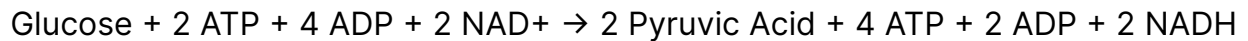
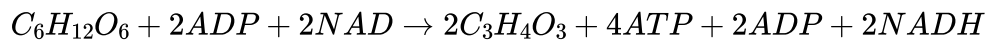
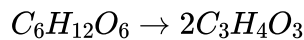


Cellular Respiration

1) Glycolysis

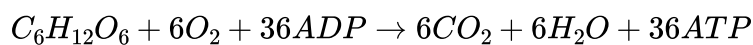


Simplified:



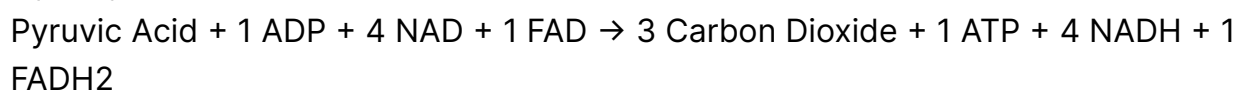
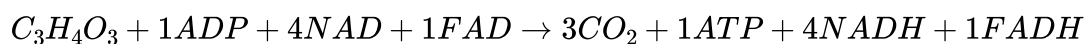
- Happens **outside the Mitochondria** in the cytoplasm
- Phosphorelates **2 ADP** to **2 ATP**
- Reduces **2 NAD**
- The process requires two ATP to begin
- All cellular respiration, **both aerobic and anaerobic**, goes through glycolysis

Aerobic respiration

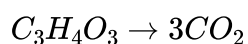


- Cellular respiration is different from breathing
- Cellular respiration is a chemical reaction to break down glucose to release energy
- it is aerobic because of the **presence of oxygen**
- Each glucose produces **38 ATP**, it is very efficient

Overview of processes after Glycolysis



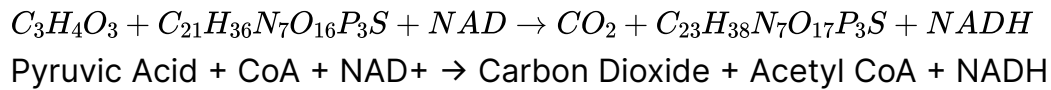
Simplified:



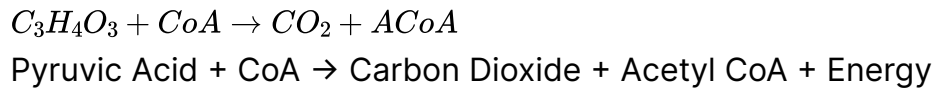
Steps in Aerobic respiration

1) Glycolysis

2) Formation of Acetyl CoA (optional learning)



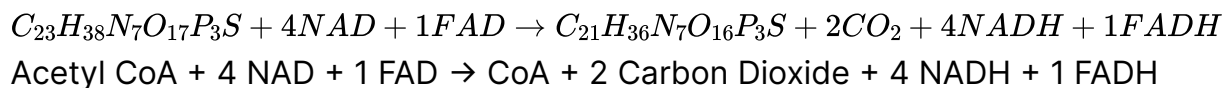
Simplified:



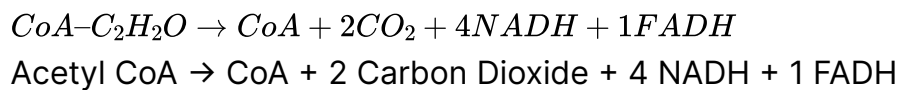
- **Not** part of the Krebs cycle, it happens before
- Gets the Pyruvic acid ready to be used in the krebs cycle
- Performed by the Pyruvate dehydrogenase

3) Krebs Cycle (Citric Acid cycle or TCA)

Overview of the Kerbs Cycle



Simplified:

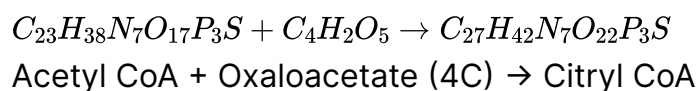


- Happens inside the **Mitochondria**
 - In the mitochondrial **Matrix**
- Reduces **4 NAD** and **1 FAD** to **4 NADH** and **1 FADH**

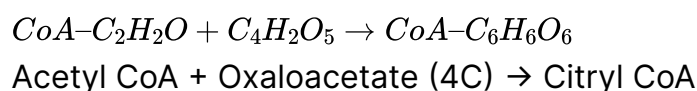
Steps in the Kerbs Cycle (optional learning)

1) Formation of Citrate

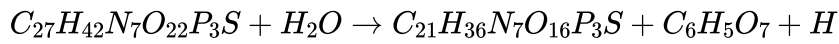
1. Formation of the Citryl CoA



Simplified:

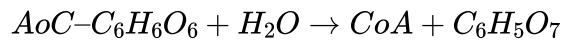


2. Formation of the Citrate



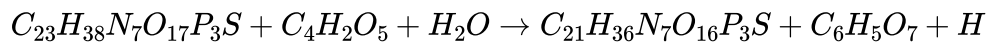
Citryl CoA + Water → CoA + Citrate + Hydrogen

Simplified:



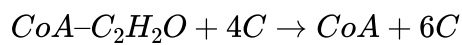
Citryl CoA + Water → CoA + Citrate

Overview



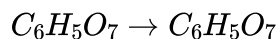
Acetyl CoA + Oxaloacetate (4C) + Water → CoA + Citrate (6C) + Hydrogen

Simplified:



Acetyl CoA + Oxaloacetate (4C) → CoA + Citrate (6C)

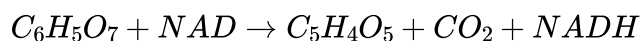
2) Formation of Isocitrate



Citrate → Isocitrate

- The Chemical formula is the same, but the bonds are in different places
- This process consists of removing the water molecule and readding it in a different place

3) Formation of α-ketoglutarate and oxidation of Isocitrate



Isocitrate (6C) + NAD → α-glutenate (5C) + Carbon Dioxide + NADH

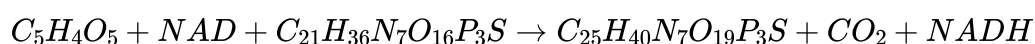
Simplified:



Isocitrate (6C) → α-glutenate (5C) + Carbon Dioxide + NADH

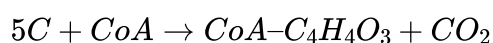
- Produces **1 NADH**

4) Formation of Succinyl CoA and oxidation of the ketoglutarate



α-glutenate (5C) + NAD + CoA → Succinyl CoA + Carbon Dioxide + NADH

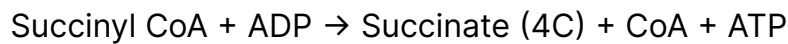
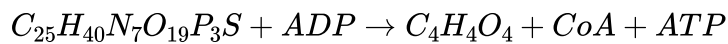
Simplified:



α-glutenate (5C) + CoA → Succinyl CoA + Carbon Dioxide + NADH

- Produces **1 NADH**

5) Formation of Succinate

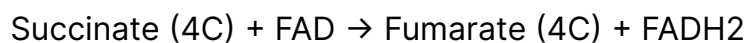
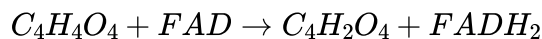


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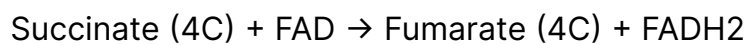
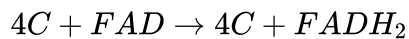


- ATP production is actually from GDP→GTP, which's phosphate group gets moved to an ADP, making it an ATP
- Produces **1 ATP**

6) Production of Fumarate and oxidation of Succinate

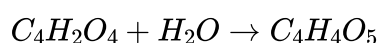


Simplified:

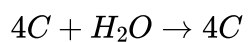


- Produces **1 FADH₂**

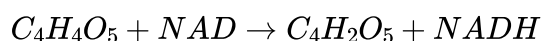
7) Production of Malate



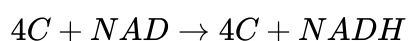
Simplified:



8) Production of Oxaloacetate and oxydation of Malate



Simplified:



- Produces **1 NADH**

4) Electron Transport Chain

The Hydrogen and electrons from the Hydrogen carriers (NADH + FASH) are released, which creates a **positive concentration gradient**, which forces the **ATP Synthase** to produce ATP from ADP.

- Happens inside the Mitochondria
 - In the inner mitochondrial membrane (crystae)
- The 4 Complexes remove Hydrogen from the Hydrogen carriers
 - Complex 1 converts NADH to NAD⁺
 - Complex 2 converts FADH₂ to FAD
 - Complex 3 uses additional energy from complex 1 and 3 to pump additional protons (hydrogen ions) to the Intermembrane Space
 - Complex 4 helps produce Water using Hydrogen and Oxygen
- The positive proton gradient of the Intermembrane Space pushes the ATP synthase to produce ATP from ADP
 - The process of making ATP takes the Hydrogen from the Intermembrance space back into the Matrix
- Additionally, Oxygen will bond with the uncharged Hydrogen to take away extra Hydrogen

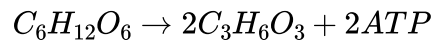
Carrier	ATP produced
NADH	3 (or 2.5) ATP
FADH	2 (or 1.5) ATP

Aerobic Respiration Summary

-	Number of ATP produced	Number of NADH produced	Number of FADH produced
-	-	NADH	FADH
Glycolysis	2 ATP	2 NADH	0 FADH
Krebs Cycle	2 ATP	8 NADH	2 FADH
Electron Transport Chain	-	x3	x2
Total ATP produced	4ATP	30 ATP	4 ATP
Grand Total			38 ATP

Anaerobic respiration

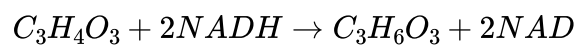
Animal Cells (Lactic Acid Fermentation)



Glucose \rightarrow Lactic acid + Chemical Energy

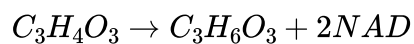
- Very inefficient, only produces **2 ATP**
- When you accumulate lactic acid, it is called oxygen debt, because you owe oxygen to your body (lactic acid)
- Lactic acid is **harmful** to your body
- Is only used in emergencies to quickly make energy
- This whole process is called **Fermentation**

NADH+ regeneration



Pyruvic Acid + 2 NADH \rightarrow Lactic Acid + 2NAD

Simplified:



Pyruvic Acid \rightarrow Lactic Acid + 2 NAD

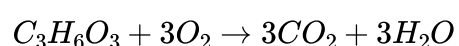
- Converts the Pyruvic Acid into Lactic Acid
- Recycles the NADH back to NAD⁺ so that it can be reused in Glycolysis

Anaerobic Respiration Summary

- Happens **outside the Mitochondria**
- Phosphorylates **2 ADP** to **2 ATP**
- The process requires two ATP to begin (Glycolysis)

-	Number of ATP produced	Number of H-carriers produced
-	-	NADH
Glycolysis	2 ATP	2 NADH
NAD ⁺ regeneration	-2 NADH	
Grand Total	2 ATP	

Repaying the Oxygen Debt

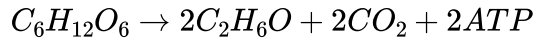


Lactic acid + Oxygen \rightarrow Carbon Dioxide + Water

- Break down lactic acid by adding oxygen
- Does not produce any energy at all

- Aerobic process
- Having Lactic Acid is called having an Oxygen debt

Yeast Cells (Alcoholic Fermentation)

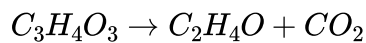


Glucose → Ethanol + Carbon Dioxide + Chemical Energy

- Very ineffecient, only produces **2 ATP**
- Ethanol is toxic to yeast, and cannot be reversed
 - The Oxygen debt **cannot be reversed**
- Is only used in emergencies to quickly make energy
- Happens **outside the Mitochondria**
- The process requires two ATP to begin, and makes 4 ATP, making a net gain of 2 ATP

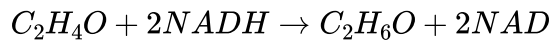
Steps of fermentation

1) Pyruvate Oxidation



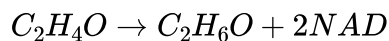
Pyruvic acid → Acetaldehyde + Carbon Dioxide

2) NAD⁺ Regeneration



Acetaldehyde + 2 NADH → Ethanol + 2NAD

Simplified:



Acetaldehyde → Ethanol + 2 NAD

Anaerobic Respiration Summary

-	Number of ATP produced	Number of H-carriers produced
-	-	NADH
Glycolysis	2 ATP	2 NADH
Further Fermentation		-2 NADH
Grand Total	2 ATP	