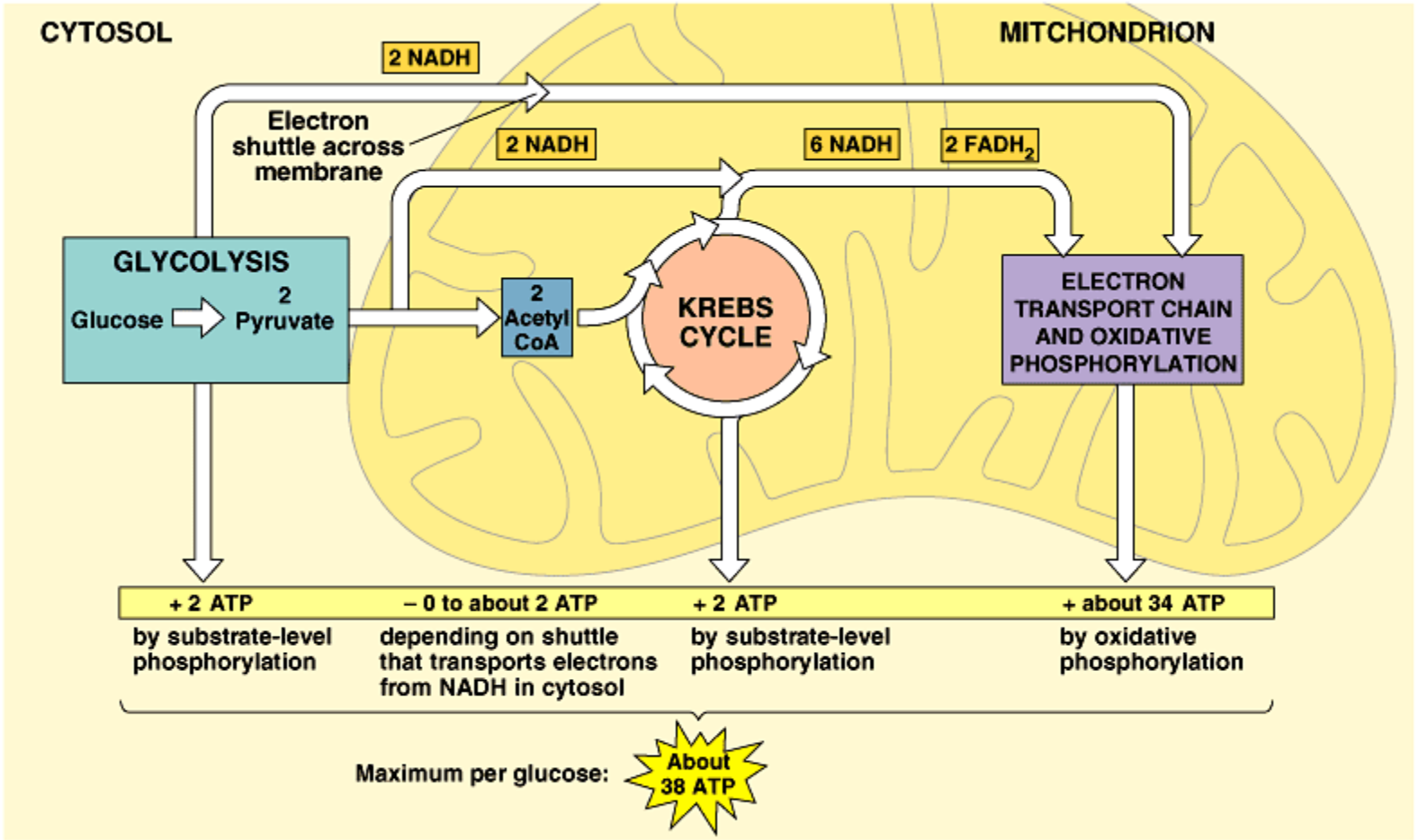
- Plants
- Animals
- Fungi
- Protists

Steps of aerobic respiration

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

3.1 Electron transport chain

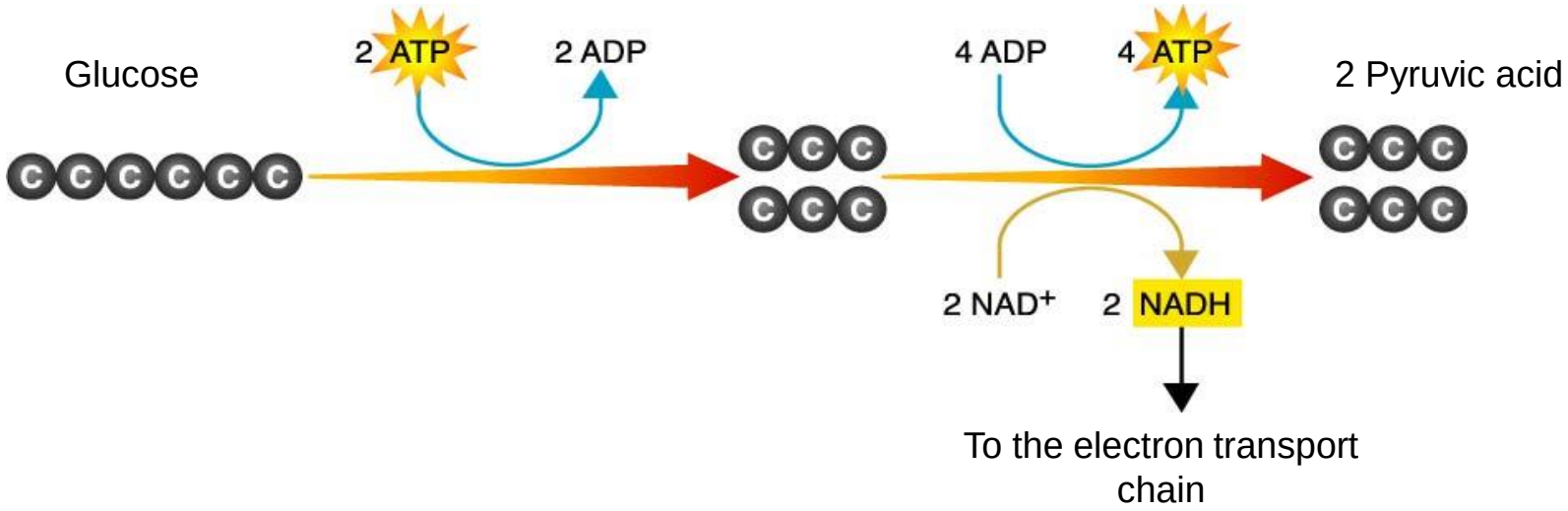
3.2 ATP synthase (Oxidative Phosphorylation)



Step 1: Glycolysis

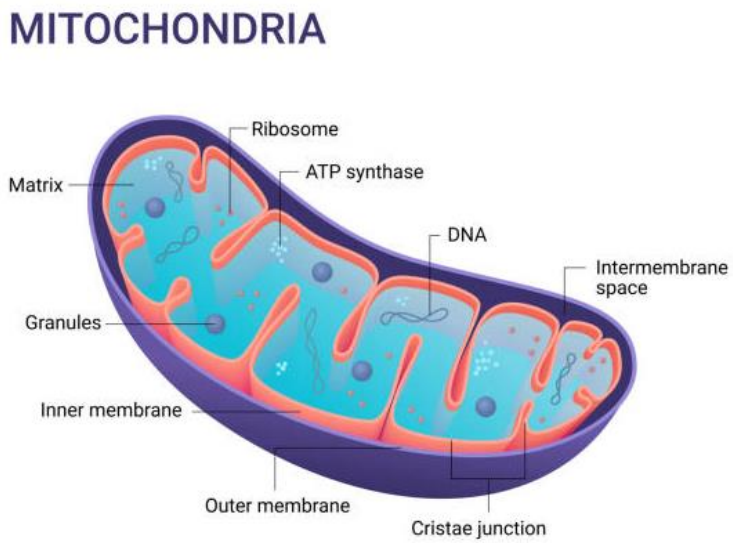
- Glucose molecules are broken down into two smaller carbohydrate molecules in the Cytosol/Cytoplasm

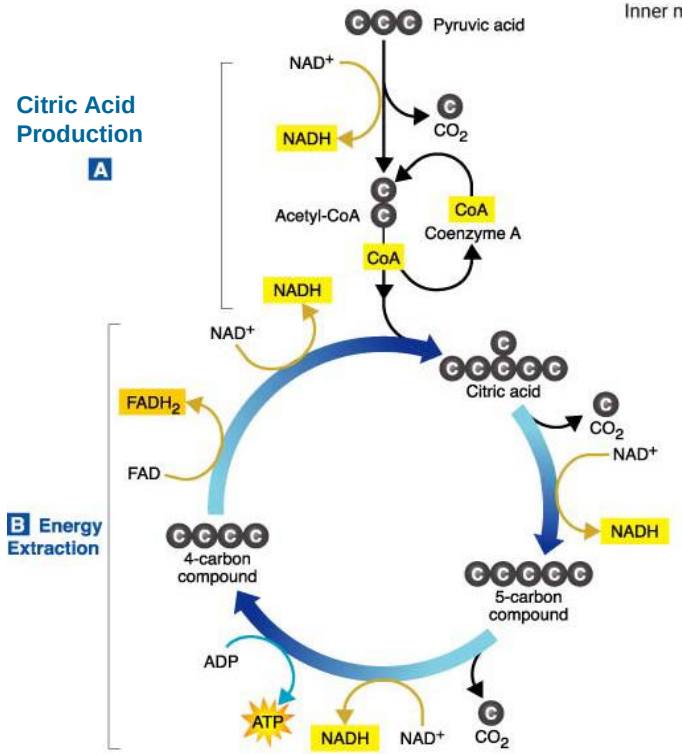
- Energy is released when you break molecules.



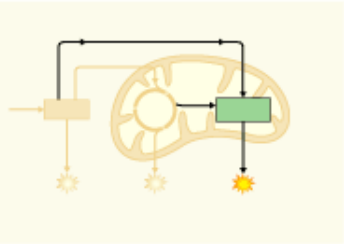
Step 2: Krebs or Citric Acid cycle

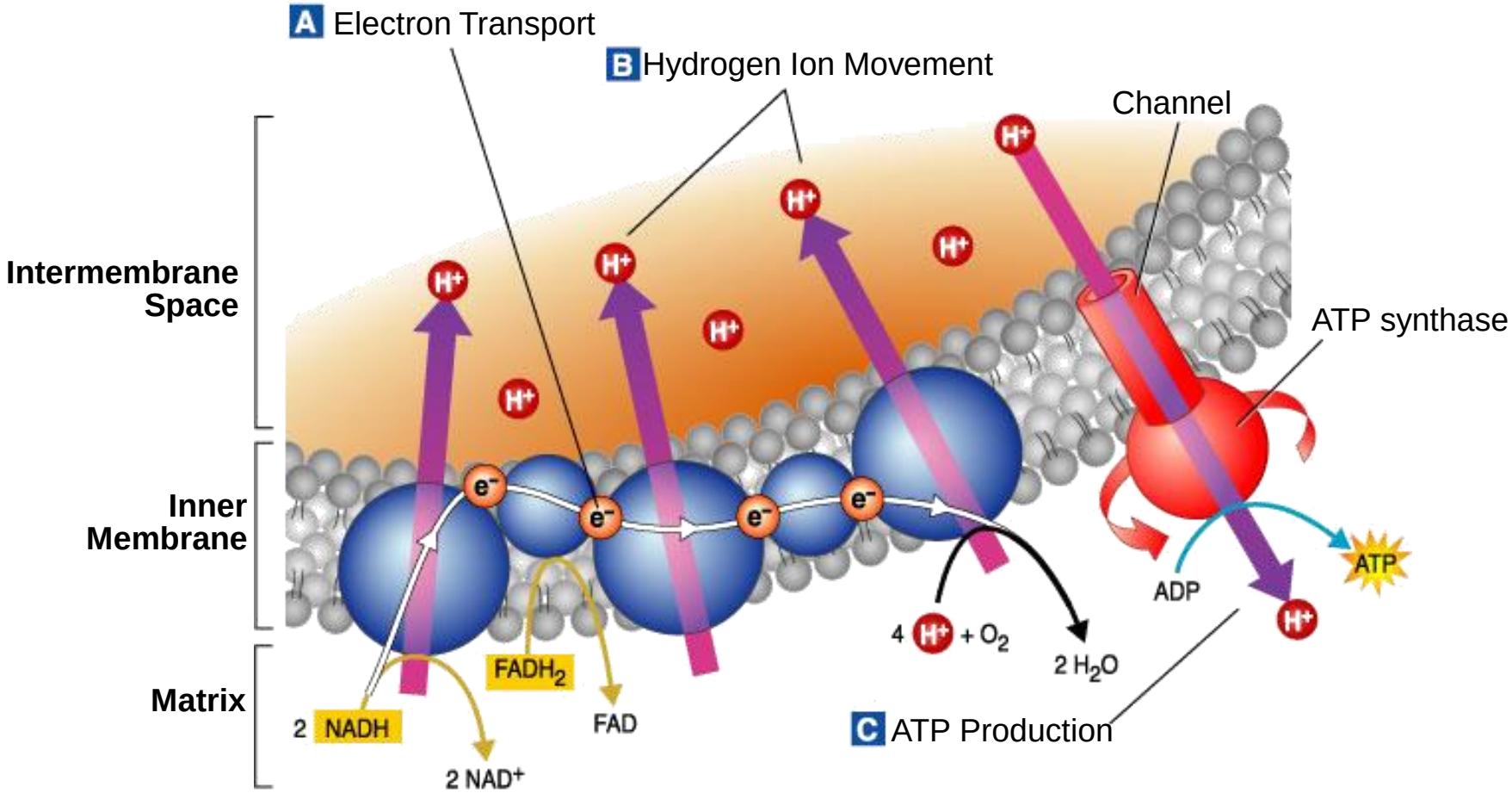
- Small carbohydrates from Glycolysis are broken into even smaller molecules inside the Mitochondria
- CO_2 is created here from the carbohydrates
- Energy is created when carbohydrates are broken down into CO_2





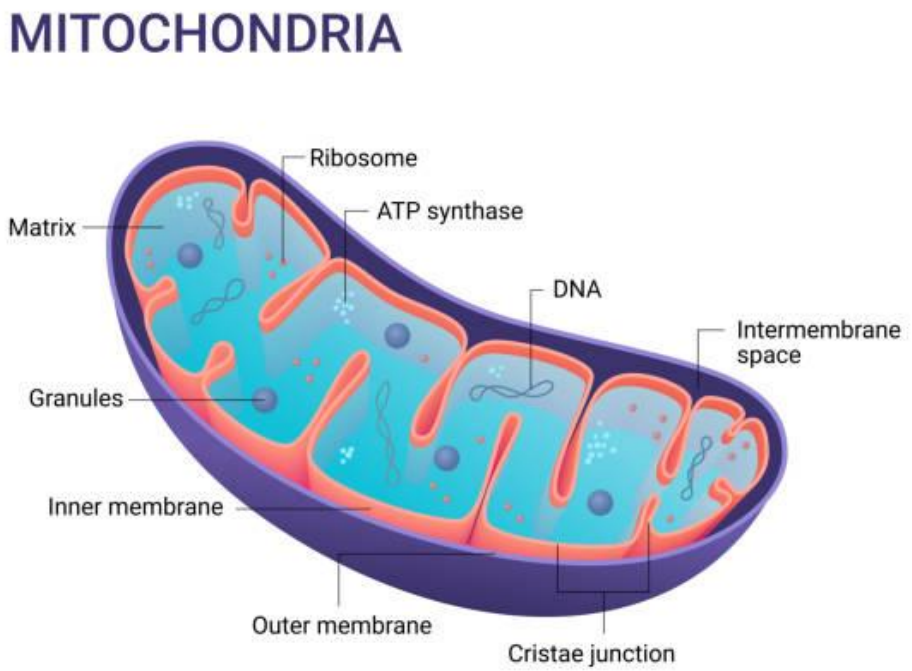
Step 3: **ATP production** (oxidative phosphorylation)





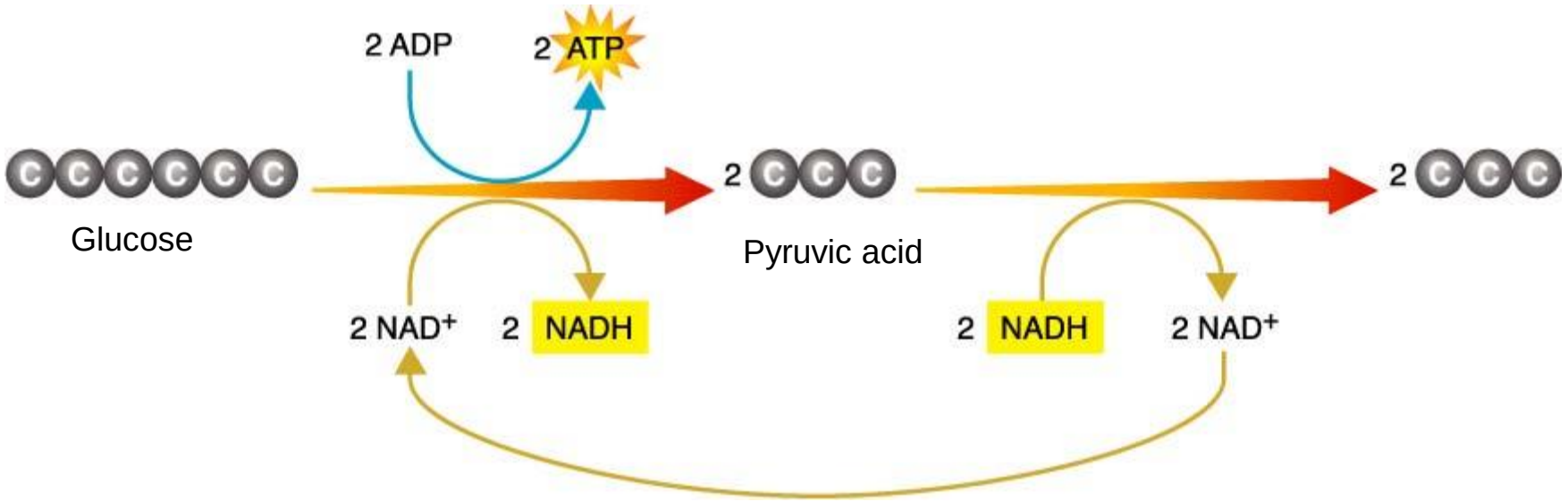
Electron transport chain (ETC) & Oxidative Phosphorylation

- **Location**: Inner Mitochondria Membrane
- Energy from Glycolysis and Krebs Cycle power the creation of ATP
- Oxygen (O_2) is used and turned into Water (H_2O)



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

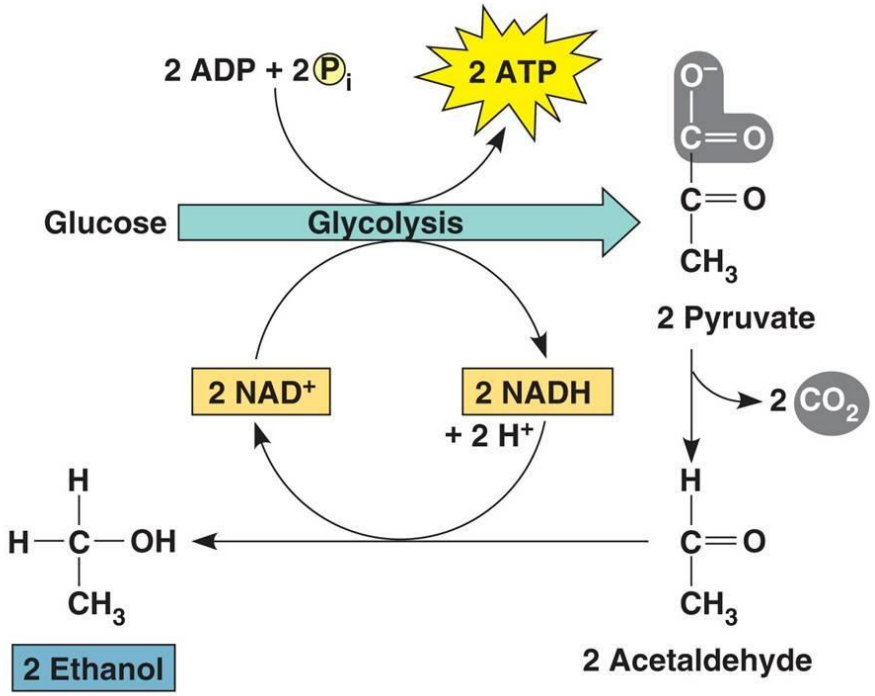
1. Glycolysis
2. Fermentation: lactic acid or alcohol



Fermentation

- The process of making a little ATP without Oxygen in the cytosol/cytoplasm

Alcoholic Fermentation
(anaerobic respiration)



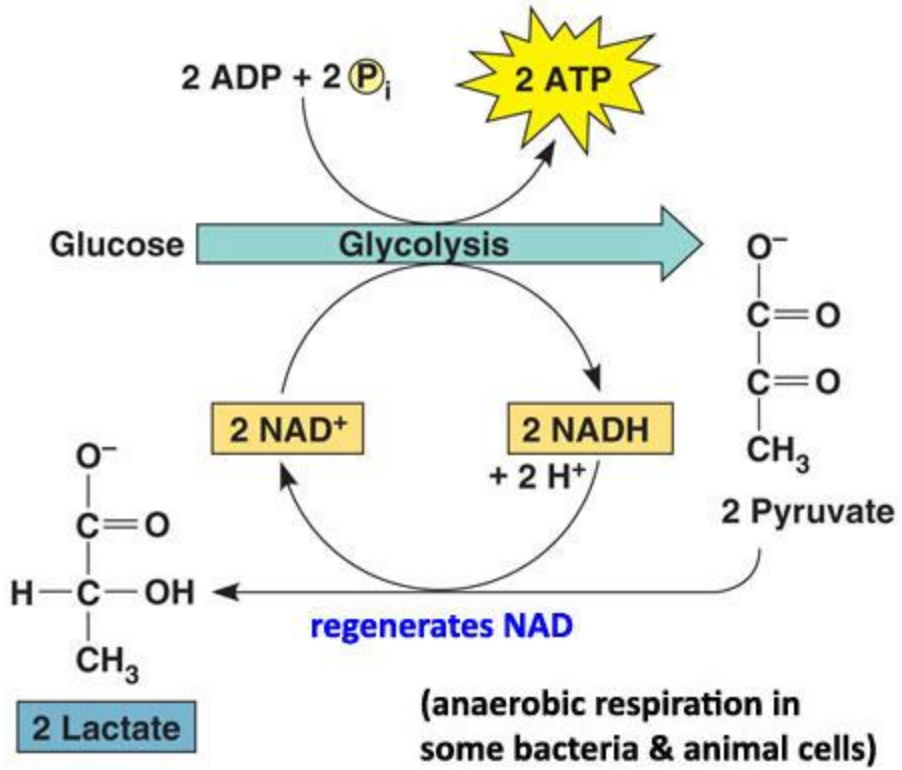
- Without enough oxygen present, an “alternate route” is taken, producing other products & ***much less*** ATP

- **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

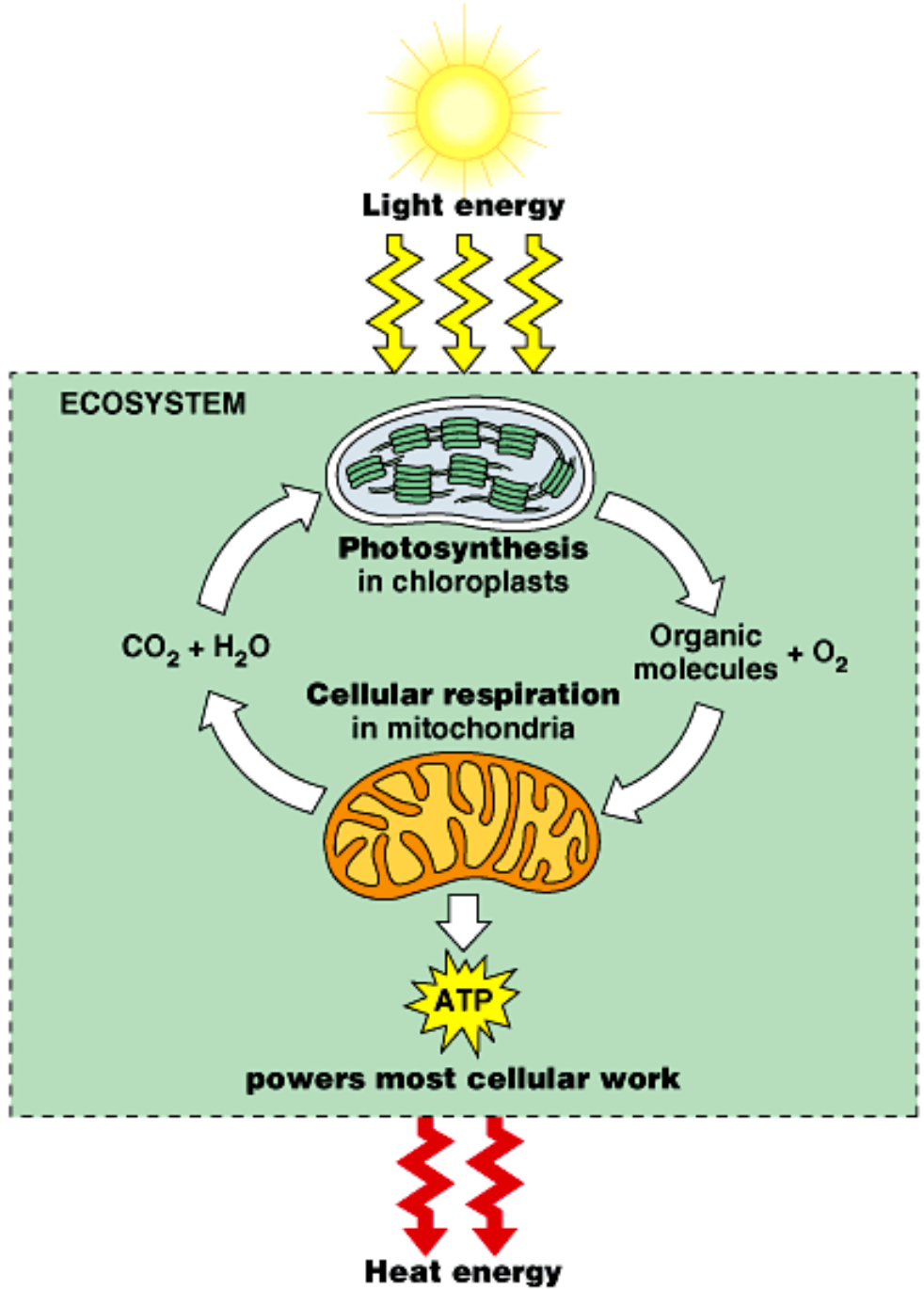
- **In muscles: lactate is produced**

- Causes sore muscles

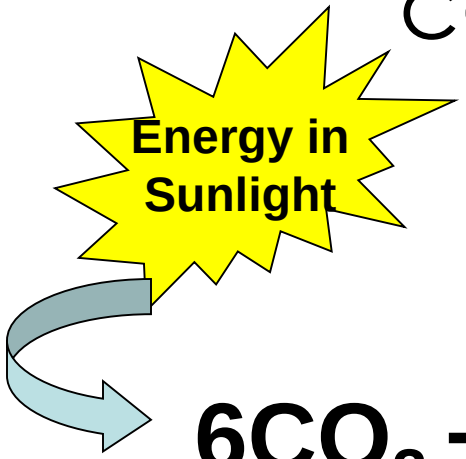
Sore muscles

- 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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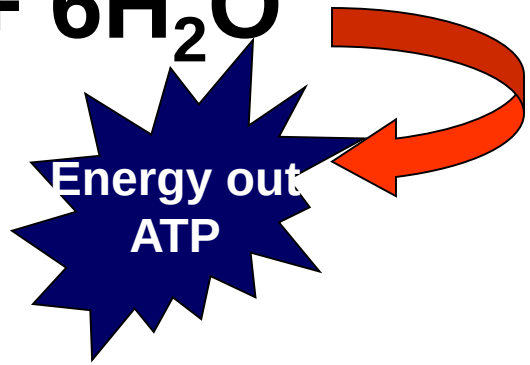


ATP and HEAT

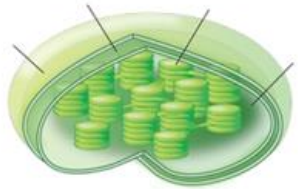
Solar Energy

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

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**)