Harvesting stored energy

- Energy is stored in organic molecules
  - Heterotrophs eat food (organic molecules)
  - Digest organic molecules to get...
  - Raw materials for building blocks and fuels for energy
  - Controlled release of energy
    - "Burning" fuels in a series of step-by-step enzyme-controlled reactions
  - "Burning" fuels
    - Carbohydrates, Lipids, Proteins and Nucleic Acids

Harvesting energy stored in glucose

- Glucose is the model
  - Catabolism of glucose to produce ATP

\[
\text{Glucose + oxygen} \rightarrow \text{carbon + water + energy + \text{dioxide}}
\]

\[
C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{ATP} + \text{heat}
\]

**COMBUSTION** = making a lot of heat energy by burning fuels in one step

**RESPIRATION** = making ATP (& less heat) by burning fuels in many small steps
How do we harvest energy from fuels?

• Digest large molecules into smaller ones
  • break bonds & **move electrons** from one molecule to another
  • as electrons move they “**carry energy**” with them
  • that energy is **stored in another bond**, **released as heat**, or **harvested to make ATP**

\[
\begin{align*}
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 &\rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP} \\
\end{align*}
\]

How do we move electrons in biology?

• Moving electrons in living systems
  • electrons cannot move alone in cells
  • electrons move as part of **H atom**

\[
\begin{align*}
\text{oxidation} &\quad \text{reduction} \\
\end{align*}
\]

**REDOX**

**Oxidation & reduction**

• REDOX reactions in respiration
  • release energy as break down organic molecules
    • break C-C bonds
    • strip off electrons from C-H bonds by removing H atoms
    • \( \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow \text{CO}_2 \) = fuel has been oxidized
    • electrons attracted to more electronegative atoms
      • in biology, the most electronegative atom?
        • \( \text{O}_2 \rightarrow \text{H}_2\text{O} = \) oxygen has been reduced
    • release energy to synthesize ATP

\[
\begin{align*}
\text{oxidation} &\quad \text{reduction} \\
\end{align*}
\]

**Oxidation**

• Oxidation
  • adding O
  • removing H
  • loss of electrons
  • releases energy
  • exergonic

\[
\begin{align*}
\text{oxidation} &\quad \text{reduction} \\
\end{align*}
\]

**Reduction**

• Reduction
  • removing O
  • adding H
  • gain of electrons
  • stores energy
  • endergonic

\[
\begin{align*}
\text{oxidation} &\quad \text{reduction} \\
\end{align*}
\]
Moving electrons in respiration

- **Electron carriers** move electrons by shuttling H atoms around
  - $\text{NAD}^+ \rightarrow \text{NADH}$ (reduced)
  - $\text{FAD}^{+2} \rightarrow \text{FADH}_2$ (reduced)

Overview of cellular respiration

- 4 metabolic stages
  - Anaerobic respiration
    - 1. Glycolysis
    - Respiration without O2
    - Occurs in cytosol
  - Aerobic respiration
    - 2. Pyruvate oxidation
    - 3. Kreb’s cycle
    - 4. Electron transport chain

$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP}$ (+ heat)

What’s the point?

- **ATP Synthase**
  - Proton motive force
    - Conformational changes
    - Bond P to ADP to make ATP
  - Chemiosmosis
    - Allow the H+ to flow down concentration gradient through ATP synthase
    - $\text{ADP} + P_i \rightarrow \text{ATP}$

The Point is to Make ATP!
Got the Energy?
Ask Questions!