Chapter 6

IV. Glycolysis and Aerobic Respiration

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy} \]

Energy flow and chemical recycling in the ecosystem.
Mitochondrion Structure

![Mitochondrion diagram](image)

**FIGURE 7.17** The mitochondrion, site of cellular respiration. The two membranes of the mitochondrion are evident in the drawing and micrograph (TEM). The cristae are infoldings of the inner membrane. The cutaway drawing shows the two compartments bounded by the membranes: the intermembrane space and the mitochondrial matrix.

Aerobic Respiration
Overview

• Respiration – Extracting stored energy from glucose to form ATP.

• The breakdown of glucose occurs in two stages.
  – Glycolysis (does not require oxygen)
  – Aerobic Respiration (Requires Oxygen)
    • Preparatory step
    • Krebs Cycle (Citric Acid Cycle)
    • Electron Transport Chain

Energy Storing Compounds

• $\text{ADP} + \text{P}_i \rightarrow$
• $\text{NAD}^+ + 2e^- + \text{H}^+ \rightarrow$
• $\text{FAD}^+ + 2e^- + 2\text{H}^+ \rightarrow$
• Reduction = The addition of electrons.
  – $\text{NAD}^+ + 2e^- + \text{H}^+ \rightarrow \text{NADH}$
• Oxidation = The removal of electrons from a compound.
  – $\text{NADH} \rightarrow \text{NAD}^+ + 2e^-$
Glycolysis

- Glucose breaking down through the action of enzymes.
- Occurs in the cytoplasm of the cell.
- Glycolysis does not require oxygen
- Substrate-level phosphorylation =
Glycolysis - Summary

- 2ATP are used to “kick start” the reaction.
- 4 ADP are converted to 4 ATP via substrate level phosphorylation.
- 2 NAD$^+$ are reduced to 2NADH.
- 2 Pyruvate are produced
Aerobic Respiration

- Occurs in the mitochondrion.
- Three stages
  - Preparatory step
  - Krebs Cycle (Citric acid cycle)
  - Electron Transport Chain
Aerobic Respiration – Preparatory Steps

- **Pyruvate** is converted to **acetyl-CoA**
- **NAD**\(^+\) is reduced to **NADH**
- **CO\(_2\)** is released.
- **Remember there are two pyruvate molecules! So this reaction happens for each pyruvate molecule!**

Aerobic Respiration – Krebs Cycle (Citric acid cycle)

- Named after Hans Kreb (1930s)
- The first compound created is **citrate (citric acid cycle)**
- 3NAD\(^+\) are reduced to 3NADH.
- FAD\(^+\) is reduced to FADH\(_2\)
- 1 ATP is created via substrate level phosphorylation.
- 2CO\(_2\) are released.
- **Remember that there are two acetyl-CoA! This reaction occurs for each acetyl-CoA!**
Record Keeping – What we have so far.

<table>
<thead>
<tr>
<th></th>
<th>Glycolysis</th>
<th>Preparatory steps</th>
<th>Krebs Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 NADH</td>
<td>1 NADH x 2 = 2NADH</td>
<td>3 NADH x 2 = 6NADH</td>
</tr>
<tr>
<td></td>
<td>2 ATP (Net)</td>
<td></td>
<td>1 FADH₂ x 2 = 2 FADH₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 ATP x 2 = 2ATP</td>
</tr>
</tbody>
</table>
Aerobic Respiration - Electron Transport Chain

- Occurs at the inner mitochondrial membrane.
- This is the stage where most of the ATP is made!
- NADH and FADH$_2$ are **oxidized** to NAD$^+$ and FAD$^+$
- Electrons are released into the electron transport chain.
- H$^+$ is pumped into the intermembrane space creating a concentration gradient.
Aerobic Respiration - Electron Transport Chain

- $H^+$ passes back into the mitochondrial matrix through ATP synthases which generate ATP from ADP.

- Oxygen is the final electron acceptor!

- Oxygen combines with $2H^+$ and two electrons to form $H_2O$!

- Oxygen keeps the electrons moving through the chain! Without oxygen the electron transport chain would stop! No ATP would be generated!
Other Sources of Energy

- Fats and Proteins can be used for energy.

Record Keeping For 1 Molecule of Glucose

<table>
<thead>
<tr>
<th>Stage</th>
<th>Products</th>
<th>ATP (substrate level phosphorylation)</th>
<th>ATP (oxidative phosphorylation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycolysis</td>
<td>2 NADH, 2 Pyruvate, 2 H₂O</td>
<td>2 ATP (net)</td>
<td>4 ATP</td>
</tr>
<tr>
<td>Preparatory Steps</td>
<td>2 NADH, 2 Acetyl-CoA, 2 CO₂</td>
<td></td>
<td>6 ATP</td>
</tr>
<tr>
<td>Krebs Cycle (Citric Acid Cycle)</td>
<td>6 NADH, 2 FADH₂, 4 CO₂</td>
<td>2 ATP</td>
<td>18 ATP</td>
</tr>
<tr>
<td>Sub-Total</td>
<td></td>
<td>4 ATP</td>
<td>32 ATP</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>4 ATP + 32 ATP = 36 ATP</td>
<td></td>
</tr>
</tbody>
</table>