CH 9 CELLULAR RESPIRATION

9-1 Chemical Pathways

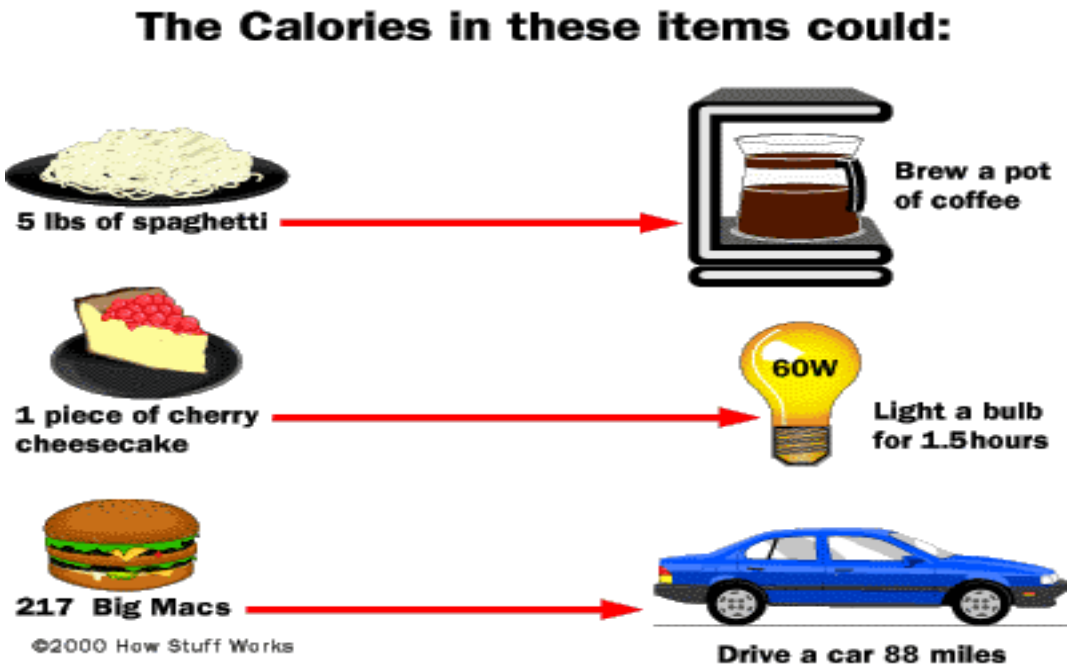
9-2 The Krebs Cycle and Electron Transport

Chemical Energy and Food

- Energy source = food = ATP
- A "**calorie**" is the unit for the amount of energy needed to raise the temp. of 1 gm of water 1 degree Celsius.
- 1 calorie gets you approx. 9000 ATP's!
- Food you eat will be used for restoring ATP, lost as heat, waste or stored for later use.

9.1 CHEMICAL PATHWAYS

- A calorie is the amount of energy needed to raise the temperature of 1 gram of water 1 degree Celsius
  - A Calorie (capital C) is 1000 calories often used to measure food

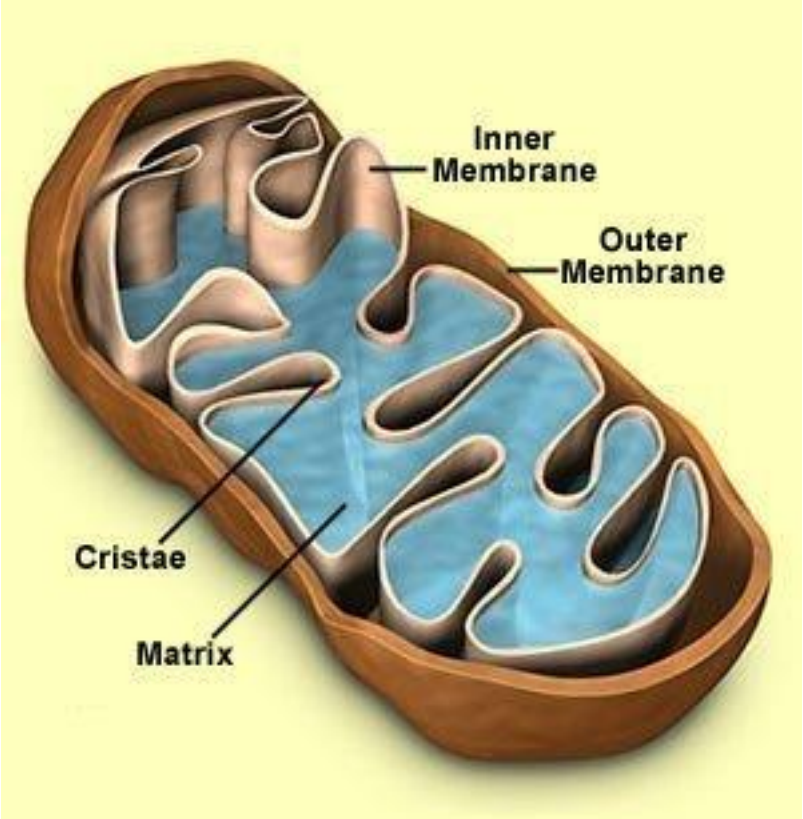


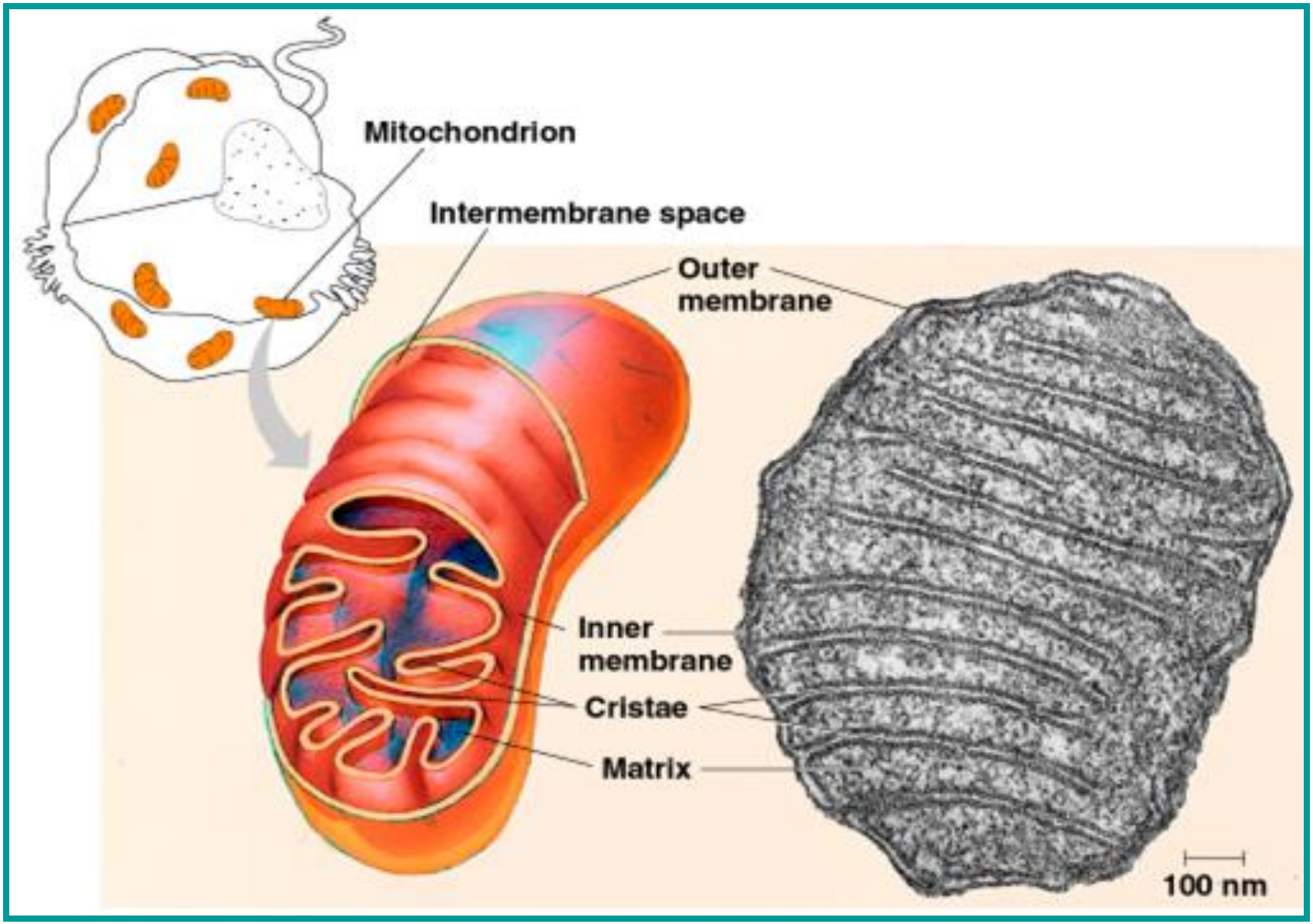
Where is this ATP produced in a cell?

MITOCHONDRIA

Mitochondria

- Double membrane bound organelle.
- Inner membrane encloses a fluid-filled **matrix**.
- Folded **cristae** project into the matrix. ***Increases surface area***
- Small circular DNA.




Mitochondrion
Intermembrane space
Outer membrane
Inner membrane
Cristae
Matrix
100 nm

Cellular Respiration Overview

- Overall Equation is:

  Glucose **+** ***Oxygen*** ⟶ ***Carbon dioxide*** **+** ***Water*** **+** ***ATP!***

- Why do this process? To make **ATP**!
- There are two ways to break down food:

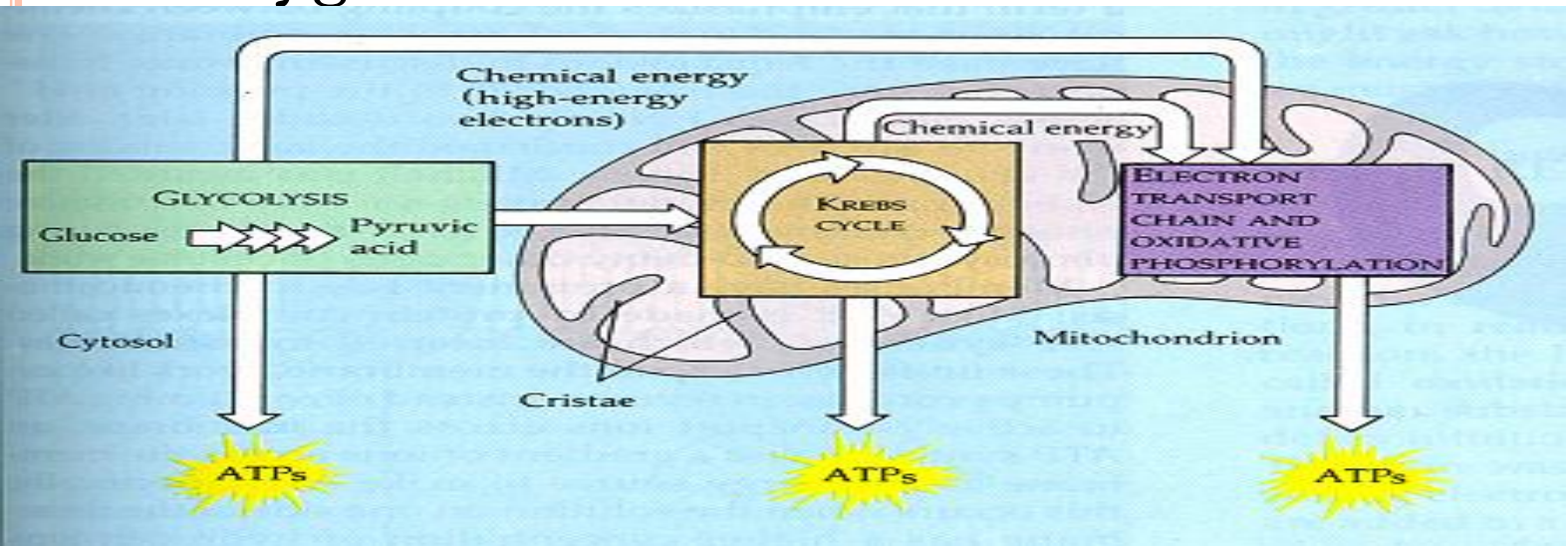
  Anaerobic cellular respiration also called: fermentation

  Aerobic cellular respiration commonly just called cellular respiration.

  First process for either method: **GLYCOLYSIS**

CHEMICAL PATHWAYS

- Glycolysis, the Krebs cycle and the electron transport chain make up a process called the Cellular Respiration
- Cellular Respiration is the process that releases energy by breaking down glucose and other food molecules in the presence of Oxygen

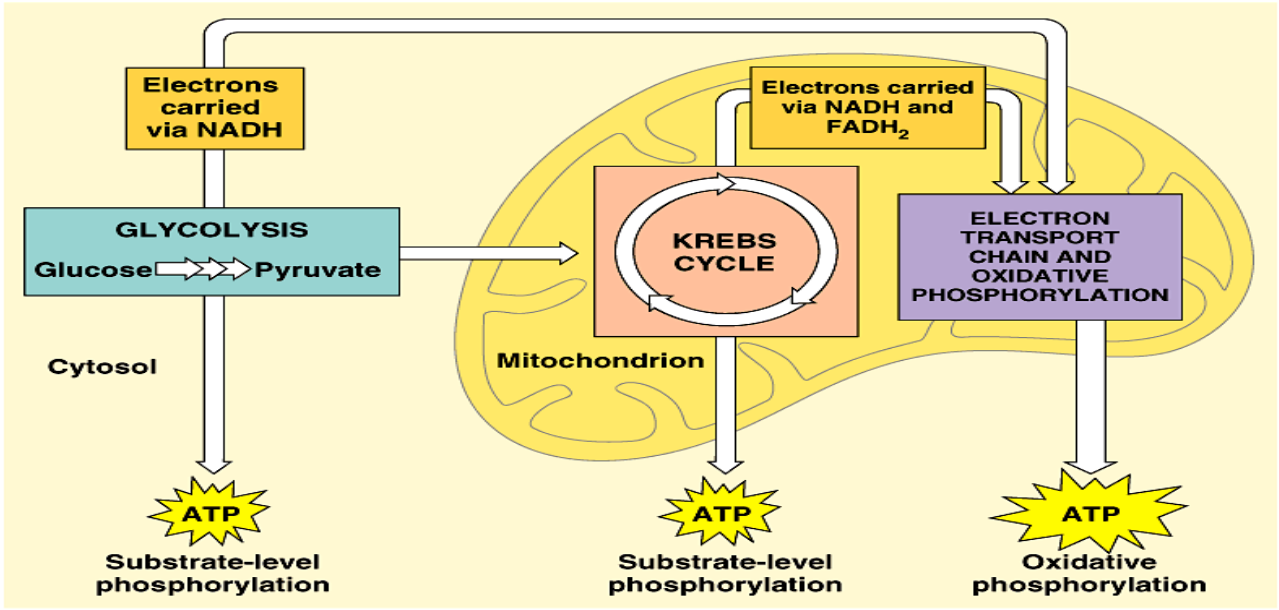


Glycolysis

- Occurs in the ***cytoplasm*** of cell.
- ***Anaerobic process***
- Glucose is broken down into 2 molecules of ***Pyruvic Acid***.
- ***NADH*** is produced and carries the high energy electrons to the ETC (last step).
- **Total ATP made are: 2**

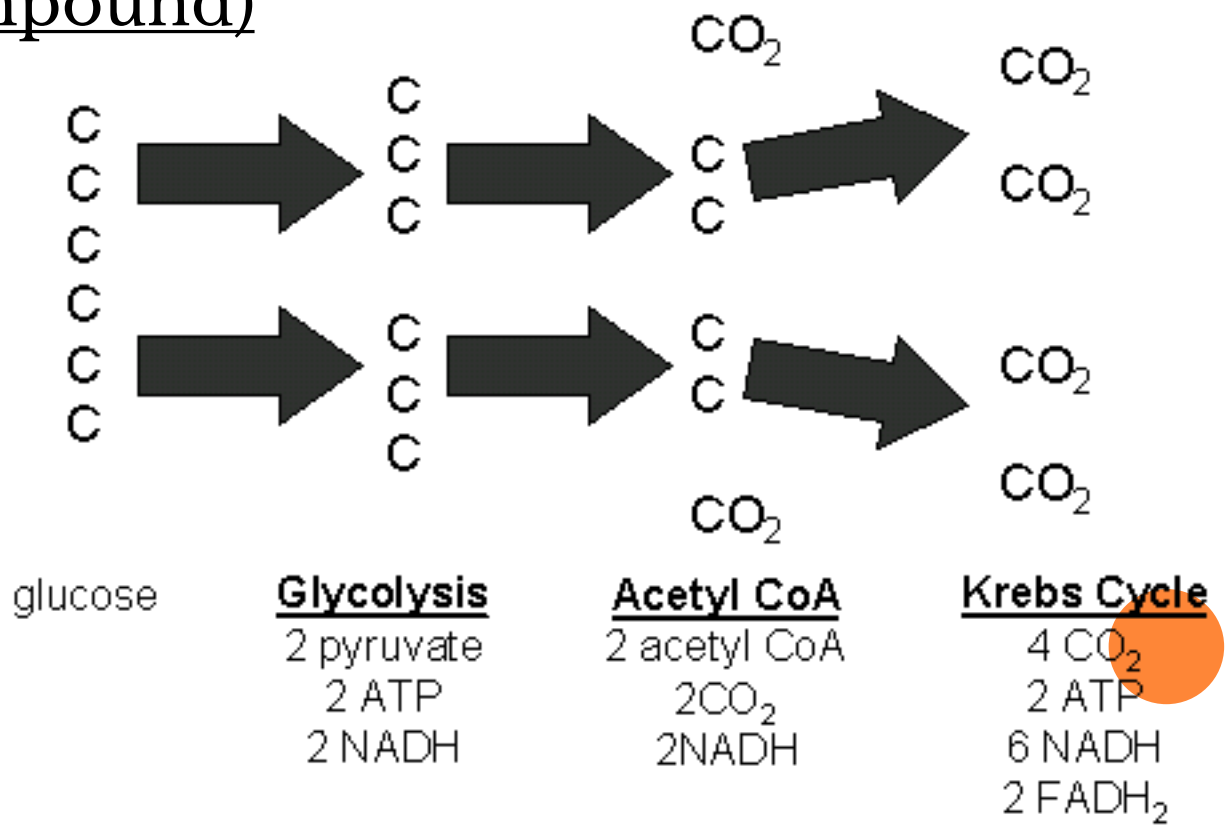
9.1 CHEMICAL PATHWAYS

- The first step to breaking down food into energy is called Glycolysis
  - If oxygen is present, glycolysis will lead to two other pathways that creates large amounts of energy
  - If oxygen is not present, glycolysis is followed by a different pathway



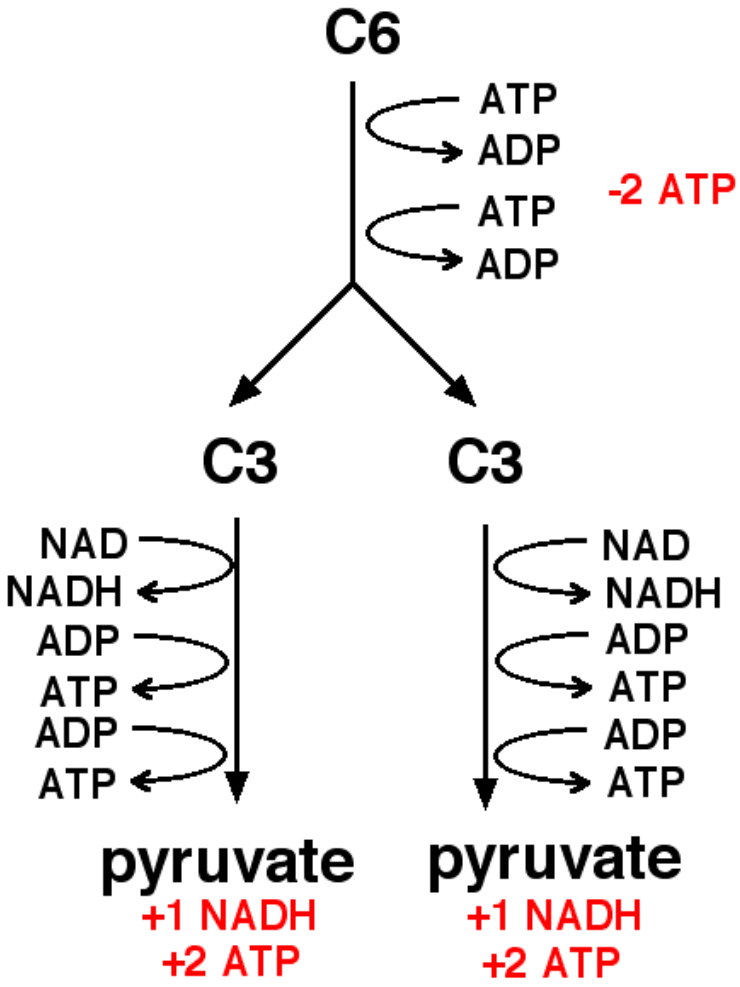
9.1 CHEMICAL PATHWAYS

- Glycolysis is the process in which one molecule of glucose is broken in half, producing two molecules of pyruvic acid (a 3 carbon compound)

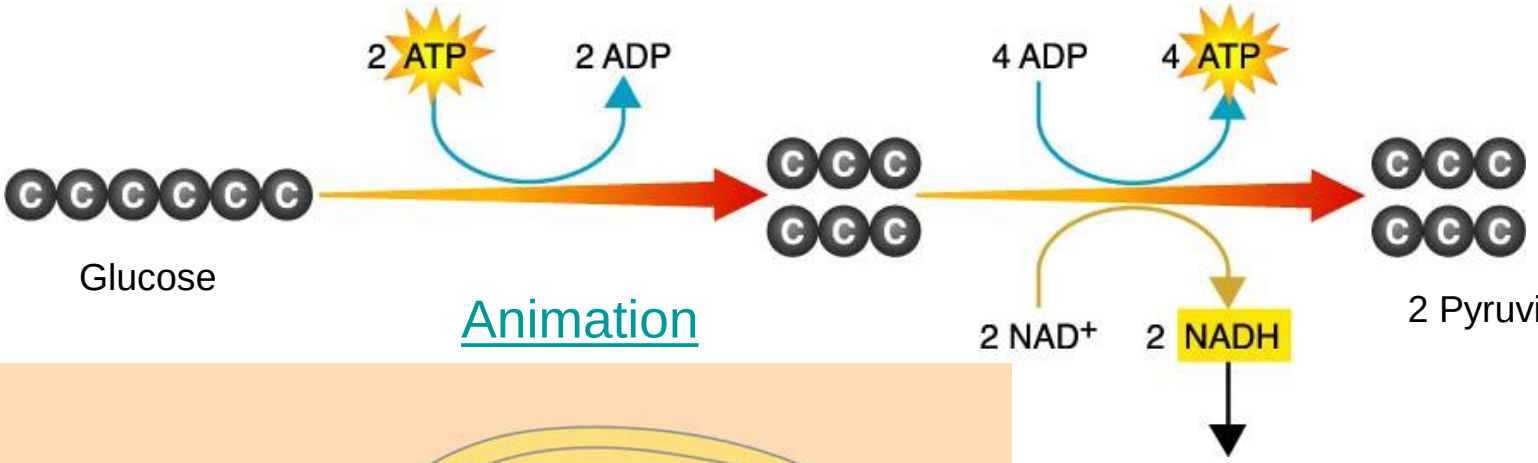


9.1 CHEMICAL PATHWAYS

- During Glycolysis high energy electrons are removed and received by NAD+ (same concept as NADP+ in photosynthesis)

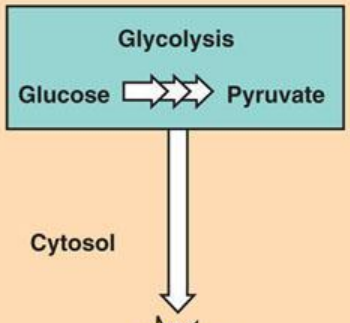


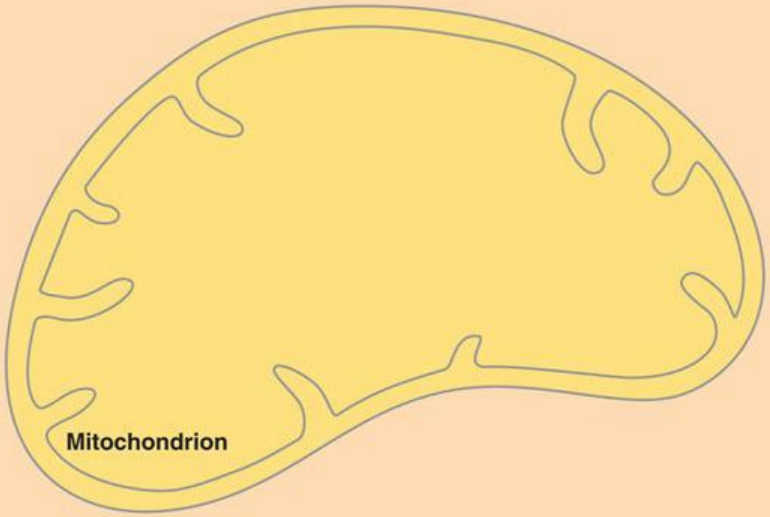
Glycolysis



Animation

To the electron transport chain





9.1 CHEMICAL PATHWAYS

- Pg 225 (1-6)

Aerobic Respiration

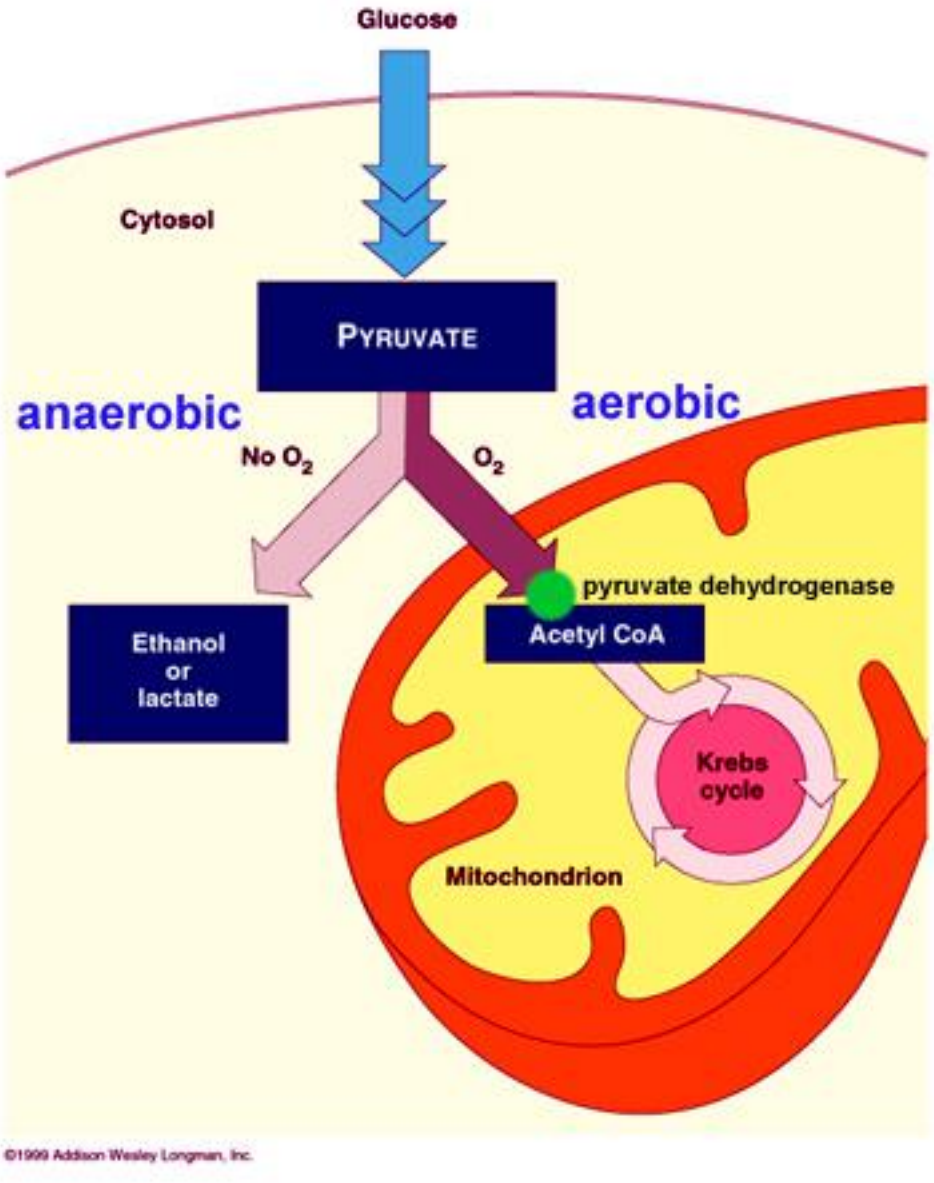
- Location: **Mitochondria**
- Process cells use to get the **most** energy out of food molecules.
- **Aerobic** process – requires oxygen
- ***Balanced Equation***:

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

- 2 processes: **Krebs cycle** and **ETC**

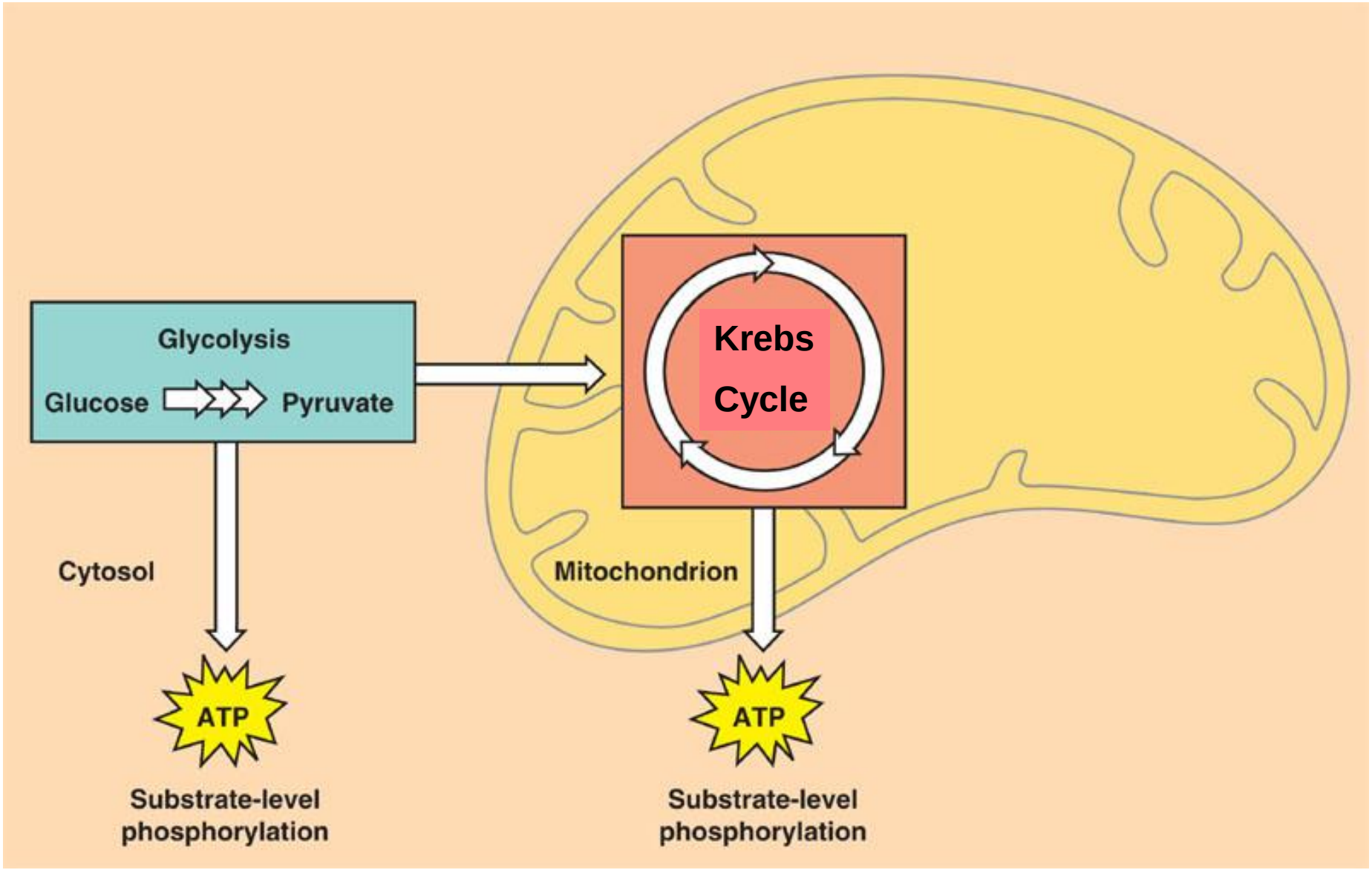
9.2 THE KREBS AND ELECTRON TRANSPORT

- Cellular respiration that requires oxygen is called Aerobic
- In the presence of oxygen, pyruvic acid produced in glycolysis passes to the second stage of cellular respiration, the **Krebs Cycle**



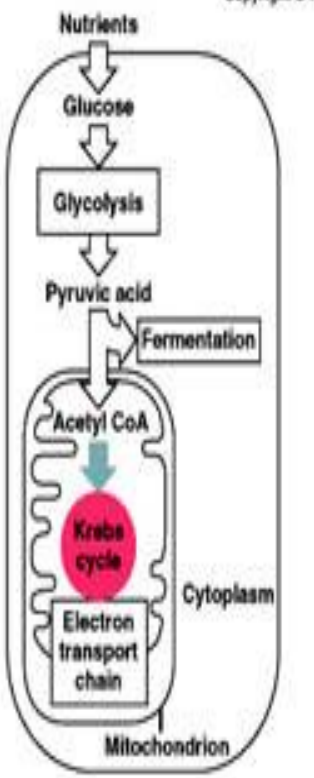
Krebs Cycle

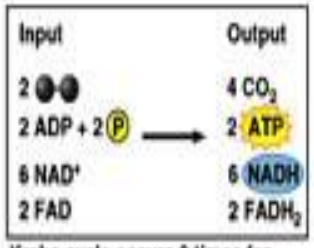
- Location: **matrix** of mitochondria.
- First, pyruvic acid is broken down into **Acetyl Co-enzyme A.**
- **CO_2 is produced** ***(What happens to this?)***
- Electron carriers produced: **$FADH_2$** and **NADH**.
- Net of **2 ATP** are formed. *(1 from each pyruvic acid from glycolysis)*


Glycolysis
Glucose
Pyruvate
Krebs
Cycle
Cytosol
Mitochondrion
ATP
ATP
Substrate-level
phosphorylation
Substrate-level
phosphorylation

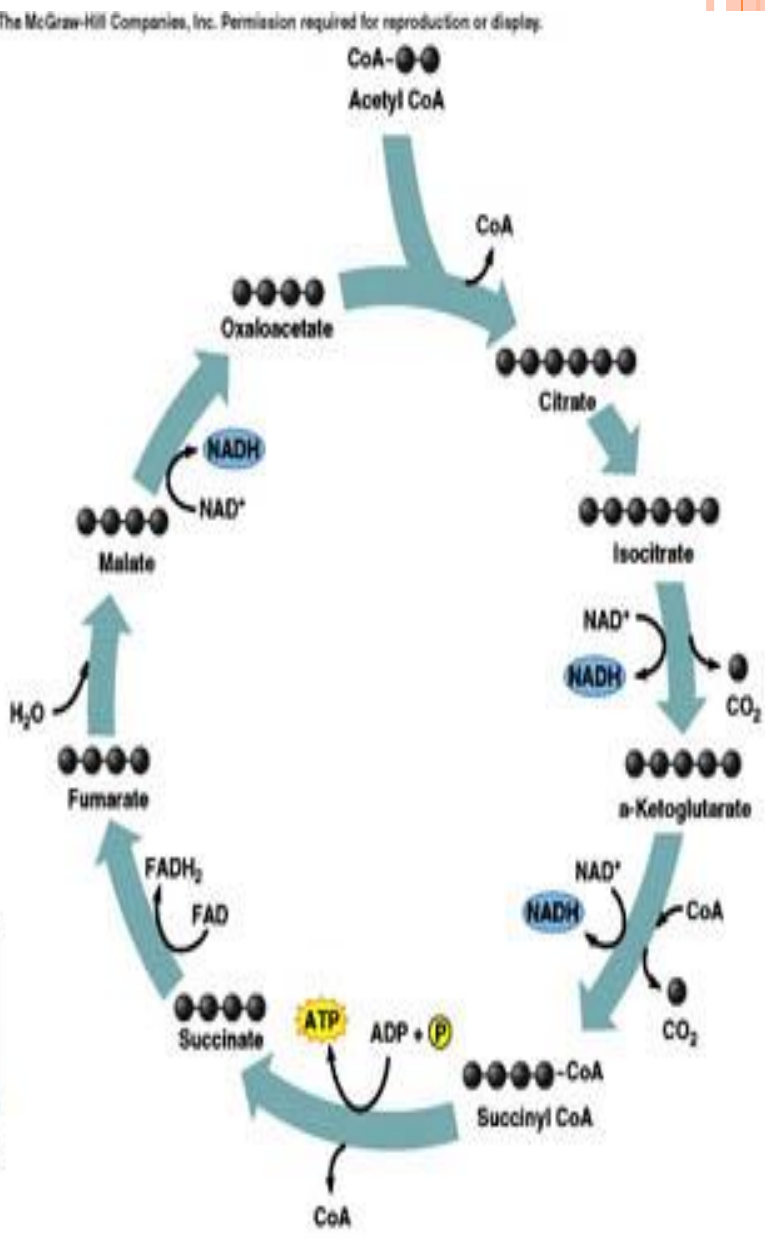
9.2 THE KREBS AND ELECTRON TRANSPORT

- During the Krebs cycle, pyruvic acid is broken down into carbon dioxide in a series of energy-extracting reactions
  - During Krebs
    - NAD+ is converted to NADH
    - ADP is converted to ATP
    - Carbon Dioxide is a waste product





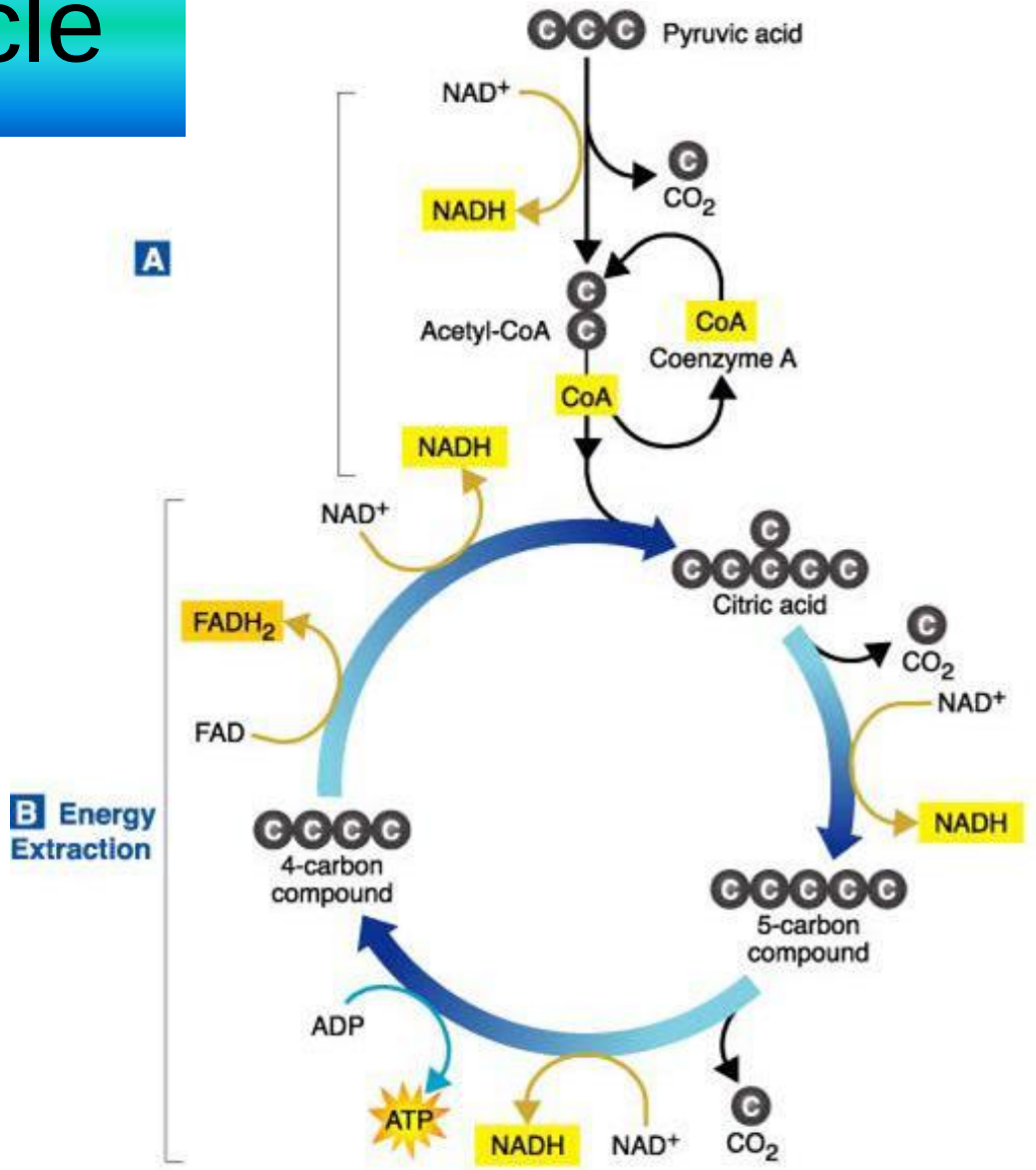
Krebs cycle occurs 2 times for each glucose entering glycolysis



Krebs Cycle

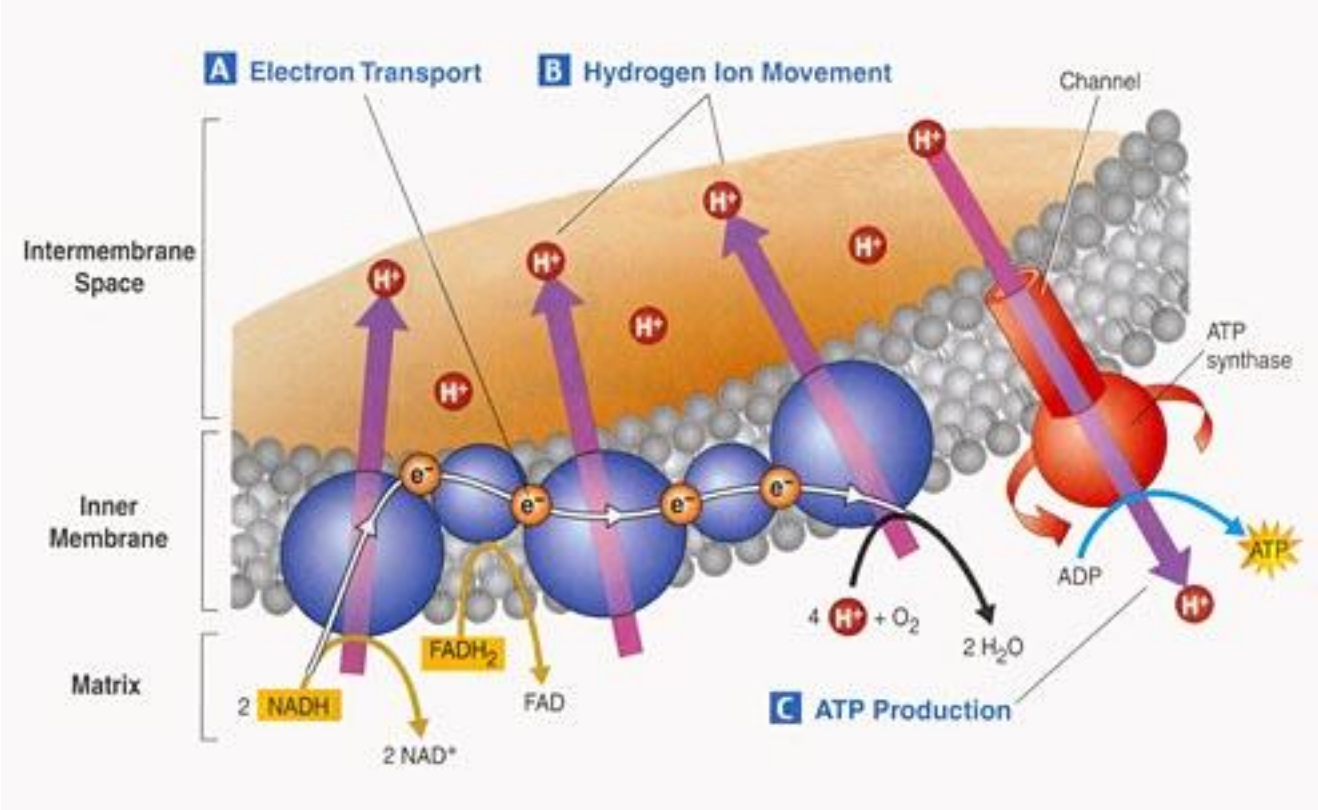
NADH and $FADH_2$ carry high energy *electrons*.

Those electrons will generate ATP in the next step: ETC!



9.2 THE KREBS AND ELECTRON TRANSPORT

- The electron transport chain uses the high-energy electrons from the Krebs cycle to convert ADP into ATP

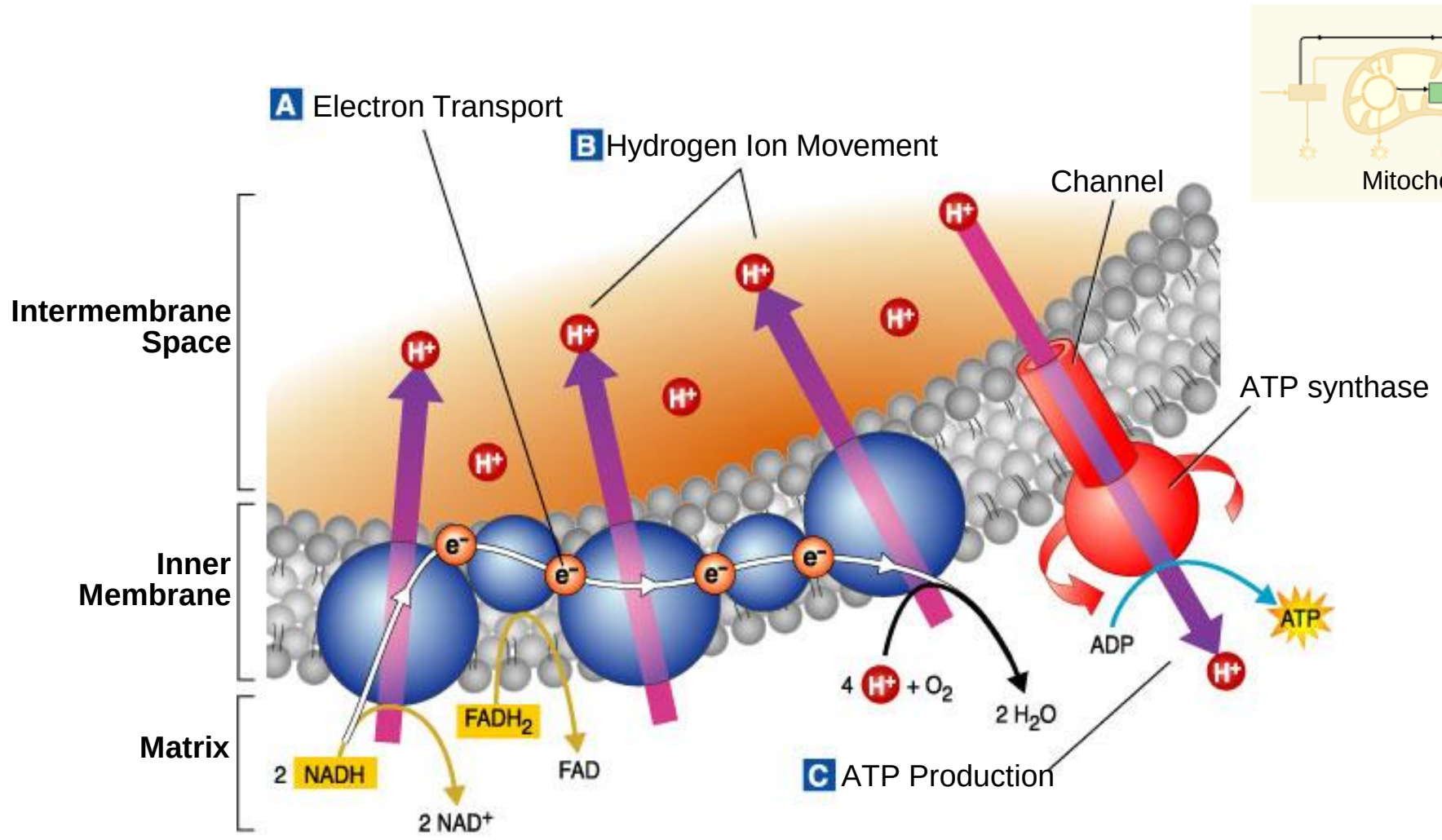


Electron Transport Chain

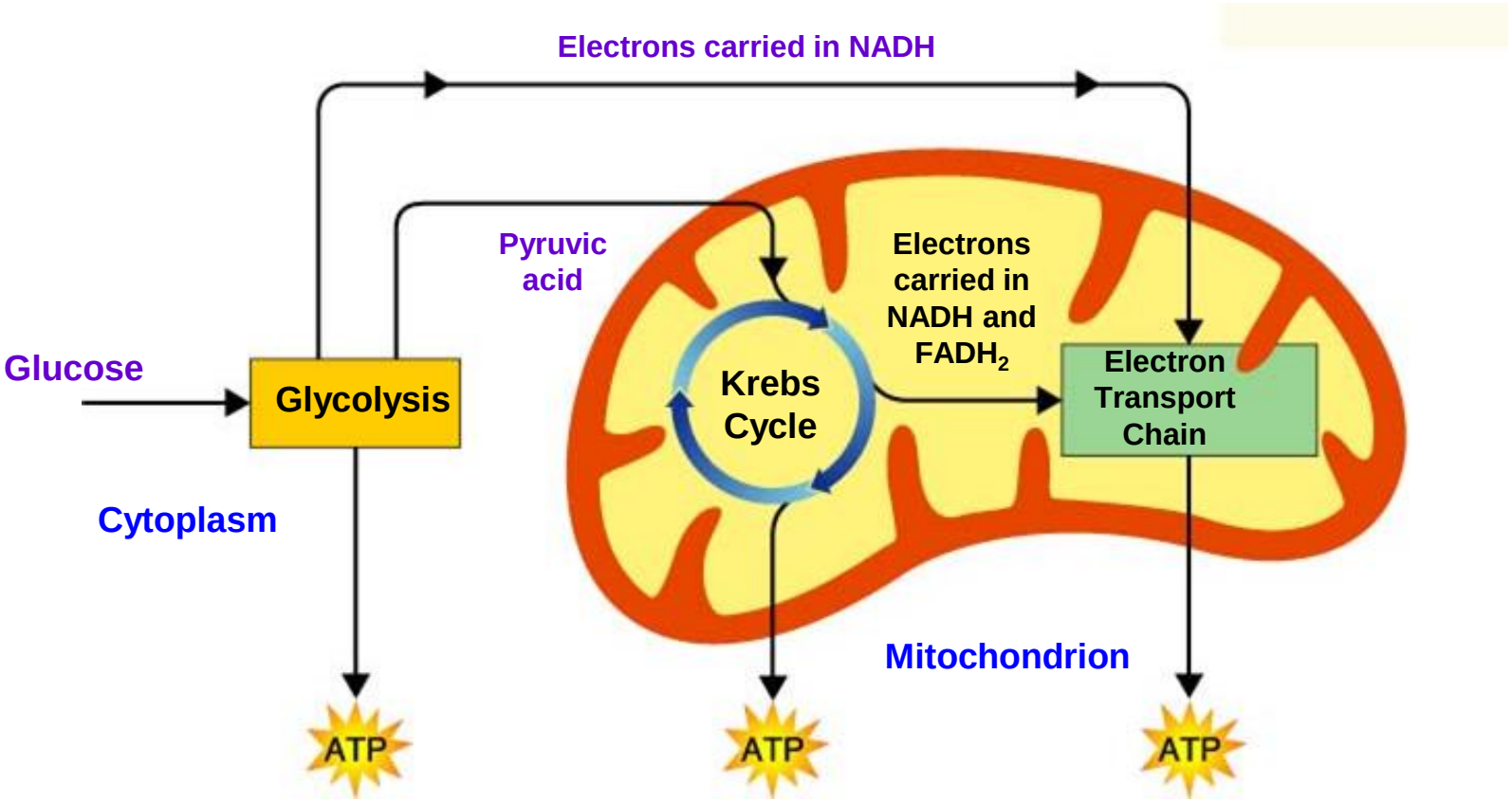
- Location: **cristae** (inner membranes) of the mitochondria.
- The electron carriers (**NADH** and **$FADH_2$**) release their high energy electrons to carrier membrane proteins.
- **H+ ions** move through **ATP Synthase** channel to generate the **ATP**.
- **Oxygen** is the final electron acceptor in the chain and combines with the H+ ions = **H_2O**.
- Net total of **30-34 ATP**.

Animation

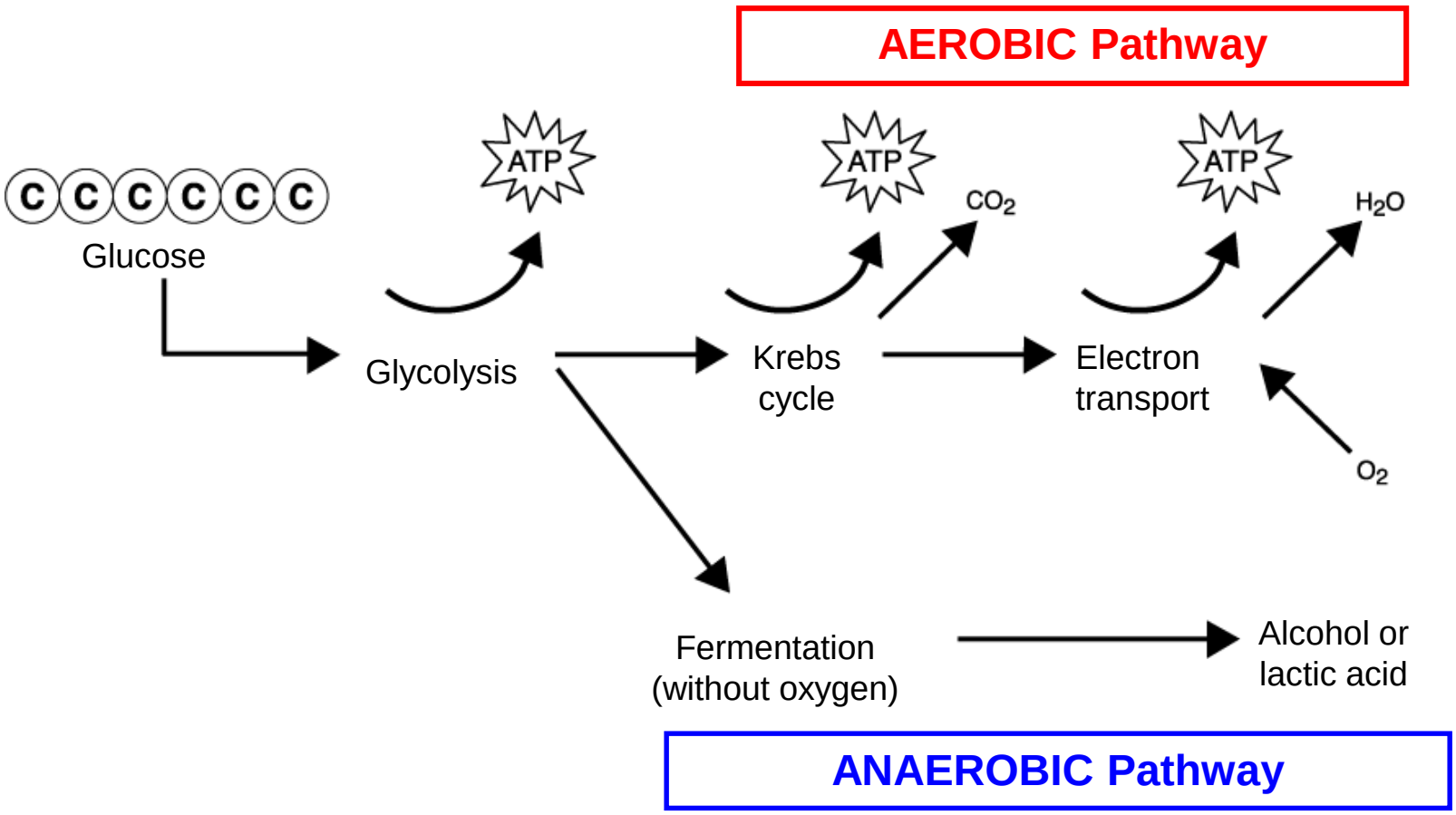
ETC


A Electron Transport
B Hydrogen Ion Movement
Channel
Intermembrane Space
Inner Membrane
Matrix
ATP synthase
H+
e−
FADH2
FAD
2 NADH
2 NAD+
4 H+ + O2
2 H2O
ADP
ATP
C ATP Production
Mitochondrion

Aerobic Cellular Respiration: An Overview



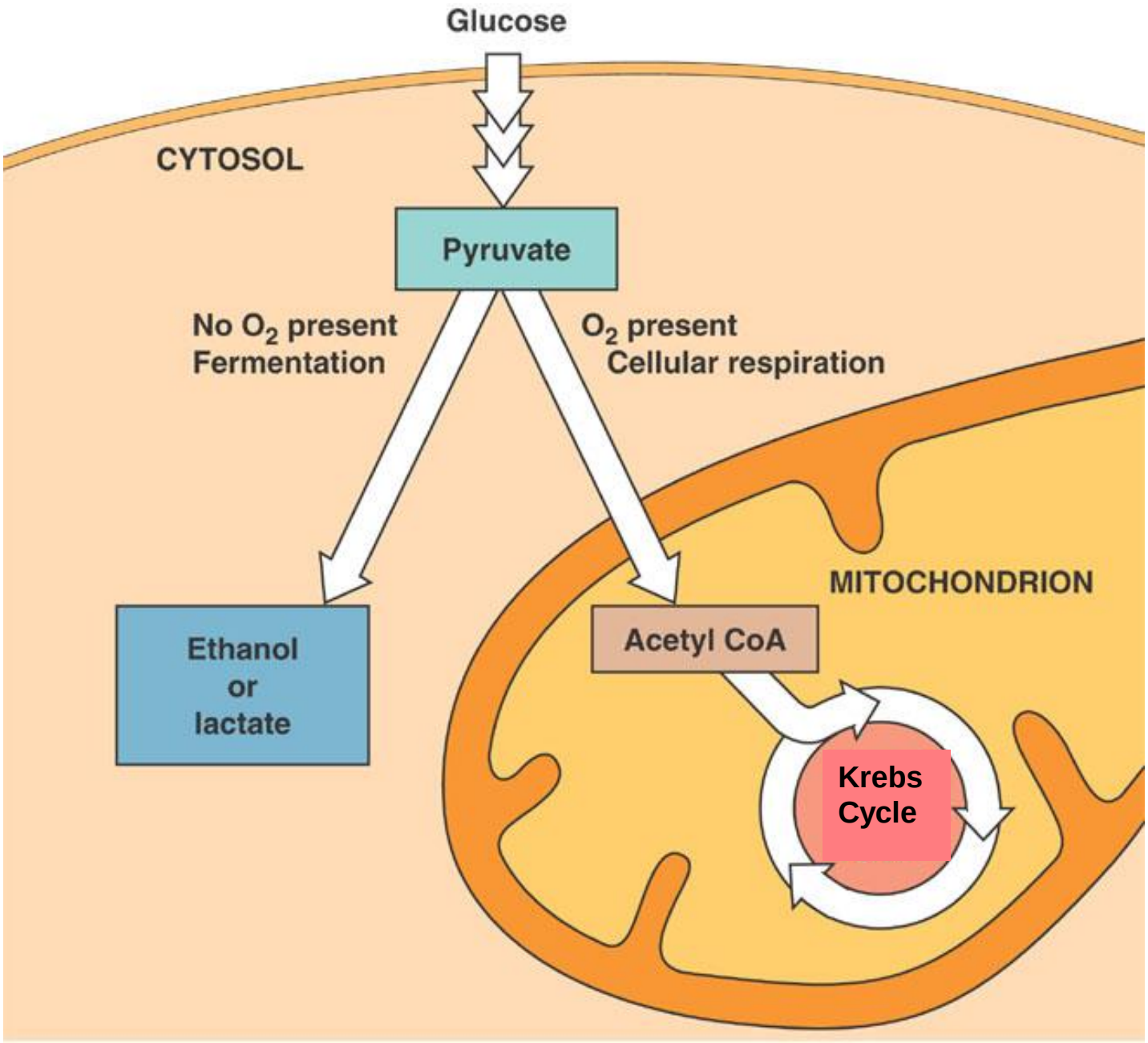
How many ATP's were made at each step?


AEROBIC Pathway
C C C C C C
Glucose
ATP
ATP
ATP
CO_2
H_2O
Glycolysis
Krebs cycle
Electron transport
O_2
Fermentation (without oxygen)
Alcohol or lactic acid
ANAEROBIC Pathway

What if NO OXYGEN is available?

Anaerobic Respiration

Fermentation!


Glucose
CYTOSOL
Pyruvate
No O_2 present
Fermentation
O_2 present
Cellular respiration
MITOCHONDRION
Ethanol
or
lactate
Acetyl CoA
Krebs
Cycle

Anaerobic Respiration

- Occurs in just the ***cytoplasm*** of cell.
- ***ANAEROBIC*** process.
- Starts off with ***Glycolysis*** (same as Aerobic)
- After glycolysis:

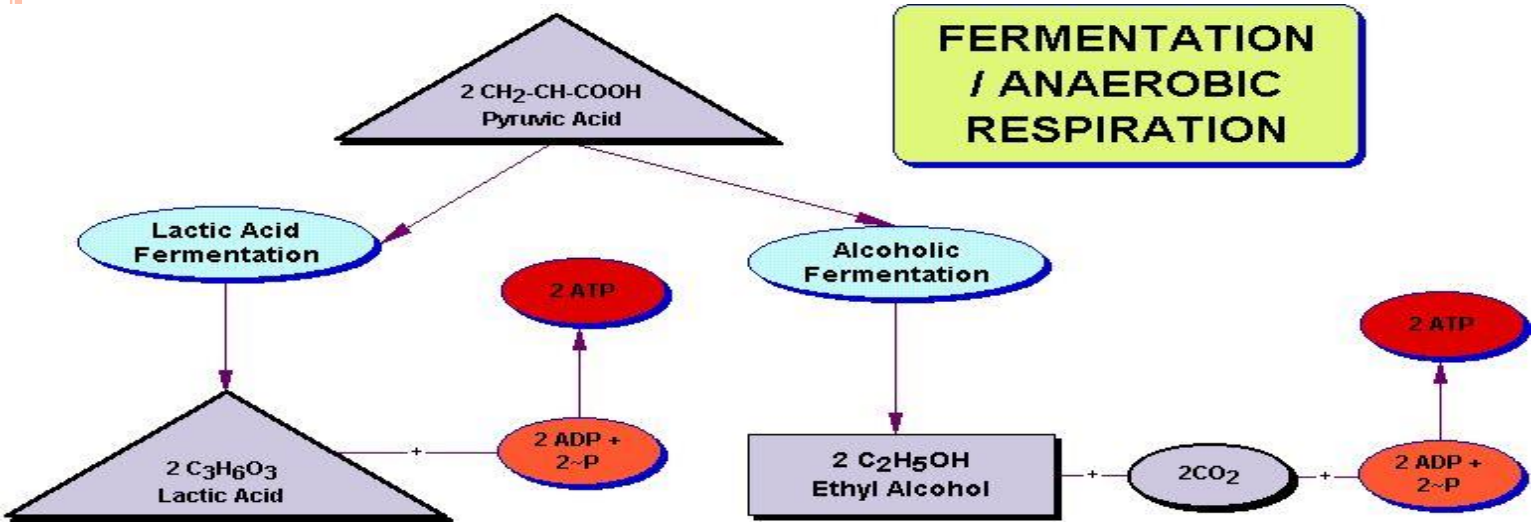
  1. **Lactic Acid Fermentation** – pyruvic acid is turned into ***lactic acid***. **Bacteria** produce dairy products with lactic acid.

  2. **Alcoholic Fermentation** – Yeast cells produce **CO_2** and **ethanol**.

- Total ATP produced is: **2** *(from glycolysis, not fermentation)*

9.2 CHEMICAL PATHWAYS

- **Fermentation** releases energy from food molecules by producing ATP in the absence of O2
  - Anaerobic means "not in air"
- **The two main types of fermenation are alcoholic fermentation and lactic acid fermentation (look at the difference)**



ANAEROBIC RESPIRATION

Alcoholic Fermentation

Glucose

feeds yeast

Glycolysis

2 Ethanol

+

2 Carbon Dioxide Molecules

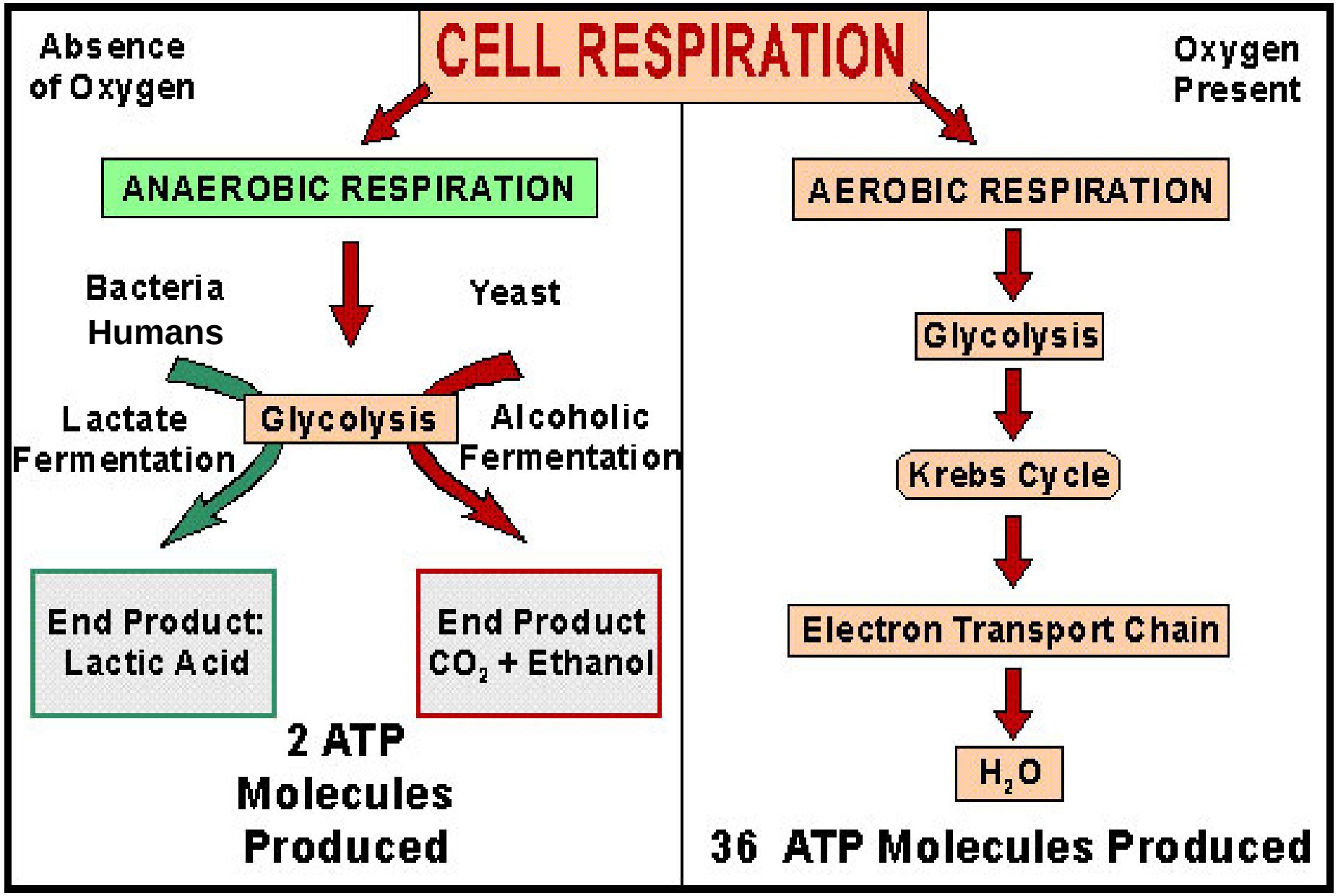
Lactate Fermentation

Glucose

feeds certain bacteria

Glycolysis

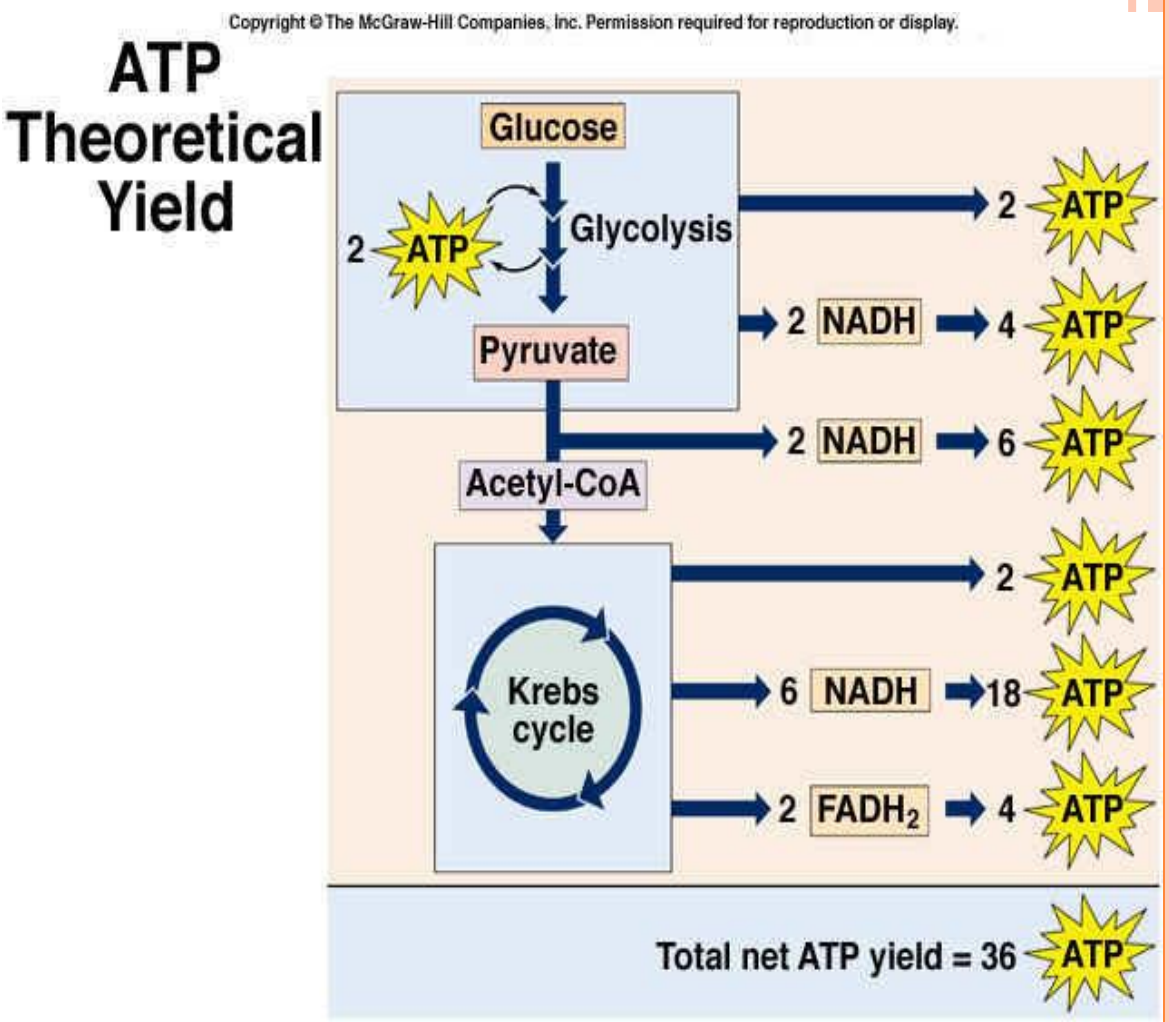
2 Lactate Molecules


CELL RESPIRATION
Absence of Oxygen
Oxygen Present
ANAEROBIC RESPIRATION
AEROBIC RESPIRATION
Bacteria
Humans
Yeast
Glycolysis
Lactate Fermentation
Glycolysis
Alcoholic Fermentation
Krebs Cycle
Electron Transport Chain
End Product: Lactic Acid
End Product CO_2 + Ethanol
H_2O
2 ATP Molecules Produced
36 ATP Molecules Produced

9.2 THE KREBS AND ELECTRON TRANSPORT

- Glycolysis creates 2 ATP
- Krebs + ETC creates 36
- 18 Times as much as Fermentation

- PG 232 (1-6)



Why do photosynthesis and cell respiration need each other?