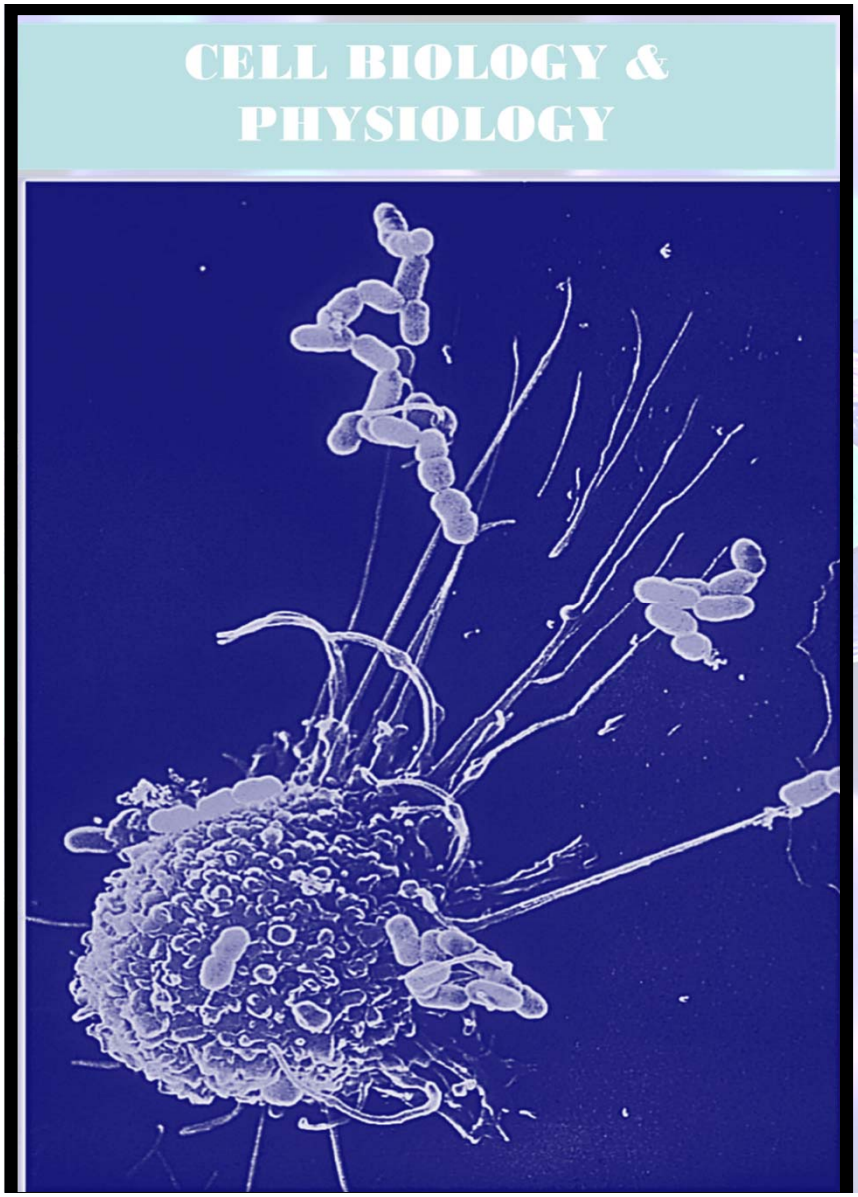



جامعة الملك سعود
King Saud University

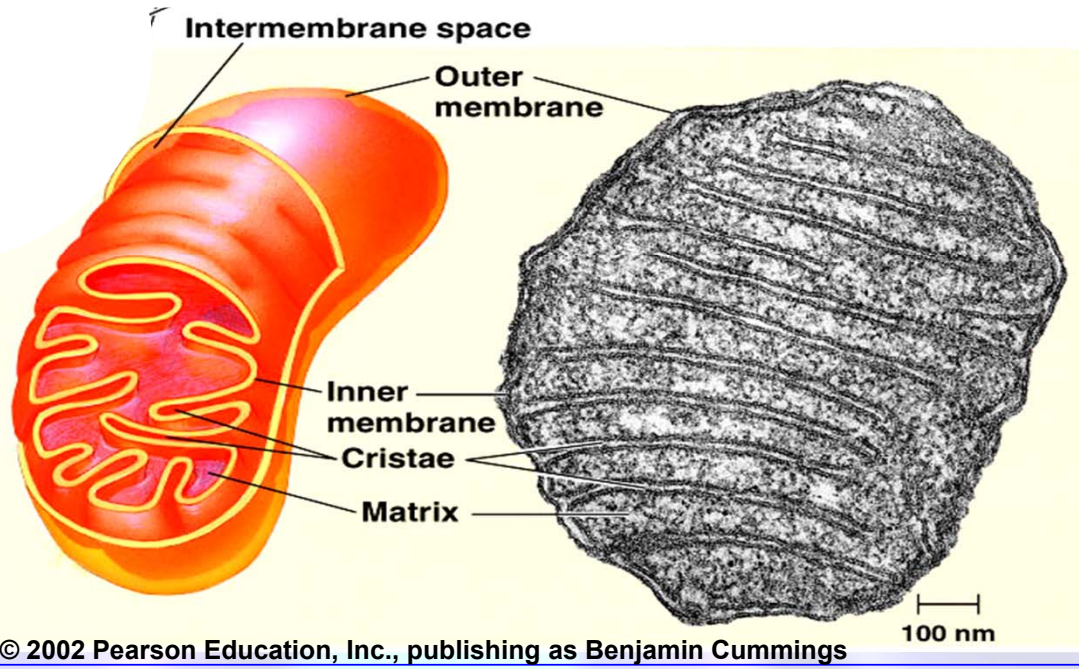
college of sciences
Zoology Department

# Cell Biology and Physiology

## ZOO (242)

بسم الله الرحمن الرحيم

# CELLULAR RESPIRATION:
## Oxidative Phosphorylation and the Electron Transport Chain



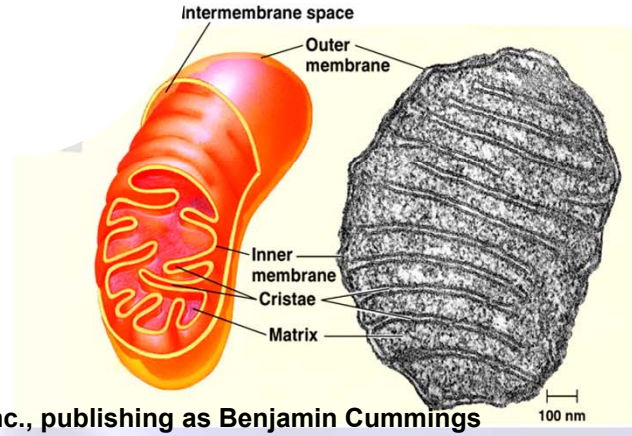
# Objectives

- Oxidative Phosphorylation and the Electron Transport Chain
  - Electron transport chain (The Pathway of Electron Transport).
  - Chemiosmosis (*the Oxidative Phosphorylation*)

- Fermentation and anaerobic respiration: enable cells to produce ATP without the use of oxygen:
  - Types of Fermentation.
  - Comparing Fermentation (Anaerobic Respiration) with Aerobic Respiration

# 3- Electron transport chain: (oxidative phosphorelation)

- Only 4 of 38 ATP ultimately produced by respiration of glucose are derived from substrate-level phosphorylation (2 from glycolysis and 2 from Krebs Cycle).
- The vast majority of the ATP (90%) comes from the energy in the electrons carried by NADH and $FADH_2$.
- The energy in these electrons is used in the electron transport chain to power لتدعم ATP synthesis.
- Thousands of copies of the electron transport chain are found in the extensive surface of the cristae (*the inner membrane of the mitochondrion*).
- Electrons drop in free energy as they pass down the electron transport chain.



# Electron transport chain

- Electrons carried by NADH are transferred to the first molecule in the electron transport chain (the flavoprotein; FMN).
- The electrons continue along the chain which includes several Cytochrome proteins and one lipid carrier.
- The electrons carried by $FADH_2$ have lower free energy and are added to a later point in the chain.
- Electrons from NADH or $FADH_2$ ultimately pass to oxygen.
- The electron transport chain generates no ATP directly. Rather, its function is to break the large free energy drop from food to oxygen into a series of smaller steps that release energy in manageable amounts كميات مناسبة.

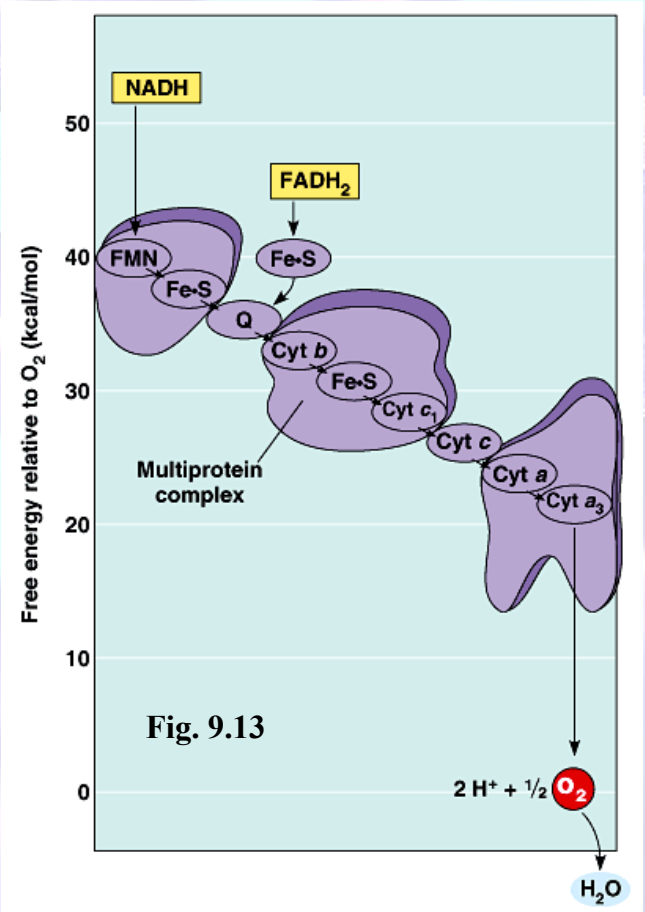
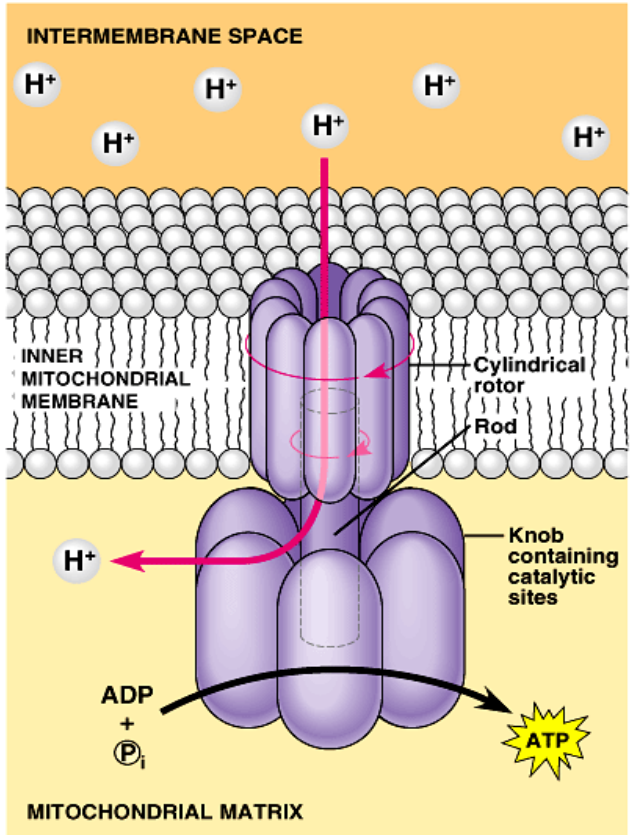


Fig. 9.13

# Electron transport chain

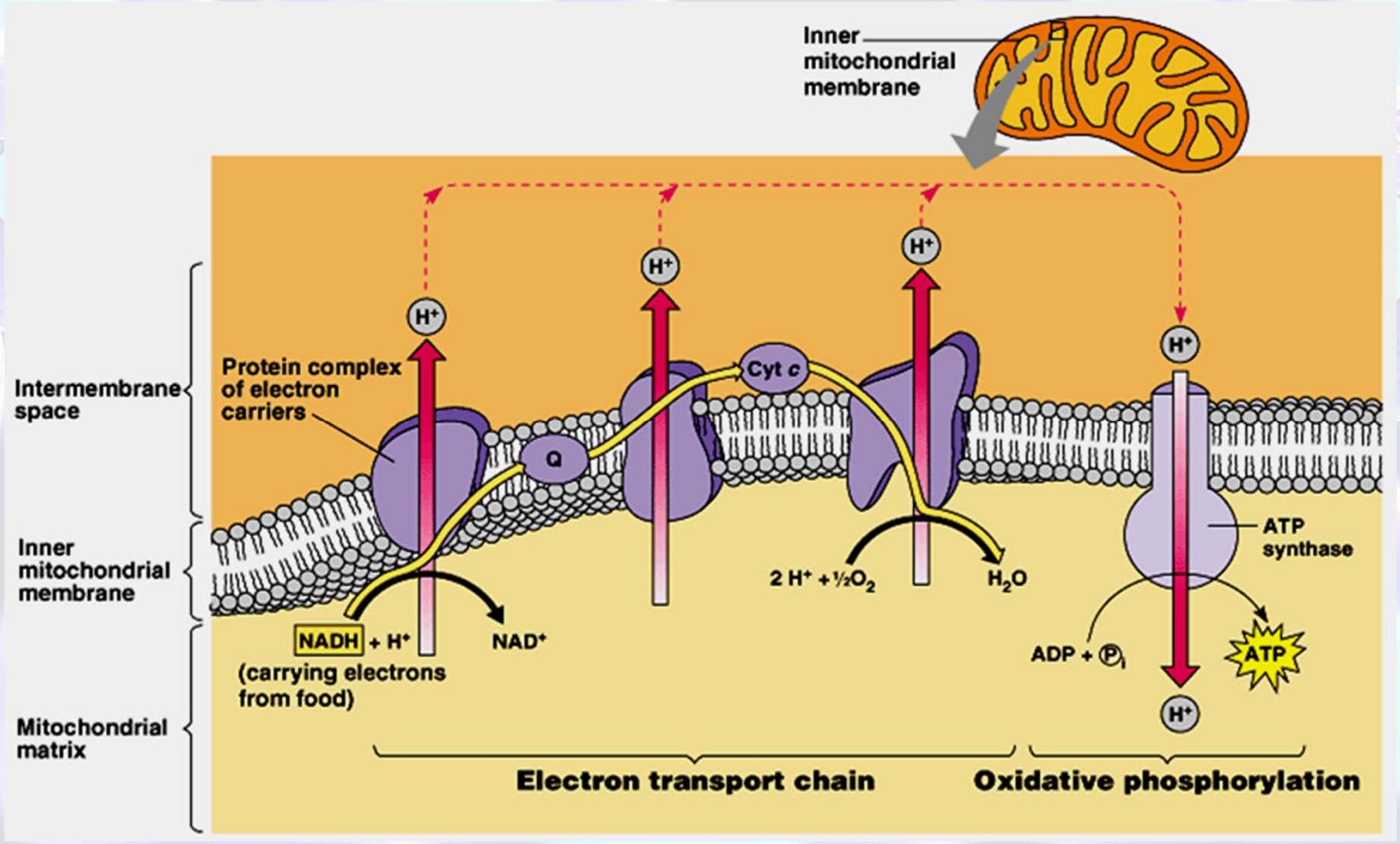
- **ATP-synthase**, in the cristae actually makes ATP from ADP and $P_i$.
- ATP used the energy of an existing proton gradient to power ATP synthesis.
  - This proton gradient develops between the inter-membrane space and the matrix.
  - This concentration of $H^+$ is the **proton-motive force**.
- The ATP synthase molecules are the only place that will allow $H^+$ to diffuse back to the matrix (**exergonic flow of $H^+$**).
- This flow of $H^+$ is used by the enzyme to generate ATP in a process called "**Chemiosmosis**".




- **Chemiosmosis:** (osmos = puch)

  It is the oxidative phosphorelation that results in ATP production in the inner membrane of mitochondria.

**Energy carried by NADH and $FADH_2$ give a maximum yield of 34 ATP is produced by oxidative phosphorylation.**



# Cellular respiration generates many ATP molecules for each sugar molecule it oxidizes

- During respiration, most energy flows from glucose → NADH → electron transport chain → proton-motive force → ATP.
- Some ATP is produced by substrate-level phosphorylation during glycolysis and the Krebs cycle, but most ATP comes from oxidative phosphorylation (through electron transport chain).
- Energy produced in Glycolysis and Krebs cycle gives a maximum yield of 4 ATP by substrate-level phosphorylation.
- Energy produced in electron transport chain gives a maximum yield of 34 ATP by oxidative phosphorylation via ATP-synthase.
- Substrate-level phosphorylation and oxidative phosphorylation give a bottom line of 38 ATP.

# Summary of Cellular Respiration

- Glycolysis occurs in the cytosol and breaks glucose into two pyruvates

- Krebs Cycle takes place within the mitochondrial matrix, and breaks a pyruvate into $CO_2$ and produce some ATP and NAD$H$.

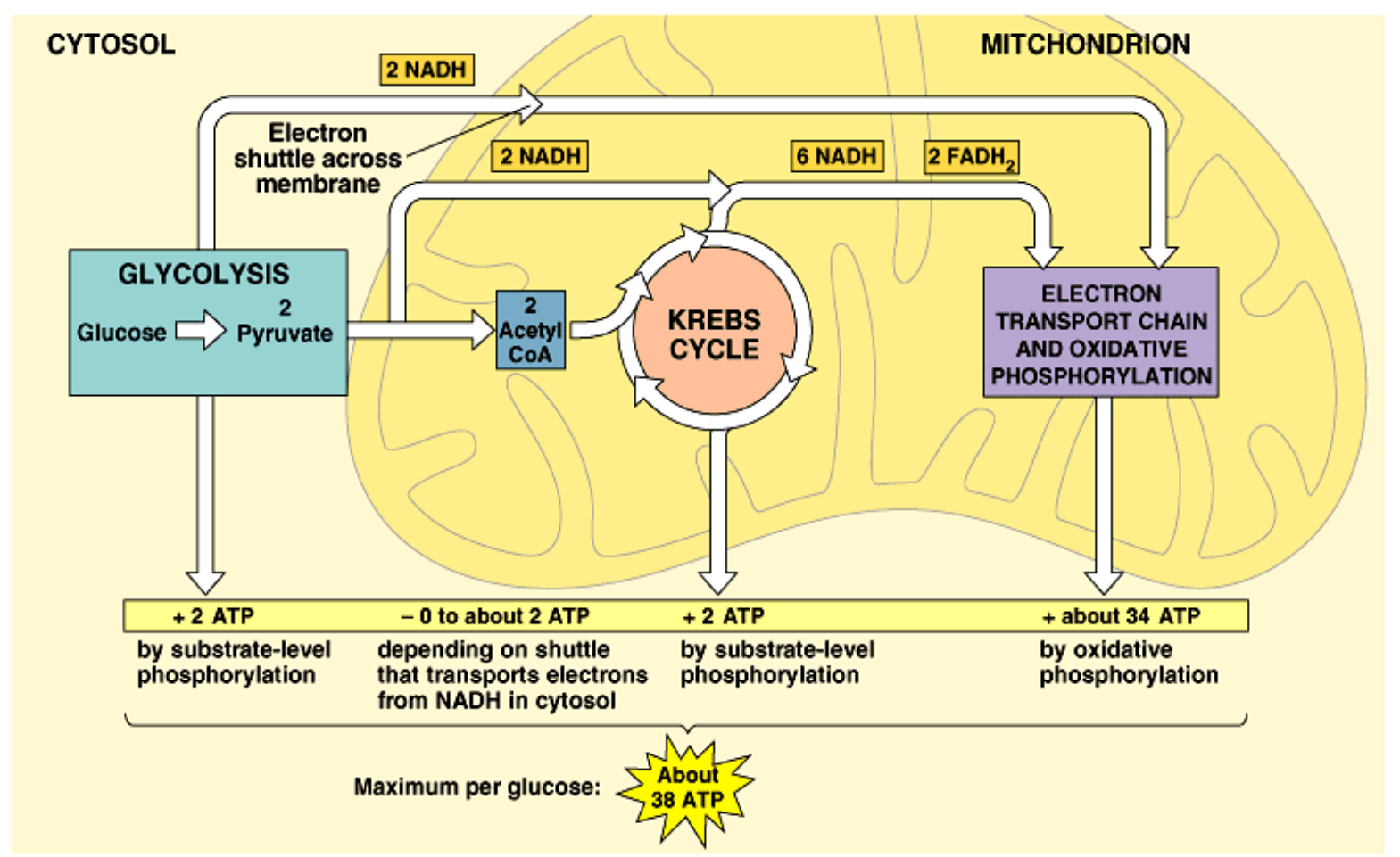
- Some of ATP is produced at these two steps via (substrate-level-phosphorylation).

- Electron Transport Chain accepts $e^-$ from NAD$H$ and passes these $e^-$ from one protein molecule to another.

- At the end of the chain, $e^-$ combine with both $H^+$ and $O_2$ to form $H_2O$ and release energy.

- These energy are used by mitochondria to synthesis 90% of the cellular ATP *via* ATP-synthase, a process called Oxidative Phosphorylation, in the inner membrane of mitochondria.

# Summary of cell respiration



# Definitions: تعريفات

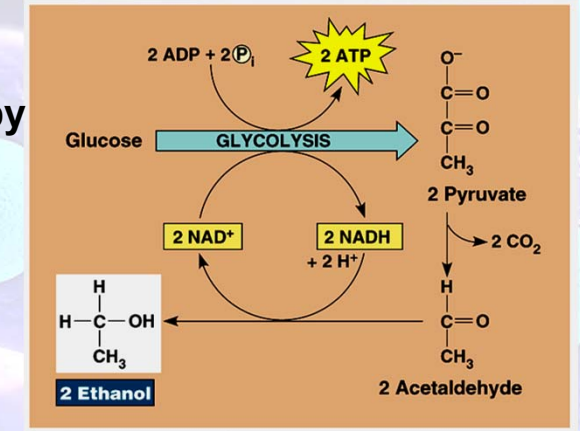
- **Chemiosmosis:** a process *via* which oxidative phosphorylation takes place at the end of the Electron Transport Chain to produce 90% of ATP *via* ATP-synthase.
  - Or, is the process in which ATP synthesis powered by the flow of H+ back across ATP synthase.
- **ATP-synthase:** an enzyme presents in the inner mitochondrial membrane and used in making ATP by using H+ (protons).
- **$NAD^+$:** Nicotinamide adenine dinucleotide, which is an electron acceptor that helps electron transfer during redox reactions in cellular respiration.
- **FAD:** Flavin adenine dinucleotide, which is an electron acceptor that helps electron transfer during Krebs Cycle and Electron Transport Chain in cellular respiration.

# Fermentation: Enables يُمَكِن some cells to produce ATP without the help of oxygen

- Oxidation refers to the loss of electrons to any electron acceptor, not just to oxygen.
  - In glycolysis, glucose is oxidized to 2 pyruvate molecules with $NAD^+$ as the oxidizing agent (not $O_2$).
  - Some energy from this oxidation produce 2 ATP.
  - If oxygen is present, additional ATP can be generated when NADH delivers its electrons to the electron transport chain.
- Glycolysis generates 2 ATP when oxygen is absent (anaerobic لاهوائي).
- Anaerobic catabolism of sugars can occur by fermentation.
- Fermentation can generate ATP from glucose by substrate-level phosphorylation as long as there is a supply of $NAD^+$ (the oxidizing agent) to accept electrons.
  - If the $NAD^+$ pool is exhausted إستُنفِذ, glycolysis shuts down.
  - Under aerobic هوائى conditions, NADH transfers its electrons to the electron transfer chain, recycling $NAD^+$.
- Under anaerobic conditions, various fermentation pathways generate ATP by glycolysis and recycle $NAD^+$ by transferring electrons from NADH to pyruvate.

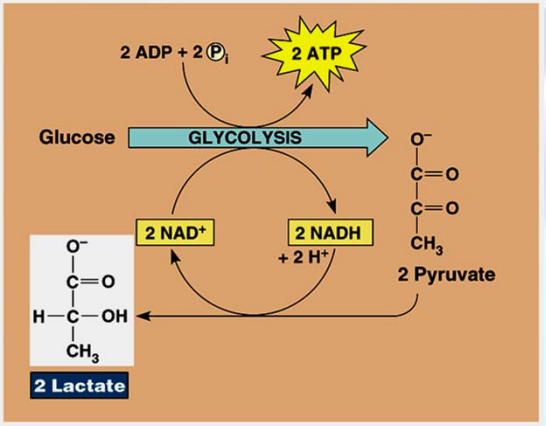
# Fermentation

- **Alcohol fermentation:**
  the pyruvate is converted to ethanol in two steps.
  - First, pyruvate is converted to acetaldehyde by the removal of $CO_2$.
  - Second, acetaldehyde is reduced by NADH to ethanol.
  - Alcohol fermentation by yeast is used in wine-making.



(a) Alcohol fermentation

- **Lactic acid fermentation:**
  the pyruvate is reduced directly by NADH to form lactate (ionized form of lactic acid).
  - Lactic acid fermentation by some fungi and bacteria is used to make cheese and yogurt.
  - Muscle cells switch from aerobic respiration to lactic acid fermentation to generate ATP when lack of O2 ($O_2$ is scarce نادر)
    - The waste product, lactate, may cause muscle fatigue, but ultimately it is converted back to pyruvate in the liver.



(b) Lactic acid fermentation

# Examples of anaerobic respiration:

## A)- During exercise our bodies require a lot of energy

- The body can only supply a limited amount of oxygen for cellular respiration.
- Energy is not produced at the rate required.
- Cells will use anaerobic respiration to release extra energy
- This produces lactic acid (a waste product).

## B)- We use yeast to make bread

- $CO_2$ produced causes bread to rise by creating air pockets
- The ethanol (alcohol) produced is evaporating during baking

# References


- **"Cellular respiration and Fermentation" chapter 09 Biology** by Jane B Reece; Neil A Campbell; et al Boston : Benjamin Cummings / Pearson, ©2011. English : 9th Ed.