**Energy**

- Energy & Laws of Thermodynamics
- Chemical Reactions
- Enzymes
- How cells “make” and use Energy: ATP
- Cell Respiration
- Photosynthesis

**Cells transform energy as they perform work**

- **Energy** is the capacity to do work & cause change
  - **Work** is accomplished when an object is moved against an opposing force, such as friction
  - There are two kinds of energy
    - **Kinetic energy** is the energy of motion
    - **Potential energy** is energy that an object possesses as a result of its location

**Kinetic & Potential Energy**

<table>
<thead>
<tr>
<th>Kinetic</th>
<th>Potential</th>
<th>Kinetic to Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Kinetic Energy" /></td>
<td><img src="image2.png" alt="Potential Energy" /></td>
<td><img src="image3.png" alt="Kinetic to Potential" /></td>
</tr>
</tbody>
</table>

**Energy transformations**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Energy conversion</th>
<th>Waste products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline + Oxygen</td>
<td>Heat Energy</td>
<td>Carbon dioxide + Water</td>
</tr>
<tr>
<td>Combustion</td>
<td>Kinetic energy of movement</td>
<td>Energy conversion in a car</td>
</tr>
</tbody>
</table>
Energy conversion in a cell

Energy for cellular work

Cellular respiration

Heat

Carbon dioxide

Energy conversion Waste products

Glucose + Oxygen

Energy conversion in a cell

Two laws govern energy transformations

- It is important to understand two laws that govern energy transformations in organisms
- The first law of thermodynamics — energy in the universe is constant
- The second law of thermodynamics — energy conversions increase the disorder of the universe
  - Entropy is the measure of disorder, or randomness

Exergonic reactions release energy

Endergonic reactions require energy
Chemical reactions either release or store energy

- A living organism produces thousands of endergonic and exergonic chemical reactions
  - All of these combined is called **metabolism**
  - A **metabolic pathway** is a series of chemical reactions that either break down a complex molecule or build up a complex molecule

Cellular work is coupled to exergonic reactions

- A cell does three main types of cellular work
  - **Chemical work** — driving endergonic reactions
  - **Transport work** — pumping ions across membranes
  - **Mechanical work** — beating of cilia

- To accomplish work, a cell must manage its energy resources, and it does so by **energy coupling** — the use of exergonic processes to drive an endergonic one

ATP – Energy Currency of the Cell

- **ATP** = Adenosine Triphosphate
- **ADP** = Adenosine Diphosphate
- Hydrolysis

ATP + $\text{H}_2\text{O}$ → ADP + $\text{P}^{-}$ + Energy

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ATP Powers Cellular Work

The ATP cycle

ATP Synthesis

1. ADP + Phosphate → ATP
2. Mechanisms of ATP synthesis
   - Chemiosmosis
   - Substrate Level Phosphorylation
ATP synthesis: Chemiosmosis

ATP Synthesis
Substrate-Level Phosphorylation

HOW ENZYMES FUNCTION

Enzymes lower activation energy
**Activation Energy**

- **Activation energy**
  - extra energy required
  - destabilizes existing chemical bonds
  - initiates a chemical reaction

- **Enzyme**
  - Catalyst
  - lowers activation energy

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**The catalytic cycle of an enzyme**

1. Enzyme available with empty active site
   - Active site
   - Enzyme (sucrase)

2. Substrate binds to enzyme with induced fit

3. Enzyme available with empty active site
   - Active site
   - Substrate (sucrose)
   - Enzyme (sucrase)
The catalytic cycle of an enzyme

1. Enzyme available with empty active site
2. Substrate binds to enzyme with induced fit
3. Substrate is converted to products
4. Products are released

Enzyme (sucrase)

Substrate (sucrose)

Glucose
Fructose

H₂O

Part I: Energy