The Chemistry of Life
Chapter 2
Warm Up Exercise

- Please complete the pretest that you picked up as you came in.
Atoms

- Atom - the basic unit of matter.
- Contains subatomic particles
  - Protons (+ charge)
  - Neutrons (no charge/neutral)
  - Electrons (- charge)
- Protons and neutrons have about the same mass. Electrons are much smaller.
- Atoms have equal numbers of PROTONS and ELECTRONS.
  - Because these particles are opposite charges, the whole atom is neutral.
Elements and Isotopes

- **Element** - a pure substance that consists of only one type of atom. Elements are represented by a 1 or 2 letter symbol. (ie: C = carbon)
- The number of **protons** in an element is that element’s **atomic number**.
  - The atomic number of carbon is 6, therefore carbon has 6 protons and consequently 6 neutrons.
- **Mass Number** - the sum of the number of protons plus the number of neutrons.
- **Atomic Mass** - the average weighted mass of the isotopes.
Elements of Life

- **Essential Elements** - required for an organism to live a healthy life and reproduce.
  - Four Elements, H, O, N, C make up 96% of all living matter.

- **Trace Elements** - required by an organism, but only in very small quantities.
Isotopes

- **Isotopes** - atoms of the same element that have different numbers of neutrons.
  - Isotopes are identified by their mass number (i.e.: carbon-12, carbon-13, carbon-14)
- Isotopes have the same number of electrons, so all isotopes of an element have the same chemical properties.
Some isotopes are radioactive. This means that their nuclei are unstable and break down at a continuous rate over time.
Exit Slip

• Why do all isotopes of an element have the same chemical properties?
Warm Up Exercise

• What are the three subatomic particles and their charges?

• How do you calculate mass number and atomic mass?
Ions

- **Ion** - an atom that has gained or lost an electron, giving it a positive or negative charge.
  - **Cation** - a positively charged ion
  - **Anion** - a negatively charged ion
Chemical Compounds

- **Compound** - formed by the chemical combination of two or more elements in definite proportions.
  - Compounds are typically written as a chemical formula (i.e.: NaCl, CO$_2$, etc.) This gives you the ratio of elements in the compound.
  - The physical and chemical properties of a compound are usually very different from those of the elements from which it is formed.
Chemical Compounds

- Chemical compounds are held together by bonds, which are formed by the electrons of each element.
  - The electrons that are available to form bonds are called valence electrons, and are on the outermost energy level.
Chemical Bonds

- **Ionic Bonds** - formed when one or more electrons are transferred from one atom to another.
  - Form between a metal and a nonmetal. (between a cation and an anion)
Covalent Bonds - results when electrons are shared between atoms.

- The structure that results when atoms are joined together by covalent bonds is called a molecule.
- Covalent bonds usually form between 2 nonmetals.
- Covalent bonds are the strongest bonds between atoms.
Chemical Bonds

- **Single Covalent Bond** - atoms share 2 electrons,
- **Double Covalent Bond** - atoms share 4 electrons.
- **Triple Covalent Bond** - atoms share 6 electrons.
SHARING OF ELECTRONS

molecule

covalent bond

TRANSFER OF ELECTRON

positive ion  negative ion

ionic bond
Chemical Bonds

- **Hydrogen Bonding** - Hydrogen can form a special type of bonds with a couple of unique elements:

  H-F-O-N
Van der Waals Forces

- A slight attraction that develops between oppositely charged regions of nearby molecules.
  - Not near as strong as ionic or covalent bonds, although they can hold molecules together, especially when the molecules are large.
Forces Between Molecules

- **Intermolecular Forces** - between atoms of two different molecules.
  - Ex: Hydrogen bonding, Van der Waals forces

- **Intramolecular Forces** - between atoms of the same molecule.
  - Ex: ionic and covalent bonding
Warm Up Exercise

• List the following bonds/forces from least to greatest strength: hydrogen, van der waals, ionic, covalent.

• If I said you have a Nitrogen to Nitrogen triple bond, what type of bond would you know that to be?

• Which elements participate in Hydrogen bonding?
Properties of Water

- **Polar Molecule** - has an overall charge that is unequally distributed. (due to unequal sharing of electrons).

- **Cohesion** - the ability of like molecules to attract.

- **Adhesion** - the clinging of one substance to another substance.
  - Adhesion and Cohesion are responsible for Capillary Action
Properties of Water

- **Surface Tension** - very high in water- as a result of cohesion.
- **High Specific Heat** - this allows water to stabilize temperatures. (how well a substance resists change in temperature)
  - High specific heat is a result of Hydrogen Bonding.
- **High Heat of Vaporization** - amount of energy for evaporation to occur.
- **Evaporative Cooling** - as liquid evaporates, the surface of the liquid that remains behind cools down.
- **Less Dense As a Solid** - 4°C, water moves too slowly to break hydrogen bonds and starts to freeze.
The Water Molecule

- Water is **polar** because there is an **uneven** distribution of **electrons** between the oxygen and hydrogen atoms.
  - The hydrogen ends of the molecule are slightly **positive** and the oxygen end is slightly **negative**.
The Water Molecule

- Because of the **opposite** charges, polar molecules (such as water) can **attract** each other.
  - The attraction between the hydrogen atom on one molecule and the oxygen atom on another molecule is an example of a **hydrogen bond**.
Properties of Water

- **Cohesion** - an attraction between molecules of the same substance. (ex: water attracted to water)

- **Adhesion** - an attraction between molecules of different substances. (ex: water attracted to glass)
  - Ex: meniscus
Properties of Water

- Water also has a high **surface tension** which allows it to form a skin-like surface.
  - Water has a high surface tension due to the strong **cohesive** forces between water molecules.

- **Capillary Action** - the force that allows water to move up against gravity.
  - Example: water being absorbed up the roots in plants.
Warm Up Exercise

• Explain the difference between adhesion and cohesion.
• What does it mean for a molecule to be polar?
Acids and Bases

- **Acid** - increases the H+ (hydrogen ion) concentration of a solution. (lower OH- concentration). pH < 7.

- **Base** - increases the OH- (hydroxide) concentration of a solution. (lower H+ concentration). pH > 7.
Acids and Bases

- **Neutral**- solution where H+ and OH concentrations are equal. pH=7
  - pH = - log [H+]
  - Each pH unit represents a ten-fold difference in H+ and OH- concentrations.

- **Buffers**- substances that minimizes changes in concentrations of H+ and OH- in a solution.
  - By accepting hydrogen ions when in excess and donating when they have been depleted.
  - Most buffers are weak acid-base pairs.
Warm Up Exercise

• The strong acid hydrogen fluoride (HF) can be dissolved in pure water. Will the pH of the solution be greater or less than 7?

• Hypothesize whether or not you think KOH is an acid or a base.
Carbon Compounds

- **Organic Chemistry** - the study of all compounds that contain carbon.

- **Macromolecules** - made from thousand of smaller molecules.
  - **Polymerization** - large compounds called polymers are built by joining smaller compounds (called monomers) together.
Carbon Compounds

- There are four groups of organic compounds found in living things:
  - **Carbohydrates** - made of monosaccharides.
  - **Lipids** - made of glycerol and fatty acid.
  - **Nucleic Acids** - made of nucleotides.
  - **Proteins** - made of amino acids.
Carbohydrates

- **Carbohydrates** - compounds made up of carbon, hydrogen, and oxygen atoms, usually in a 1:2:1 ratio.
- Living things use carbohydrates as their main source of energy.
- Plants and some animals also use carbohydrates for structural purposes. (ie: cellulose- in plant walls)
- **Monosaccharides** - single sugar molecules
  - ie: glucose, galactose, fructose
- **Polysaccharides** - large macromolecules formed from monosaccharides.
  - ie: glycogen (animal starch), cellulose (plant starch)
Lipids

- **Lipids** - made mostly from carbon and hydrogen atoms, which combine to form fatty acids and glycerol.
- The common categories of lipids includes **fats**, **oils**, **waxes**, and **steroids**.
- Lipids can be used to **store energy**.
- If each carbon atom in a lipid’s fatty acid chain is joined to another carbon atom by a single bond, the lipid is said to be **saturated**, because it contains the maximum number of hydrogen atoms. If there is at least one C=C, they are said to be **unsaturated**.
Warm Up Exercise

Please complete the macromolecule graphic organizer for carbohydrates and lipids.
Nucleic Acids

- **Nucleic Acids** - macromolecules containing hydrogen, oxygen, carbon, and phosphorous.
- Nucleic acids are polymers assembled from individual monomers known as nucleotides.
- Nucleotides consist of three parts:
  - a 5-carbon sugar
  - a phosphate group
  - a nitrogenous base
- Nucleic acids store and transmit hereditary or genetic information as RNA and DNA and help control the production of proteins.
Proteins

- **Proteins** - macromolecules that contain nitrogen, carbon, hydrogen, and oxygen.
- Proteins are made of molecules called **amino acids** which are held together by **peptide bonds**.

Amino acids are compounds with an **amino group** (-NH$_2$) on one end and a **carboxyl group** (-COOH) on the other end.
Proteins (continued)

- The instructions for arranging amino acids into many different proteins are stored in DNA.
- Each protein has a specific role.
Protein Structure

• **Four Levels of Protein Structure**
  
  • **Primary** - the series of amino acids in a unique sequence. Coded for in DNA.
  
  • **Secondary** - coils and folds in the polypeptide chain. Result from H-bonds between polypeptide backbone
  
  • **Tertiary** - results from interactions between side chains (R groups).
  
  • **Quaternary** - association between multiple polypeptide chains- form a functional protein.
Denaturation

- Denaturation - protein unravels and loses its shape.
  - Because of change in pH, salinity, temperature, etc.
Protein Functions

Enzymatic proteins
Function: Selective acceleration of chemical reactions
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

Storage proteins
Function: Storage of amino acids
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.

Defensive proteins
Function: Protection against disease
Example: Antibodies inactivate and help destroy viruses and bacteria.

Transport proteins
Function: Transport of substances
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.
Protein Functions

Hormonal proteins
Function: Coordination of an organism’s activities
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.

Receptor proteins
Function: Response of cell to chemical stimuli
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.

Contractile and motor proteins
Function: Movement
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.

Structural proteins
Function: Support
Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.
Exit Slip

• Given the fact that nucleic acids are used to build DNA and RNA, in what types of foods do you think you would find nucleic acids
Warm Up Exercise

• Please complete the macromolecule graphic organizer for nucleic acids and proteins.
Chemical Reactions

- **Chemical Reaction** - a process that changes, or transforms one set of chemicals into another.
  - **Reactants** - the elements or compounds that enter into a chemical reaction. (on the left of the equation)
  - **Products** - the elements or compounds produced by a chemical reaction. (on the right of the equation)
- Chemical reactions always involve changes in the chemical bonds that join atoms in compounds.

\[ 2H_2 + O_2 \rightarrow 2H_2O \]
Chemical Reactions

- Rate of Reaction can be affected by: concentration, temperature, pressure, surface area, and size.
- **Chemical Equilibrium** - forward and reverse rate of reactions are equal.
  - Dynamic Equilibrium - reactions are still going on, but do not affect the concentration of the reactants or products, and they remain equal.
Energy in Reactions

• Break Bonds = Release Energy
  Form Bonds = Requires Energy

• Chemical reactions that release energy often occur spontaneously. Chemical reactions that absorb energy will not occur without a source of energy.
Activation Energy

- **Activation Energy** - the energy that is needed to get a reaction started.

**ENDERGONIC**

**EXERGONIC**

[Diagram showing energy-absorbing and energy-releasing reactions with graphs illustrating the process.]
**Enzymes**

- **Catalyst** - a substance that speeds up a chemical reaction.
  - Catalysts work by lowering a reaction’s **activation energy**.

- **Enzyme** - proteins that act as biological catalysts.
  - Enzymes **speed up** chemical reactions that take place in cells.
Enzyme Action

- Enzymes are very specific, generally catalyzing only 1 chemical reaction.
- **Substrates** - the reactants of enzyme-catalyzed reactions. (what the enzyme acts on)
- **Active Site** - place on the enzyme where the substrate binds.
The Enzyme-Substrate Complex

A. Substrates bind to enzyme

B. Substrates are converted into products

C. Products are released

Enzyme (hexokinase)

Active site

Enzyme-substrate complex

Glucose

Substrates

ADP

Glucose-6-phosphate

Products
Regulation of Enzyme Activity

- Enzymes work best at certain **pH** values.
- Many enzymes are affected by changes in **temperature**.
- Enzymes play essential roles in regulating chemical pathways, making materials that cells need, releasing energy, and transferring information.