Chapter 2: The Chemistry of Life

Class	Biology

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2.1 — The Nature of Matter

Atoms

Atom: basic unit of matter

- Came from *Democritus*
- The point at which you break something and it no longer what it was before
  - *Atomos* → “unable to be cut”

> Atoms are **NOT** the smallest unit of matter. There are **subatomic** particles.

- Protons, Neutrons, Electrons

Protons and Neutrons

- About the same mass

Protons: + (positively-charged)

Neutrons: 0 (neutrally-charged)

- **Nucleus:** binding of protons and neutrons at the center of the atom

Electrons

Electrons: - (negatively-charged)

- 1/1840 the mass of a proton
- Constant motion surrounding the nucleus
    - Attracted to the protons in the nucleus but remain in orbit because of the energy of their motion

Atoms have equal amounts of *protons* and *electrons* (electrically-neutral).

Elements & Isotopes

Chemical Element → a pure substance that consists of only one type of atom

- Represented by one or two-letter symbols

Isotopes

Atoms can have different numbers of *neutrons*.

- **Isotopes:** atoms that differ in the amount of neutrons they have

> **Mass Number:** total number of protons and neutrons in an atom

- *Weighted* → all possible isotopes are used in the calculation of average mass

All isotopes of an element have the same properties.

Radioactive Isotopes

- Have unstable nuclei (break down over time)

Radioactive isotopes are used to ...

- Treat/fight cancer
- Kill food-spoiling bacteria
- “Trace” the movement of substances inside an organism

Chemical Compounds

Most elements are found in *compounds* with other elements.

- **Chemical Compound:** a chemical combination of two or more elements in a definite proportion
    - Shown in a *chemical formula* (shorthand for the composition of a chemical compound)

The properties of compounds look very different from the elements that they’re formed from

Chemical Bonds

- Involves the outermost electrons of the atoms (**valence electrons**)
    - *Covalent* and *ionic* bonds

Ionic Bonds

Ionic Bond: one or more electrons are transferred from one atom to another

- Atoms that lose electrons → positively-charged **cations**
- Atoms that gain electrons → negatively-charged **anions**

Ions: positively or negatively-charged atoms

Covalent Bonds

Covalent Bond: moving electrons travel around the nuclei of both atoms

- *Single Covalent Bond* → shares 2 electrons
- *Double Covalent Bond* → shares 4 electrons

- *Triple Covalent Bond* → shares 6 electrons

Molecule: structure formed when atoms are joined together by covalent bonds

Van der Waals Forces

Some atoms have a stronger attraction to electrons than others.

- **Van der Waals Forces:** intermolecular forces of attraction between molecules

2.2 — Properties of Water

The Water Molecule

- Found in a liquid state across most of the Earth
- In a neutral state

Polarity

Water's nucleus attracts electrons.

- A partial positive and partial negative charge on two ends

Hydrogen Bonding

Hydrogen Bonding: the attraction between a hydrogen atom with a partial positive charge and another atom with a partial negative charge

- **Most Common Partially-Negative Atoms Involved in Hydrogen Bonding:** Oxygen, Nitrogen, and Fluorine

Cohesion: attraction between molecules of the same substance

Adhesion: attraction between molecules of different substances

Heat Capacity → takes large amounts of heat energy to make molecules to move faster

- Raises the temperature of water

> Water has a **HIGH** heat capacity.

- Water can take in a lot of heat and not change much temperature

Solutions & Suspensions

Water is often found in a mixture.

- **Mixture:** a material composed of two or more elements or compounds that physically mixed together (not chemically-combined)

Two Types of Mixtures that can be Made with Water: *Solutions* and *Suspensions*

Solutions

- Evenly-distributed components

Solute → substance that is being dissolved

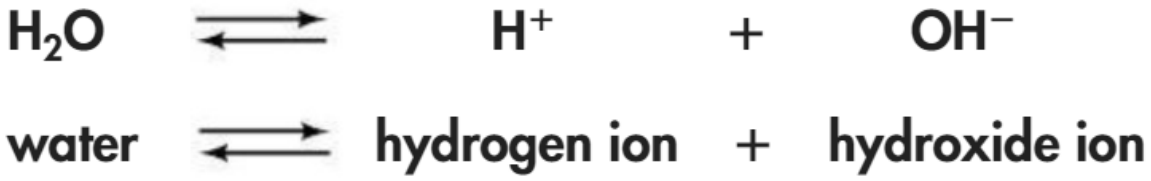
Solvent → substance in which the solute dissolves in

> Water can dissolve both ionic compounds and other polar molecules.

- Once water has dissolved all the water possible, it is **saturated**

Acids, Bases & pH

Water molecules split apart to form ions.



The pH Scale

- Measurement system to indicate the concentration of H^+ and OH^- ions in a solution
- Ranges from 0 to 14

pH of 7 → equal concentrations of H^+ and OH^-

- Ex. pure water

pH < 7 → more H^+ than OH^- (**acidic**)

pH > 7 → more OH^- than H^+ (**basic**)

> Each step on the pH scale has a factor of 10.

- *pH of 4* has 10x as many H^+ ions as *pH of 5*

Acids

Acid: any compound that forms H^+ ions in solution

- High concentrations of H^+ than pure water
- Strong acids → *pH 1-3*
  - Ex. hydrochloric acid (HCl)

Bases

Base: any compound that forms OH^- in solution

- Low concentrations of H^+ than pure water
- Strong bases → *pH 11-14*
    - Ex. lye (commonly NaOH)

Buffers

Buffers: weak acids or bases that can react with strong acids or bases to prevent sharp, sudden changes in pH

- Helps to maintain homeostasis and keep bodily fluids in check

> Human body pH should be between *6.5* and *7.5*.

2.3 — Carbon Compounds

The Chemistry of Carbon

Carbon can make strong covalent bonds with many elements.

- All living organisms have carbon
- Carbon molecules can form chains (bonding with other carbons)

Biomolecules

Biomolecules: large, organic molecules found in living things

- Also known as *macromolecules* because of their size
- Made from many smaller molecules
- Formed through *polymerization*

Polymerization: a process in which compounds are built by joining smaller ones together

- Smaller units → **monomers**
  - Can be identical or different
- Formations → **polymers**

Carbohydrates

Carbohydrates: compounds made up of carbon, hydrogen, and oxygen atoms (common ratio → 1:2:1)

- Used by living things as a source of energy
- Extra sugar can be stored as *starches*
  - Known as *sugar molecules*

Monosaccharides: single sugar molecules

Polysaccharides: large biomolecules formed by joining many monosaccharides together

- **Glycogen** → stores energy

Lipids

Lipids: a large and varied group of biomolecules that are generally not soluble in water

- Made from carbon and hydrogen atoms
- Ex. fats, oils, waxes

Steroids synthesized by the body are lipids.

- Function as chemical messengers

Lipids can be formed when glycerol & fatty acids bond.

- **Saturated** → all carbons are connected by single covalent bonds
- **Unsaturated** → at least one double bond

Nucleic Acids

Nucleic Acids: biomolecules containing hydrogen, oxygen, nitrogen, carbon, and phosphorus

- Polymers assembled from *nucleotides* (the monomers)

Nucleotides consists of:

- A 5-Carbon Sugar
- A Phosphate Group
- A Nitrogenous Base

> Nucleic acids function to **transmit genetic information**.

- Two Types of Nucleic Acids: DNA and RNA

Proteins

Proteins: biomolecules that contain *nitrogen*, carbon, hydrogen, and oxygen

- Polymers of *amino acids*

Amino Acids: compounds with an amino group on one end and a carboxyl group on the other

- Linked by peptide bonds to form a *polypeptide*

Proteins are built from one or more polypeptides.

- Variety of functions (ex. controlling reaction rate, regulating cell processes)

Amino acids can join each other.

- Proteins are some of the most diverse molecules.

Proteins have four levels of organization.

1. Sequence of Amino Acids
2. Folding of the Polypeptide Chain
3. 3D Arrangement of the Polypeptide Chain
4. How Polypeptide Chains (if more than one) are Organized in Relation to One Another

2.4 — Chemical Reactions & Enzymes

Chemical Reactions

Chemical Reaction: a process that changes a set of chemicals into another

- Mass and energy are conserved

Reactants: elements/compounds entering into a reaction

Products: elements/compounds produced by a reaction

- Chemical reactions change the chemical bonds

Energy in Reactions

Energy is released or absorbed when chemical bonds are formed or broken.

Chemical reactions that release energy occur **on their own**.

Chemical reactions that absorb energy **require an energy source**.

Organisms need energy to carry out reactions.

Activation Energy

Activation Energy: the energy needed to start a reaction

- Involved whether releasing or absorbing energy

Enzymes

Catalyst: a substance that speeds up the rate of a reaction

Nature's Catalysts

Enzymes: proteins that act as biological catalysts

- Lower activation energies

> Enzymes are very specific, tailored to certain reactions.

The Enzyme-Substrate Complex

Enzymes provide a site for reactants to react.

- Reduces energy needed

Substrates: reactants of enzyme-catalyzed reactions

- Bind to a site on the enzyme called the **active site**

Active sites and substrates have precise fits to match together.

Regulation of Enzyme Activity

Enzymes ...

- Control chemical pathways
- Make materials needed by cells
- Release energy
- Transfer information

Enzyme activity can be affected by **temperature**, **pH**, and **regulatory molecules**.

- Most enzymes work at around 37°C
- Some molecules show ‘on’ or ‘off’ chemical signals