Energy and Life
What We Need and Never Have Enough Of.

The Flow of Energy in Living Cells

- Energy is the ability to do work

- Energy is considered to exist in two states
  - **kinetic energy**
    - the energy of motion
  - **potential energy**
    - stored energy that can be used for motion

- All the work carried out by living organisms involves the **transformation** of potential energy to kinetic energy

Potential and Kinetic Energy

- There are many forms of energy but all of them can be converted to heat

- Heat energy is the most convenient form of energy to measure

- **Thermodynamics** is the study of energy or heat changes

The Laws of Thermodynamics

- Laws of thermodynamics govern the energy changes that are involved with any activity by an organism

- 1st Law of Thermodynamics
  - the total amount of energy in the universe remains constant
  - energy can change from one state to another but it can never be created nor destroyed
  - during the energy conversions, some of the energy is lost as heat energy

- 2nd Law of Thermodynamics
  - the amount of disorder, or **entropy**, in the universe is increasing
  - the increasing disorder means that energy is spontaneously transforming from potential to heat energy

Chemical Reactions

- A **chemical reaction** is the making or breaking of chemical bonds
  - the starting molecules of a reaction are called the **reactants** or, sometimes, **substrates**
  - the molecules at the end of the reaction are called **products**

- There are two kinds of chemical reactions

- **endergonic** reactions have products with more energy than the reactants
  - these reactions are not spontaneous
- **exergonic** reactions have products with less energy than the reactants
  - these reactions are spontaneous

Chemical Reactions

Chemical Reactions

- All chemical reactions require an initial input of energy called the **activation energy**
  - the activation energy initiates a chemical reaction by destabilizing existing chemical bonds

- Reactions become more spontaneous if their activation energy is lowered
  - this process is called **catalysis**
  - catalyzed reactions proceed much faster than non-catalyzed reactions

Chemical reactions: (c) Catalyzed reaction

How Enzymes Work

- **Enzymes** are the catalysts used by cells to perform particular reactions
  - enzymes bind specifically to a molecule and stress the bonds to make the reaction more likely to proceed
  - **active site** is a site on the surface of the enzyme that binds to a reactant
  - the site on the reactant where the enzyme binds is called the **binding site**

- The binding of a reactant to an enzyme causes the enzyme's shape to change slightly
  - this leads to an **"induced fit"** where the enzyme and substrate fit tightly together as a complex
  - the enzyme lowers the activation energy for the reaction while it is bound to the reactant
  - the enzyme is unaffected by the chemical reaction and be re-used

How Enzymes Work

- Catalyzed reactions may occur together in sequence
  - the product of one reaction is the substrate for the next reaction until a final product is made
  - the series of reactions is called a **biochemical pathway**

- Temperature and pH affect enzyme activity
  - enzymes function within an optimum temperature range
    - when temperature increases, the shape of the enzyme changes due to unfolding of the protein chains
  - enzymes function within an optimal pH range
    - the shape of enzymes is also affected by pH

- most enzymes work best within a pH range of 6 - 8
  - exceptions are stomach enzymes that function in acidic ranges

How Cells Regulate Enzymes

- Cells can control enzymes by altering their shape
  - **allosteric enzymes** are affected by the binding of signal molecules
    - the signal molecules bind on a site on the enzyme called the **allosteric site**
    - some signals act as **repressors**
      - inhibit the enzyme when bound
    - other signals act as **activators**
      - change the shape of the enzyme so that it can bind substrate

Allosteric Enzyme Regulation

How Cells Regulate Enzymes

- **Feedback inhibition** is a form of enzyme inhibition where the product of a reaction acts as a repressor
  - **competitive inhibition**
    - the inhibitor competes with the substrate for the active site
    - the inhibitor can block the active site so that it cannot bind substrate
  - **non-competitive inhibition**
    - the inhibitor binds to the allosteric site and changes the shape of the active site so that no substrate can bind

How enzymes can be inhibited

ATP: The Energy Currency of the Cell

- The energy from the sun or from food sources must be converted to a form that cells can use
  - **adenosine triphosphate (ATP)** is the energy currency of the cell

- The structure of ATP suits it as an energy carrier
  - each ATP molecule has three parts
    1. a sugar that acts
    2. an adenine nucleotide
    3. a chain of three phosphate groups
       - the phosphates are negatively charged and it takes a lot of chemical energy to hold them together
       - the phosphates are poised to come apart

The parts of an ATP molecule

- When the endmost phosphate group is broken off an ATP molecule, energy is released

  - $ATP \rightarrow ADP + P_i + energy$

- The P_i represents inorganic phosphate

- **Coupled reactions**
  - when exergonic reactions are used to pay for the initiation of endergonic reactions
  - usually endergonic reactions are coupled with the breakdown of ATP
    - more energy than is needed is released by the breakdown of ATP so heat is given off

- ATP cycles in the cell with respect to its energy needs
  - **photosynthesis**
    - some cells convert energy from the sun into ATP and then use it to make sugar where it is stored as potential energy
  - **cellular respiration**
    - cells break down the potential energy in sugars and convert it ATP

- Electrons pass from atoms or molecules to one another as part of many energy reactions
  - **oxidation** is when an atom or molecule loses an electron
  - **reduction** is when an atom or molecule gains an elections
  - these reactions always occur together
    - called **oxidation-reduction (re-dox) reactions**

- Re-dox reactions involve transfers of energy because the electrons retain their potential energy
  - the reduced form of an organic molecule has a higher level of energy than the oxidized form