Unit 7 - Cellular Resp

- Know that all organisms undergo cellular respiration as long as oxygen is available.
- Explain the process of harvesting energy in aerobic cellular respiration
- Explain the process of anaerobic respiration.
- Understand that compared to the chemical reactions that take place during cellular respiration, reactions during fermentation result in less ATP being produced
- Energy is required for photosynthesis and released during respiration
- Respiration is the reverse process of photosynthesis anism's body functions
- Compare the reactants and products of photosynthesis:

Menu

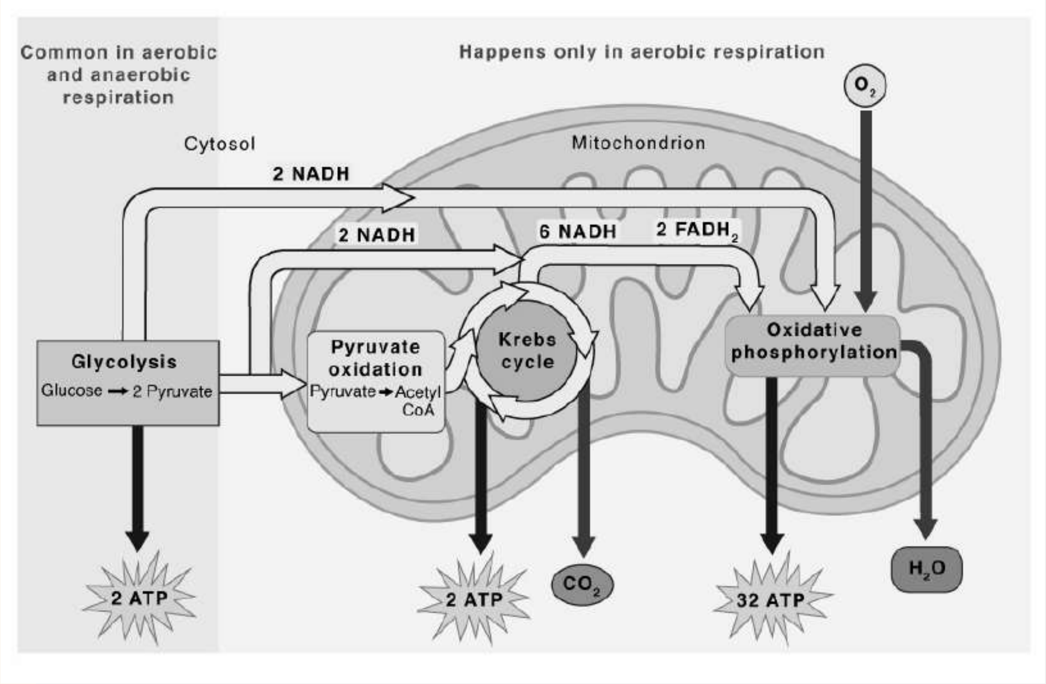
Cellular Respiration - Overview

Cellular Respiration

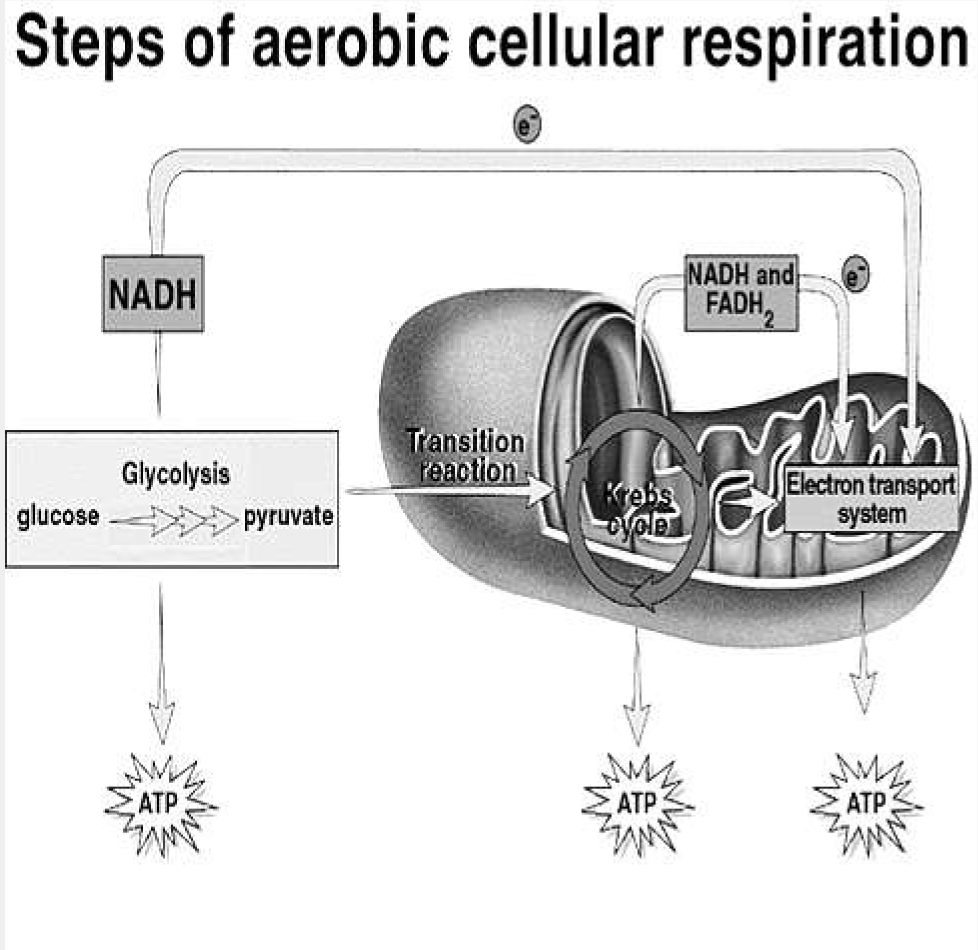
- Oxygen requiring process that uses energy extracted from macromolecules (glucose) to produce energy (ATP), water and carbon dioxide.

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

- Metabolic Pathway that breaks down carbohydrates.
- Process is exergonic as high-energy glucose is broken down into CO2 and H2O.
- Process is also catabolic because the larger glucose molecule breaks into smaller molecules.



Steps of Cellular Respiration



Steps of Cellular Respiration

1. **Glycolysis**
2. **Intermediate step**
3. **The Krebs Cycle**
4. **The Electron Transport Chain (ETC)**

- **The Where of Cellular Respiration**
  - ➔ Cellular respiration actually takes place in **two** parts of the cell.
  - ➔ **Glycolysis** occurs in the **cytoplasm**.
  - ➔ **Krebs Cycle & ETC** take place in the **mitochondria**

Glycolysis

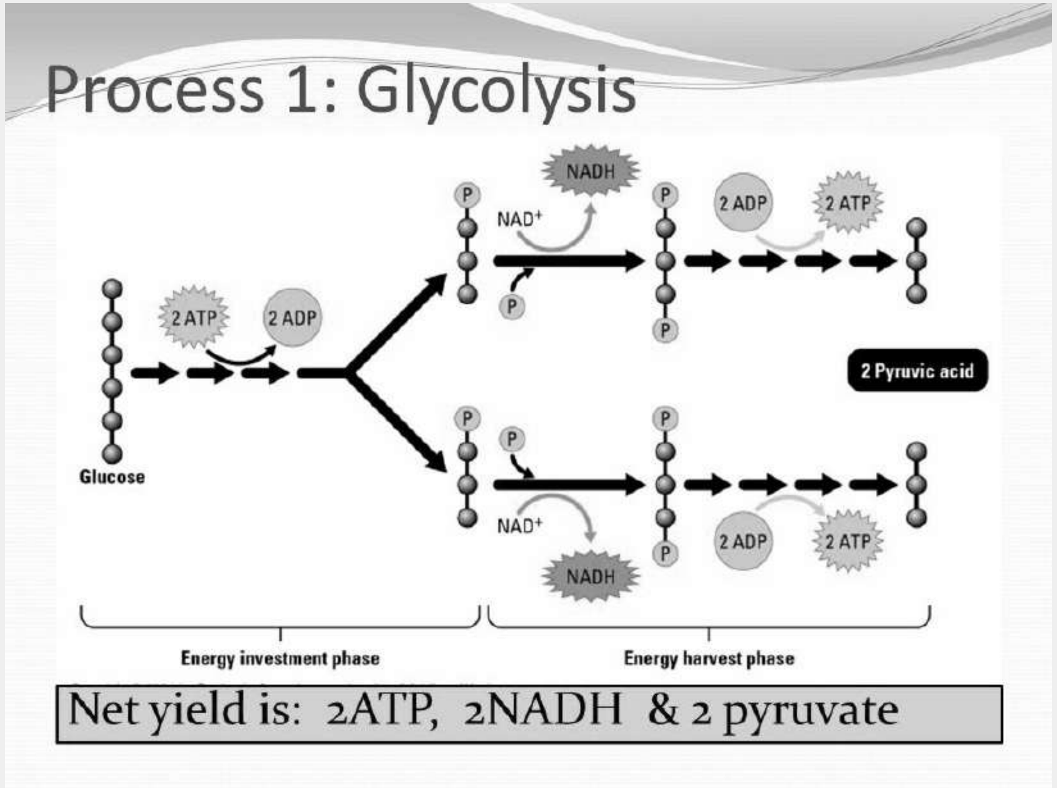
Step 1: Glycolysis

- **Overview**:
  - ➔Takes place in the **cytoplasm**.
  - ➔**Anaerobic** (doesn’t use oxygen)
  - ➔**Requires** input of **2 ATP**.
  - ➔ **Glucose splits** into two molecules of **Pyruvate** or Pyruvic Acid.
  - ➔Also **produces 2 NADH and 4 ATP**.
- Two Phases:
  - ➔**Energy Investment Phase** (**EIP**) - *Preparatory phase*

    Summary: Even though glycolysis is an energy-releasing process, the cell needs to put in a little energy to get things going. At the pathway's beginning, **2 molecules of ATP are used up**. In a way**, those 2 ATP molecules are like an investment that pays back interest.**
  - ➔**Energy Yielding Phase** (**EYP**) - *Energy payoff phase*

    Summary: One of the reactions of glycolysis **removes 4 high-energy electrons and passes them to an electron carrier called NAD+**. Like NADP+ in photosynthesis, **each NAD+ accepts a pair of high-energy electrons. This molecule, known as NADH, holds the electrons until they can be transferred to other molecules**. By doing this, **NAD+ helps to pass energy from glucose to other pathways in the cell**. An advantage is that **glycolysis itself does not require oxygen**. This means that glycolysis can supply chemical energy to cells when oxygen is not available. However, when a cell generates large amounts of ATP from glycolysis, it runs into a problem. In just a few seconds, all of the cell's available NAD+ molecules are filled up with electrons. **Without NAD+, the cell cannot keep glycolysis going, and ATP production stops**.

Steps of Cellular Respiration



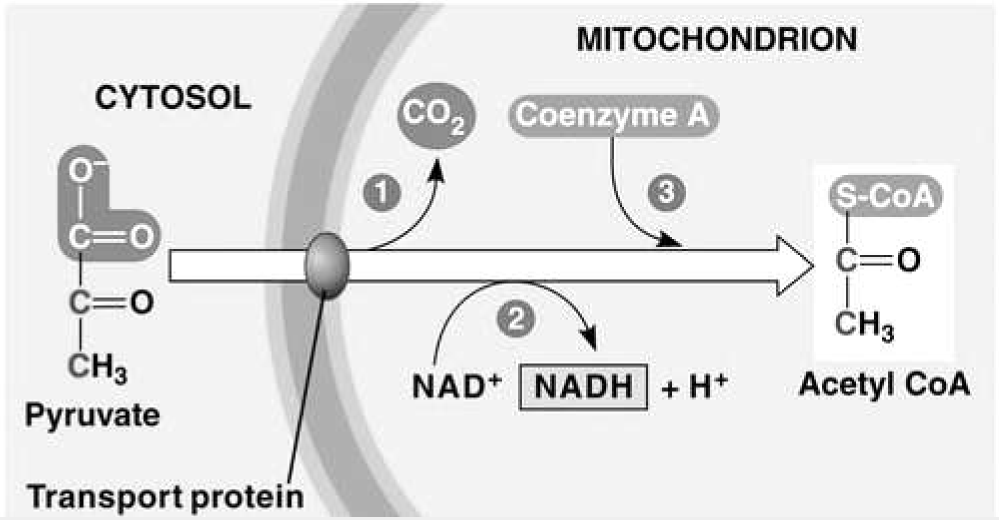
Total Net Yield in Glycolysis:

- ➔**2** - **3C-Pyruvate (PYR)**
- ➔**2** - **ATP** (*Substrate-level Phosphorylation*: ATP is formed when an enzyme transfers a phosphate group from a substrate to ADP.)
- ➔**2** - **NADH** (nicotinadenine dinucleotide)

Intermediate Step

Intermediate Step - Aerobic

- Occurs when **Oxygen** is present (**aerobic**).
- **2 Pyruvate** (3C) molecules are transported through the mitochondrial membrane to the matrix and are **converted** to 2 **Acetyl CoA** (2C) molecules.
- **End products intermediate step:**
  - → **2 - NADH**
  - → **2 - CO2**
  - → **2- Acetyl CoA (2C)**



Step 2 - The Krebs Cycle

01

Citric Acid Cycle

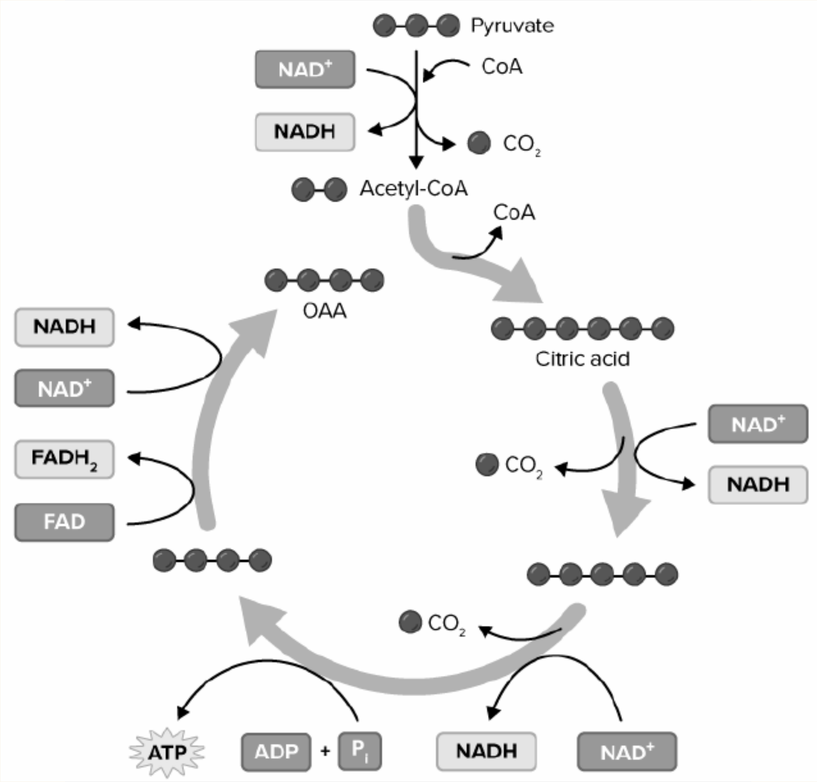
- **Location: mitochondrial matrix.**
  - ➔Acetyl CoA (2C) bonds to Oxalacetic acid (4C - OAA) to make Citrate (6C).
  - ➔It takes 2 turns of the Krebs cycle to oxidize 1 glucose molecule.

02

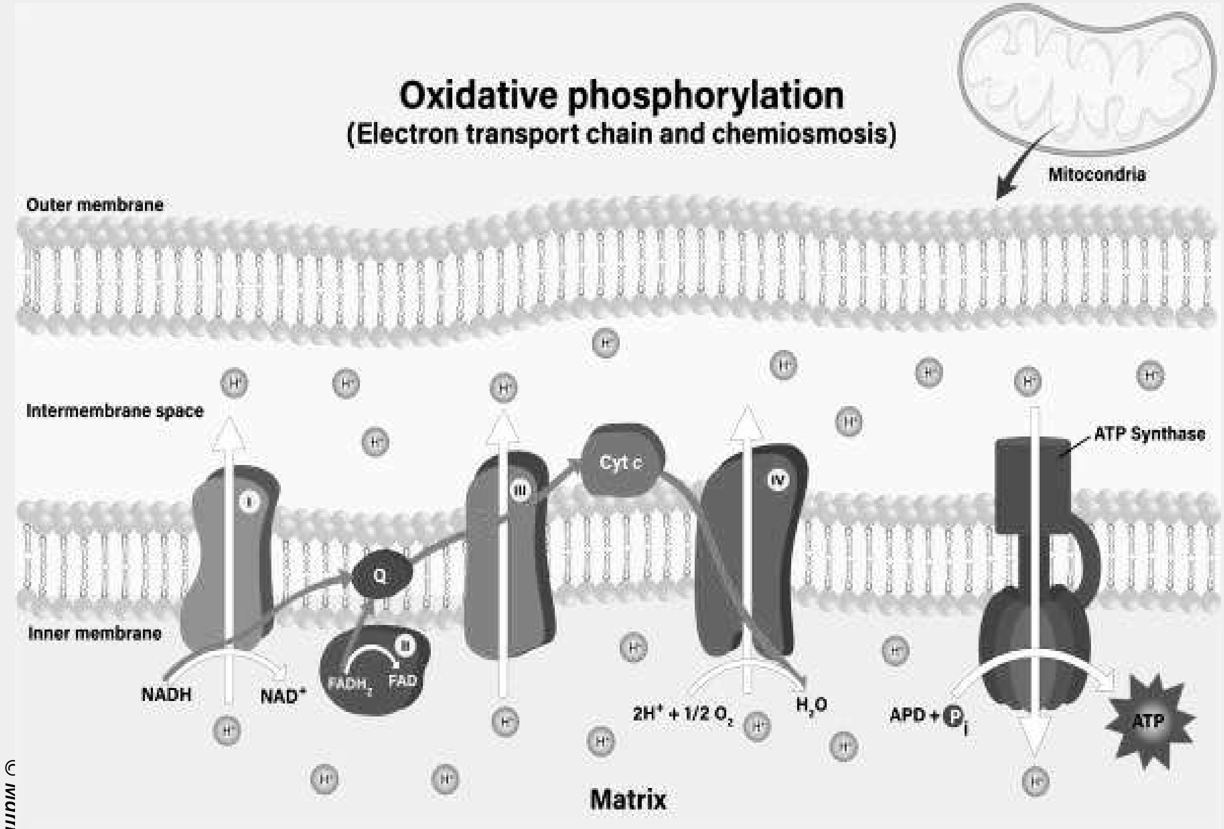
Net Yield

➔**Total Net Yield: (2 turns of Krebs Cycle)**

- ❑**2 - ATP** (substrate-level phosphorylation)
- ❑**6 – NADH**
- ❑**2 - FADH2** (Flavin-adenine dinucleotide)
- ❑**4 - CO2**



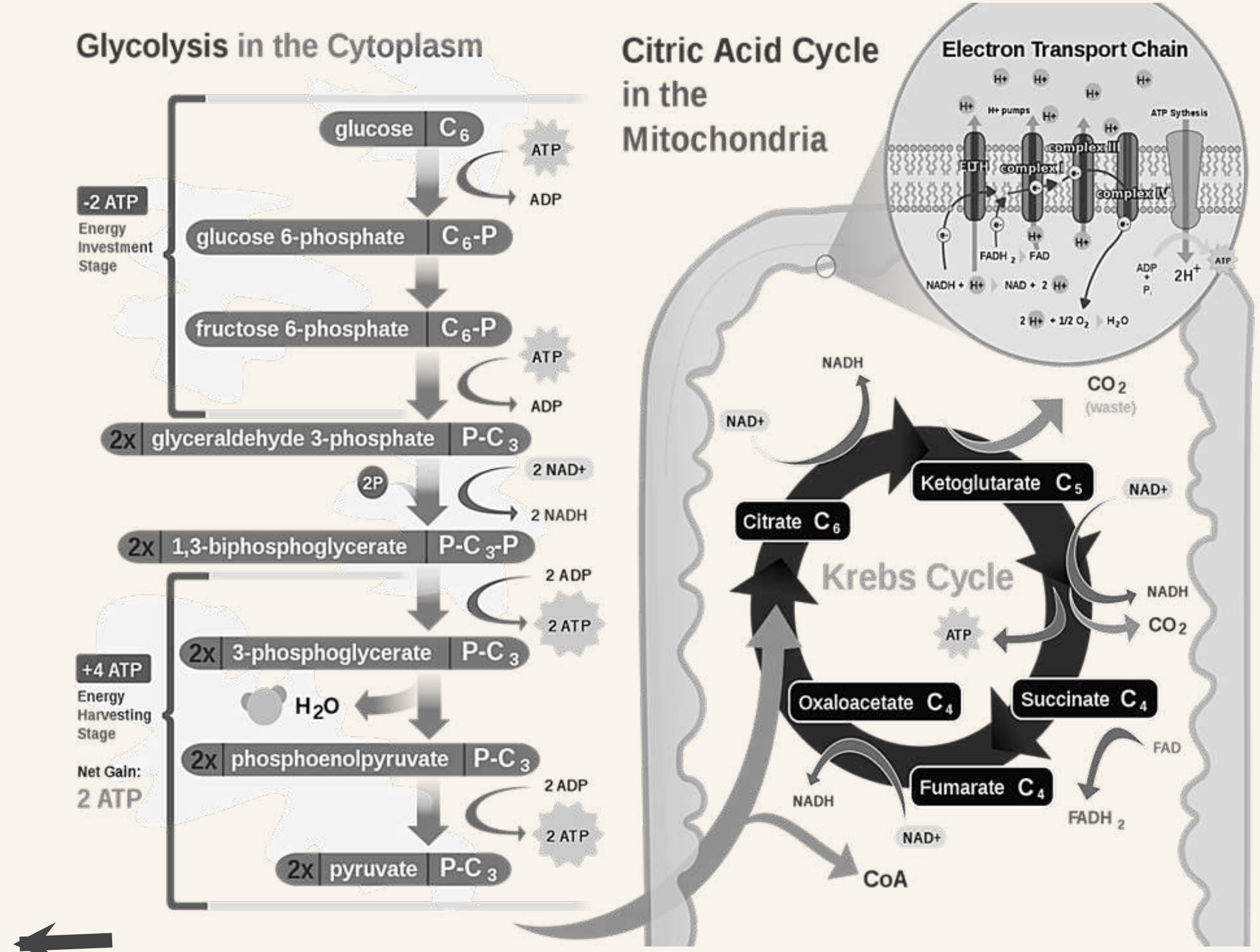
The ETC - Electron Transport Chain



Step 3: Chemiosmosis – Electron Transport Chain

- Location: **inner mitochondrial membrane**.
- Uses ETC (proteins) and **ATP Synthase** (enzyme) to make **ATP**.
  - ➔ETC pumps H+ (protons) across inner membrane
  - ➔The H+ then move via diffusion through ATP Synthase to make ATP.
  - ➔All **NADH** and **$FADH_2$** converted to ATP during this stage of cellular respiration.
  - ➔Each **NADH** converts to **3 ATP.**
  - ➔Each **$FADH_2$** converts to **2 ATP** (enters the ETC at a lower level than NADH).

Aerobic Cellular Respiration - Summary



Total ATP Yield from Cellular Respiration

- → **02 ATP - Glycolysis** (substrate-level phosphorylation)
- → **06 ATP** - converted from 2 NADH - **Glycolysis**
- → **06 ATP** - converted from 2 NADH –**intermediate step**
- → **02 ATP** - **Krebs cycle** (substrate-level phosphorylation)
- → **18 ATP** - converted from 6 NADH - **ETC**
- → **04 ATP** - converted from 2 $FADH_2$ - **ETC**

38 ATP – TOTAL

Fermentation - Alcohol

Anaerobic: Fermentation

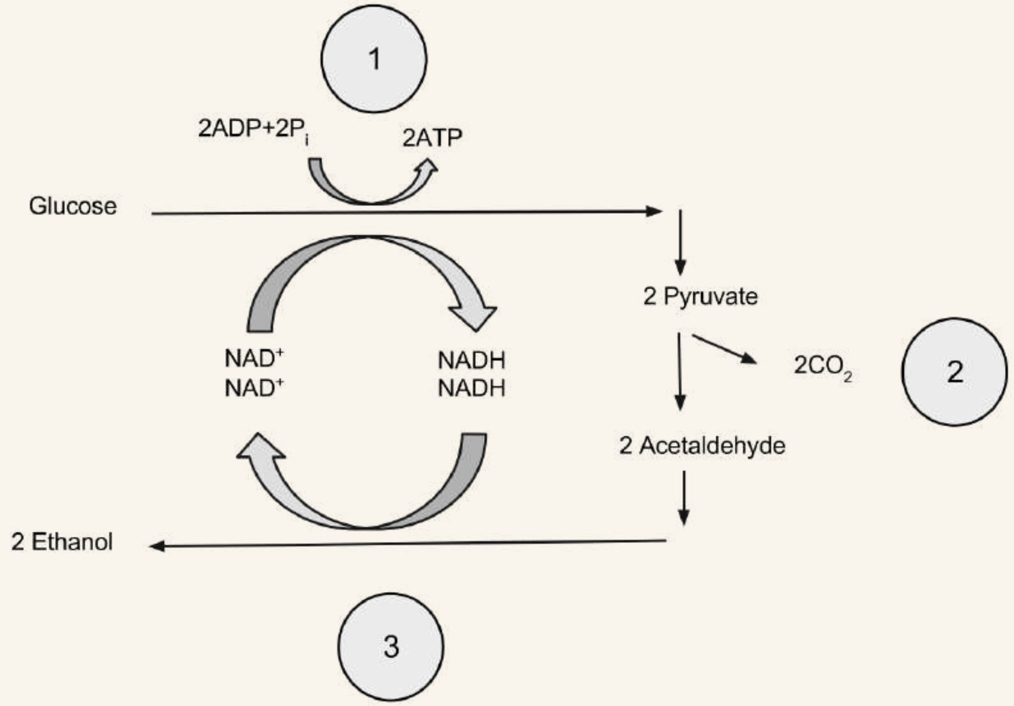
- Occurs in cytosol when oxygen is not present (called **anaerobic**).
- Glycolysis is a part of fermentation.
- Two Types:

1. **Alcohol Fermentation:**

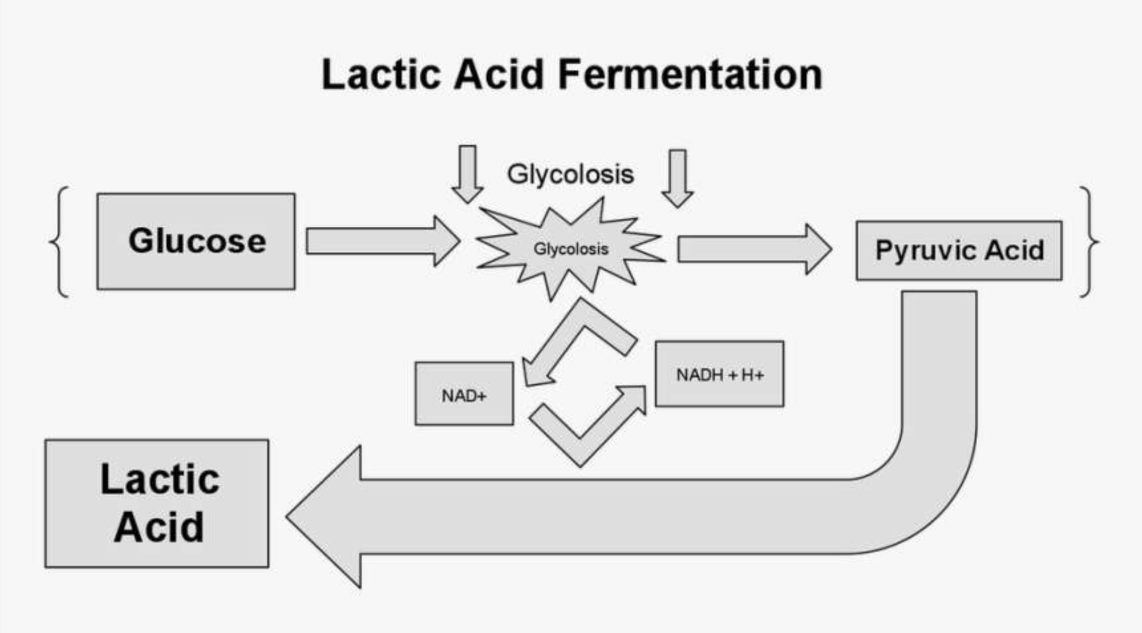
   Summary: Alcoholic Fermentation Yeasts and a few other microorganisms use alcoholic fermentation, forming ethyl alcohol and carbon dioxide as wastes. The equation for alcoholic fermentation after glycolysis is:

   Pyruvic + NADH → alcohol + CO2 + NAD^+

   Alcoholic fermentation produces carbon dioxide as well as alcohol. Alcoholic fermentation causes bread dough to rise. When yeast in the dough runs out of oxygen, it begins to ferment, giving off bubbles of carbon dioxide that form the air spaces you see in a slice of bread. The small amount of alcohol produced in the dough evaporates when the bread is baked. Occurs in some Plants and Fungi (yeast) and is used to make beer, wine and bread.



Fermentation - Lactic Acid



2. **Lactic Acid Fermentation**

Summary: Lactic Acid Fermentation In many cells, the pyruvic acid that accumulates as a result of glycolysis can be converted to lactic acid. Because this type of fermentation produces lactic acid, it is called lactic acid fermentation. This process regenerates NAD+ so that glycolysis can continue. The equation for lactic acid fermentation after glycolysis is: **Pyruvic acid + NADH → lactic acid + NAD$^+$**

Lactic acid is produced in your muscles during rapid exercise when the body cannot supply enough oxygen to the tissues. Without enough oxygen, the body is not able to produce all of the ATP that is required. When you exercise vigorously by running, swimming, or riding a bicycle as fast as you can, the large muscles of your arms and legs quickly run out of oxygen. Your muscle cells rapidly begin to produce ATP by lactic acid fermentation. The buildup of lactic acid causes a painful, burning sensation. This is why muscles may feel sore after only a few seconds of intense activity. Unicellular organisms also produce lactic acid as a waste product during fermentation. For example, prokaryotes are used in the production of a wide variety of foods and beverages, such as cheese, yogurt, buttermilk, and sour cream. Pickles, sauerkraut, and kimchee are also produced using lactic acid fermentation.

Aerobic Respiration Chemical Summary

Aerobic Cellular Respiration Biochemical Summary

$$C_6H_{12}O_6 + \underline{6}O_2 \rightarrow \underline{6}CO_2 + \underline{6}H_2O + 36\text{-}38\ ATP\text{'s}$$

	Consumed	Produced
Glycolysis	**2 ATP's**	**2** - **3C-Pyruvate (PYR)** **2** - **ATP** **2** - **NADH**
Intermediate Step	**2 Pyruvate**	**2 - NADH** **2 - CO2** **2- Acetyl CoA (2C)**
Krebs Cycle	**2- Acetyl CoA (2C)**	**2 - ATP** (substrate-level phosphorylation) **6 – NADH** **2 - FADH$_2$** (Flavin-adenine dinucleotide) **4 - CO2**
Electron Transport	10 NADH 2 - FADH$_2$	34 - ATP's

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Thank you!

Do you have any questions?

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