

Chapter 6-1 – Energy and ATP

The chemistry of life is organized into metabolic pathways

- The totality of an organism's chemical reactions is called metabolism.
- Enzymes selectively accelerate each step. (more on enzymes later ☺)
- Catabolic pathways release energy by breaking down complex molecules to simpler compounds.
 - This energy is stored in organic molecules until it needs to do work in the cell. (*Where is this energy stored within the molecule??????*)
 - An example of a catabolic pathway is cellular respiration
- Anabolic pathways consume energy to build complicated molecules from simpler compounds.
- The energy released by catabolic pathways is used to drive anabolic pathways.
 - An example of an anabolic pathway is photosynthesis
- Energy: fundamental to all metabolic processes.
 - Bioenergetics – the study of how organisms manage their energy resources

Organisms transform energy (Thermodynamics)

- Energy is the capacity to do work - to move matter against opposing forces.
 - Energy is also used to rearrange matter.
- Kinetic energy is the energy of motion.
 - Objects in motion, photons, and heat are examples.
- Potential energy is the energy that matter possesses because of its location or structure...STORED ENERGY!
 - Chemical energy is a form of potential energy in molecules because of the arrangement of atoms.
- Cellular respiration and other catabolic pathways unleash energy stored in sugar and other complex molecules.
- This energy is available for cellular work.
- The chemical energy stored in these organic molecules was derived primarily from light energy by plants during photosynthesis.
- A central property of living organisms is the ability to transform energy.

The energy transformations of life are subject to two laws of thermodynamics

- Thermodynamics is the study of energy transformations.
- In this field, the term *system* indicates the matter under study and the *surroundings* are everything outside the system.
- A closed system is isolated from its surroundings.
 - Liquid in a thermos
- In an open system energy (and often matter) can be transferred between the system and surroundings.

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Organisms are open systems!!

- The **first law of thermodynamics** states that energy can be transferred and transformed, but it cannot be created or destroyed.
 - Plants transform light to chemical energy; they do not produce energy.
- The **second law of thermodynamics** states that every energy transformation must make the universe more disordered.
 - **Entropy** is a quantity used as a measure of disorder, or randomness.
 - Cells stay ordered because they are open systems—the entropy of their surroundings increases
- In most energy transformations, ordered forms of energy are converted at least partly to heat.
- Heat is energy in its *most random state*.
- Combining the two laws, the *quantity* of energy is constant, but the *quality* is not.

Organisms live at the expense of free energy

- **Spontaneous processes:**
 - can occur without outside help
 - Increase stability of a system
 - Free energy decreases
- **Non spontaneous processes:**
 - Can only occur if energy is added
 - Decrease the stability of a system
- **Free energy (G)** is the portions of a system's energy that is able to perform work when temperature is uniform throughout the system.
 - A measure of the stability of a system
- **Chemical reactions are classified based on free energy:**
 - **Exergonic reaction**: spontaneous reaction
 - Free energy is released into surroundings
 - ΔG must be negative
 - Products have less energy than reactants
 - Example: Cellular Respiration
 - $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + ATP$
 - **Endergonic reaction**: non spontaneous reaction
 - Free energy is absorbed from surroundings
 - ΔG must be positive
 - Products have more energy than reactants
 - Store energy

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- Example: Photosynthesis
 - $6\text{H}_2\text{O} + 6\text{CO}_2 + \text{sunlight} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
- Reactions in closed systems eventually reach equilibrium and can do no work.
- A cell that has reached metabolic equilibrium has a $\Delta G = 0$ and is dead!
 - ***Metabolic disequilibrium is one of the defining features of life.***
- Cells maintain disequilibrium because they are **open** with a constant flow of material in and out of the cell.
- A cell continues to do work throughout its life.
- A catabolic process in a cell releases free energy in a *series of reactions*, **NOT** in a single step.
- Some reversible reactions of respiration are constantly “pulled” in one direction as the product of one reaction does not accumulate, but becomes the reactant in the next step.
- Sunlight provides a daily source of free energy for the photosynthetic organisms in the environment.
- Non photosynthetic organisms depend on a transfer of free energy from photosynthetic organisms in the form of ***organic molecules***.

ATP powers cellular work by coupling exergonic reactions to endergonic reactions

- A cell does three main kinds of work:
 - *Mechanical work*, beating of cilia, contraction of muscle cells, and movement of chromosomes.
 - *Transport work*, pumping substances across membranes against the direction of spontaneous movement. (*What type of diffusion is this????*)
 - *Chemical work*, driving endergonic reactions such as the synthesis of polymers from monomers.
- ATP is most often the source of this energy
- ATP (adenosine triphosphate) is a type of nucleotide
 - consists of the nitrogenous base adenine
 - the sugar ribose
 - and a chain of three phosphate groups (functional groups).
- Energy is stored in the unstable phosphate bonds
- These bonds can be broken by hydrolysis:
 - $\text{ATP} + \text{H}_2\text{O} \rightarrow \text{P}_i + \text{ADP} + \text{free energy}$
 - Exergonic reaction