Cell Respiration

From Glucose to 36 ATPs
What is Cellular Respiration?

• The breakdown of biomolecules (especially glucose) to release the energy stored in the bonds.
• The energy is stored in smaller amounts in ATP.
• The Mitochondria is the main organelle that participates in respiration.
• Both Plant and Animal cells do this.
Respiration’s Overall Reaction

- Glucose + Oxygen $\rightarrow$ Carbon Dioxide + Water + Energy

- $\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \rightarrow 6 \text{CO}_2 + 6 \text{H}_2\text{O}$

Energy

36 ATP
Two Steps of making ATP

• Anaerobic: This is the first step and DOES NOT require Oxygen.

• Aerobic: This is the second step and DOES require Oxygen.
1st step: Anaerobic Process

- Also called GLYCOLYSIS
  - Glyco: glucose
  - Lysis: breaking apart

- This occurs in the cytoplasm of the cell.

- No $O_2$ required
Anaerobic Process: Glycolysis

- **Glucose is split into 2 new molecules**
  - 2 Pyruvic Acids
  - Some energy is released to form a net of 2 ATPs
  - 2 NADHs are produced. NADHs pick up Hydrogen and energized electrons.
Anaerobic Process: Glycolysis

- Glucose is broken down into 2 Pyruvic Acids, and 2 NADHs. Breaking bonds releases energy stored as 2 ATPs.

\[
\begin{align*}
6 \text{-Carbons Glucose} & \rightarrow 2 \text{Pyruvic Acids} + 2 \text{ATP} \\
2H^+ + 2\text{NAD}^+ & \rightarrow 2\text{NADH}
\end{align*}
\]

If \(O_2\) is available then the **Aerobic Process** begins.

If No \(O_2\) is available then **Fermentation** will begin.
Anaerobic Process: Glycolysis

Used: Glucose
Produced: 2 Pyruvic Acids, 2 ATP, 2 NADH
Fermentation:
- An anaerobic process that allows glycolysis to continue.
- Does not make ATP
- Removes electrons from NADH to make NAD+. NAD+ is recycled back to glycolysis.
Aerobic Process: Citric Acid Cycle

- The 2 Pyruvic Acids are broken down into 2 Acetyl-CoA molecules and 2 CO₂.

\[ 2 \text{C-C-C} \rightarrow 2 \text{CO}_2 + 2 \text{C-C-CoA} \]

- Then the [Citric Acid Cycle](#) follows
  - Also known as the Krebs Cycle
  - Acetyl CoA joins the cycle
    - Produces CO₂
    - 2 ATP Produced
    - Produces NADH and FADH₂ (electron carriers that are useful for making more ATP)

- Occurs within the matrix of the Mitochondria

- The main function of the Krebs Cycle is to transfer high energy electrons to molecules that carry them to the electron transport chain.
At the end of the cycle, the molecule is only 4 C and starts again. Acetyl CoA joins the cycle to make a 6 C molecule.
**Citric Acid Cycle**

**Used:** Pyruvate from Glycolysis

**Produced:** ATP, NADH & FADH\(_2\) (electron carriers), and CO\(_2\) as waste
Aerobic Process: ETC

- **Electron Transport Chain**: The part of the Process that produces a net of 34 ATP

- Occurs in the inner membrane of the Mitochondria

- The Aerobic Part of respiration as it requires $O_2$. 
Electron Transport Chain

• NADH and FADH$_2$ from earlier give up electrons which goes through a series of carrier molecules to provide energy to produce ATP.

• H$^+$ ions are used to drive the process. They combine with O$_2$ to produce H$_2$O.

• How does the ETC work? Like a hydroelectric Power Plant.
  – The flow of positive (H$^+$) and negative (e$^-$) charges generates energy to form ATP
How the ETC Works

A. Electron Transport

B. Hydrogen Ion Movement

C. ATP Production

Intermembrane Space

Inner Membrane

Matrix

2 NADH

2 NAD^+

FADH_2

FAD

4 H^+ + O_2 → 2 H_2O

ATP synthase

ADP

ATP
**Electron Transport Chain**

**Used:** NADH & FADH$_2$ (electron carriers from Krebs Cycle), O$_2$

**Produced:** H$_2$O and ATP

*(Cellular Respiration cannot occur unless O$_2$ is present)*
GLYCOLYSIS
Glucose → Pyruvate
-2  +4

ELECTRON SHUTTLE ACROSS MEMBRANE

2 NADH or 2 FADH₂

KREBS CYCLE
2 NADH → 6 NADH
2 FADH₂ → pdh = +6
etc = 18

MITOCHONDRION

2 Acetyl CoA → 2 ATP

ELECTRON TRANSPORT CHAIN AND OXIDATIVE PHOSPHORYLATION

2 Acetyl CoA → 2 ATP

Maximum per glucose:

36 to 38 depending on shuttles

1 mole glucose = 686 Kc
38 ATP = 277 Kc or 40% efficient

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Steps to Cellular Respiration

• **Glycolysis** *occurs in cytoplasm*
  – Glucose is broken down to 2 pyruvate
  – ATP is made

• **Citric Acid Cycle/Krebs Cycle** *occurs in matrix of mitochondria*
  – Pyruvate is converted to Acetly-CoA, releasing CO\(_2\) as a waste
  – Acetyl-CoA is added to a 4-carbon molecule to make citric acid
  – Citric acid goes through a series of reactions producing ATP, and NADH & FADH\(_2\) that carry high energy electrons to the Electron Transport Chain

• **Electron Transport Chain** *occurs at inner membrane of mitochondria*
  – NADH and FADH\(_2\) drop off electrons that go through the ETC
  – O\(_2\) is the final electron acceptor creating H\(_2\)O
  – Hydrogen ions are pumped through the ATP synthase to create ATP
Comparing Photosynthesis & Cellular Respiration

**Photosynthesis** in chloroplasts:
- 
- 

**Cellular respiration** in mitochondria:
- 
- 

ECOSYSTEM

- 

**Carbon dioxide**

Plants, algae, many bacteria (Autotrophs)

Organic compounds

Water

Oxygen

Animals, fungi, many bacteria (Heterotrophs)

ATP

powers most cellular work

Heat energy

Light energy
Cellular Respiration Overview Video

- http://www.youtube.com/watch?v=j7gPtASv0SQ
Comparing Photosynthesis & Cellular Respiration

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<td>proteins within inner mitochondrial membrane</td>
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<td><strong>Cycle of chemical reactions</strong></td>
<td>Calvin cycle in stroma of chloroplasts builds sugar molecules</td>
<td>Krebs cycle in matrix of mitochondria breaks down carbon-based molecules</td>
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