Biochemistry: Chemistry & Biology meet head-on

- Living things require millions of chemical reactions within the body, just to survive.

- Metabolism = all the chemical reactions occurring in the body.

- **Biochemistry** - is the study of the chemical interactions of living things.
Matter and Energy

- **Matter** - anything occupying space and having mass
- **Mass** - is the amount of matter something contains
- **Weight** - gravitational force exerted on a mass
  \[ W = mg, \quad g = 9.8 \text{ m/s}^2 \text{ or } 32.3 \text{ ft./s}^2 \]
- **States of Matter**
  - solid, liquid, gas, plasma
- **Energy** - Energy is the capacity to do work, or put matter into motion
- **Total energy of an object has two components:**
  - **Kinetic Energy** - (energy in the form of movement) - energy in action that does the actual work
  - **Potential Energy** - (stored energy) – energy an object has because of its position (or internal structure)
Forms of Energy

- **Chemical** - energy stored in the bonds of chemical substances
  - When bonds broken the PE is released for use and becomes kinetic energy
  - Ex. Energy from the foods that you eat, is temporarily captured in the bonds of ATP (Adenosine Triphosphate)

- **Electrical** - energy that reflects the movement of charged particles
  - electrical currents created by ions that move across cell membranes and nervous system impulses

- **Mechanical** – is the energy directly involved in moving matter

- **Radiant or Electromagnetic** - energy that travels in waves
Matter Composition: Atoms & Elements

- **Elements** - substance that can’t be broken down to another substance and is composed of atoms all of which have the same number of protons in their nucleus
  - 25 chemical elements required for life
  - 96% Carbon, Hydrogen, Oxygen, Nitrogen (proteins, fats, carbohydrates and nucleic acids-example: DNA)
  - 4% Examples: Calcium, Phosphorus, Potassium, Sulfur, Sodium (important biological functioning)
- **Atoms** - are defined as the smallest part of an element that maintains the properties of that element
- **Atomic Symbol** – one- or two- letter chemical shorthand for each element
Word atom comes from the Greek word meaning “indivisible” or “incapable of being divided”

Democritus of ancient Greece proposed that all matter must be made of some indivisible unit

Subatomic particles - evidence that atom is divisible, each having a different mass, charge, & location

- **protons** – in the nucleus, +1 charge, 1 amu, p⁺
- **neutrons** – in the nucleus, no charge, 1 amu, n⁰
- **electrons** - outside the nucleus, -1 charge, 0 amu, e⁻

**Nucleus** - contains protons and neutrons
Planetary Vs. Orbital Models

- **Planetary Model**
  - Shows the atom as a miniature solar system in which protons & neutrons are clustered at center in the nucleus with the electrons moving around the nucleus in a fixed orbit
  - Like planets around the sun (Neils Bohr)
  - Hard to predict exact location of electrons because they jump around following unknown paths
Planetary Vs. Orbital Models

Orbital Model

- Depicts the general location of electrons outside the nucleus as a haze of negative charge, called and **electron cloud**
- Are in regions called **orbitals**, in which an electron or electron pair is likely to be found
- Based on probability of finding an electron
- Electrons have the run of nearly the entire volume of the atom
- Electrons determine the chemical behavior of an atom, its ability to bond with other atoms
Identifying Elements

Three things are used to ID an element:

- **Atomic Number** – equals the number of protons in the nucleus of an atom, unique to each element
  - Also can tell indirectly the number of electrons

- **Mass Number** – is the sum of the masses of protons and neutrons, (protons + neutrons)
  - Mass of electrons so small that it is ignored

- **Atomic Weight** – average of the mass numbers of all of the isotopes of an element

- **Isotope** – different atomic form of the same element, same atomic # just different atomic mass
  - same number of protons but different number of neutrons
Identifying Elements

- Element’s isotopes have the same number of electrons, which determine bonding, their chemical properties are the same.
- Atomic weight is approximately equal to the mass number of its most abundant isotope.
- **Radioisotopes** – heavier isotopes of atoms that are unstable & tend to decompose to become more stable.
  - “glue” that holds atoms together in heavy isotopes is weak.
- **Radioactivity** - spontaneous atomic decay, like a tiny explosion.
  - Involve ejection of particles (alpha, beta) or energy (gamma rays) from atom’s nucleus.
How Matter is Combined: Molecules & Mixtures

- **Molecules and Compounds**
  - **Molecule** - two or more *like* atoms combine chemically, ex. $\text{H}_2$
  - **Compound** - two or more *different* atoms combine chemically, ex. $\text{CH}_4$

- **Mixtures**
  - **Mixture** – a physical blending of two or more states of matter
    - **Heterogeneous Mixture** - not uniform in composition
    - **Homogeneous Mixture** - uniform in composition, same throughout
  - **Solution** – a homogenous mixture
    - **Solvent** – part of a solution that does the dissolving
    - **Solute** - part of a solution that gets dissolved
How Matter is Combined: Molecules & Mixtures

- **Percent Composition**
  \[ \text{% composition} = \frac{\text{part of mixture/compound}}{\text{whole mixture/compound}} \times 100 \]

- **Distinguishing Mixtures from Compounds**
  - no chemical bonding in mixtures (physical)
  - chemical bonding in compounds
Chemical Bonds & Chemical Reactions

- **Chemical Reactions** - occur whenever atoms combine with, or dissociate from, other atoms
- When atoms unite chemically, chemical bonds are formed
- Bond Formation
  - Is an energy relationship that involves interactions between the electrons of the reacting atoms
- The Role of Electrons in Chemical Bonding
  - **Electron shells/Energy levels** – fixed regions of space around the nucleus where electrons are
  - Maximum # shells known is seven
  - Electrons close to nucleus are less likely to interact with other atoms than the outer electrons, which are less securely held
Chemical Bonds & Chemical Reactions

- **Number of electrons in shells**
  - Shell 1 - 2 electrons, Shell 2 – 8 electrons, Shell 3 – 18 electrons, Shell 4 – 32 electrons

- **Valence Electrons** - electrons in the outermost shell of an atom
  - Determine the chemical behavior and are involved in bonding

- **Octet Rule** – states that the maximum number of valence electrons needed to be stable, or chemically inert is 8
  - If < 8 the atom will tend to gain, lose, or share electrons with other atoms making a chemical bond
  - Reactivity of atoms based on number of valence electrons, follow “rule of 8s”
Types of Chemical Bonds

- **Ionic Bonds** – when electrons are transferred from one atom to another (opposites attract)
  - **Ions** - negatively or positively charged particles, that result from atoms gaining or losing electrons
    - (anions (-), nonmetals & cations (+) metals)
  - Crystalline structure, also called salts
  - Ex. NaCl, sodium chloride, aka table salt

- **Covalent Bonds** - when electrons are shared between atoms
  - single, double and triple covalent bonds – sharing of one, two, or three pairs of electrons
  - polar versus non-polar covalent molecules
    - **Polar** – when electrons are shared unequally, ex. $\text{H}_2\text{O}$
    - **Non-Polar** - when electrons are shared equally, ex. $\text{H}_2$
Types of Chemical Bonds

- **Hydrogen Bonds** are weak bonds that occur when a hydrogen is bound to one electron-hungry and then creates a bridge to another electron-hungry atom.

- Are an important **intramolecular bond** – help to bind different parts of the same molecule together in a special three-dimensional shape.

- These fragile bonds are important in helping maintain the structure of protein molecules.

- ex. water molecule
Chemical Reactions

- **Chemical Reaction** – involves the making or breaking of bonds between atoms
  - Atoms are united by chemical bonds
  - Atoms dissociate from other atoms when chemical bonds are broken

- **Chemical Equations** – are used to show a chemical reaction
  - Ex. $2H_2 + O_2 \rightarrow 2H_2O$

- Types of Chemical Reactions:
  - **Synthesis Reactions** - when two or more atoms or molecules combine to form a larger more complex molecule
    - $A + B \rightarrow AB$
  - **Decomposition Reaction** – when a molecule is broken down into smaller molecules, atoms, ions
    - $AB \rightarrow A + B$
Chemical Reactions

- **Single Exchange (or displacement) Reactions** - when a single ion changes place with another similarly charged ion
  \[ AB + C \rightarrow AC + B \]

- **Double Exchange (or displacement) Reactions** - when two ions change places with another
  \[ AB + CD \rightarrow AD + CB \]

- **Redox Reactions** – short for oxidation-reduction reactions, which involves the transfer electrons in a two part reaction process
  - “LEO the Lion goes GER”
    - Lose electrons oxidation
    - Gain electrons reduction
Chemical Reactions

- Energy Flow in Chemical Reactions
  - Exergonic Reactions
    - **Exothermic** – lose heat energy to the environment
  - Endergonic Reactions
    - **Endothermic** – gain heat energy from the environment

- Reversibility of Chemical Reactions
  - **Chemical Equilibrium** - rate at which reactants being lost is equal to rate of the products being formed

- Factors Influencing the Rate of Chemical Reactions
  - temperature
  - concentration
  - catalysts/enzymes
Chemical Composition of Living Matter

- **Organic Compounds**
  - Usually associated with living things.
  - Always contain **CARBON**.
  - Are “large” molecules, with many atoms
  - Usually covalently bonded
  - Carbohydrates, lipids, proteins, and nucleic acids important to body

- **Inorganic Compounds**
  - Lack carbon
  - Smaller and simpler molecules, with fewer atoms
  - Covalent and ionic bonding
  - Water, salts, and acids/bases are important to body
Inorganic Compounds

- **Water** (dihydrogen monoxide)
  - **High Heat Capacity** - can absorb and release large amount of heat before its temperature changes appreciably, thus prevents sudden changes in body temperature
  - **Polarity/Solvent Properties** – because of its polarity is an excellent solvent “universal solvent”
    - **Solution** – homogeneous mixture with two parts: solvent (does the dissolving) & solute (is dissolved)
    - Chemicals in body need to be in solution for reactions and transport, water is the solvent for the body's solutes
  - **Chemical Reactivity** – water is an important reactant for body in hydrolysis reactions, where water breaks down larger molecules
  - **Cushioning** – in form of cerebrospinal fluid, water forms a protective cushion around the brain
Inorganic Compounds

- **Salts** – of metal elements are found in the body
  - Most plentiful contain calcium and phosphorus, found chiefly in bones & teeth
  - When dissolved in body fluids, salts, which are ionic compounds easily separate into their ions in a process called dissociation
  - Salts, both in ionic forms and in combination with other elements are vital to body functions
    - Ex. sodium and potassium ions are essential for nerve impulses and iron forms part of the hemoglobin molecule that transports oxygen in blood
  - All salts are electrolytes - substances that can conduct electrical current in solution
    - When ionic(electrolyte) balance is disturbed body starts to shut down
Inorganic Compounds

- Acids and Bases – are electrolytes like salts
  - **Acids** – release hydrogen ions, $H^+$, called proton donors
    - Release Hydrogen ions, or protons in water, called ionization (sour taste)
    - Strong acids completely ionize and weak partially ionize
      - Ex. HCl produced by stomach to aid in digestion (strong)
        \[ HCl \rightarrow H^+ + Cl^- \]
      - Body also has or produces acetic acid & carbonic acid (weak)
  - **Bases** – release hydroxyl ions/ $OH^-$, proton acceptors (bitter taste and slippery)
    - Strong bases completely ionize and weak partially ionize
      - Ex. NaOH strong base, $NaOH \rightarrow Na^+ + OH^-$
      - $HCO_3^-$ - bicarbonate important base in blood, weak base
pH Scale - Acid/Base Concentrations

- pH – measures relative concentration of hydrogen ions, $pH = - \log[H^+]$
- $pH + pOH = 14$, $pOH = -\log[OH^-]$
- pH 7 = neutral
- pH below 7 = acidic
- pH above 7 = basic
- **Buffers** – chemical that can resist changes in pH or can help regulate pH
pH Scale
Inorganic Compounds

- **Neutralization** – when an acid and base are mixed, they react to produce water and salt
  - $\text{HCl} + \text{NaOH} \rightarrow \text{H}_2\text{O} + \text{NaCl}$
- **Buffers** - are chemical that resist changes in pH
- Living cells are very sensitive to changes in pH, the acid-base balance is regulated by the kidneys, lungs, and buffers in body fluids
  - consist of weak acids and bases (carbonic acid-bicarbonate system)- blood
  - blood comes into close contact with nearly every body cell, regulation of blood pH is very critical, ranges from 7.35-7.45, if changes more than a few tenths of a pH unit, death can occur (if dips acidic side lowers the ability for blood to carry oxygen)