WHY IS THIS IMPORTANT?

- An understanding of chemistry is essential to understand cellular structure and function, which are paramount for your understanding of microbiology.
- Many of the pathogenic effects of infectious diseases occur at the molecular level.
- To understand the infection process, you need to understand basic chemistry.
WHY CHEMISTRY?

- Life on earth is based on chemical reactions.
- You need to understand how cells and tissues are constructed and how they function.
- The construction and function of cells and tissues play a role in infection.

WHY CHEMISTRY?

- Tissues are organized in the following way:
  
  Atoms
  └── Molecules
  │   └── Cells
  │       └── Tissues

CHEMICAL BONDING

- Atoms bond together to make molecules.
- Molecules bond together to make cells.
- Cells bond together to make tissues.
CHEMICAL BONDING

- Atoms are composed of three types of particles: protons, neutrons, and electrons.
- Protons possess the following qualities:
  - Located in the core of the atom
  - Have a positive charge
  - The number of protons in an atom is equal to the atomic number of the atom.

- Neutrons possess the following qualities:
  - Located in the core of the atom
  - Neutrons have no charge
  - The number of neutrons is usually equal to the number of protons
  - The total number of protons and neutrons equals the atomic weight of an atom.

- Electrons possess the following qualities:
  - Have a negative charge
  - Located in shells (orbitals) around the outside of the core
  - In an uncharged atom, the number of electrons is equal to the number of protons.
CHEMICAL BONDING

- Shells occupied by electrons have a limited capacity.
  - First shell can only hold 2 electrons
  - Second shell can only hold 8 electrons
  - Third shell can hold 18 electrons but needs 8 to be stable

- If the electron shell is not full, it is unstable.
- Atoms with unstable electron shells can give or receive electrons to other atoms.
- This stabilizes the atom and makes ionic bonding possible.
IONIC BONDS

- Ionic bonds occur when one atom donates an electron and one atom receives an electron.
- The best example of an ionic bond is sodium chloride:
  - Sodium donates an electron.
  - Chloride receives an electron.
  - Both outer shells are stabilized.
- When electrons are donated or received, atoms are ionized.

COVALENT BONDS

- In covalent bonds, electrons are shared.
  - One pair shared forms a single bond.
  - Two pairs shared form a double bond.
- Covalent bonds can have polarity. The two types of polarity are:
  - Nonpolar – equal sharing of electrons
  - Polar – unequal sharing of electrons
    - Polar covalent bonds have a weak electrical charge.
Covalent bonding is the basis for organic molecules. Carbon has an atomic number of 6:
- Two electrons in the first shell
- Four electrons in the second
- Needs 4 shared electrons to make second shell stable.
HYDROGEN BONDS

- Hydrogen bonds are found between and within molecular structures.
  - They help determine and maintain molecular shape.
- They can be affected by temperature and pH.
- Water is a good example of a molecule with hydrogen bonds.

WATER

- Water may be the most important component for life because it has properties very important for physiological function.
- Water has three major properties:
  - Solubility
  - Reactivity
  - Heat capacity
WATER: Solubility

- Many molecules can be dissolved in water.
- In any solution, there are two primary ingredients:
  - Solvent – water
  - Solute – anything dissolved in the water
- Water causes spheres of hydration.

WATER: Solubility

- Chemical reactions normally occur in water.
- Removing water to build molecules is known as dehydration synthesis.
- Using water to break down molecules is known as hydrolysis.
WATER: Heat Capacity

- Heat capacity is the ability to absorb and retain heat.
- Chemical reactions give off heat as a by-product.

ACIDS, BASES AND pH

- Microorganisms can live in acidic or alkaline environments.
- Acidity can be viewed as excessive numbers of H\(^+\) ions.
  - Lower numbers on the pH scale.
- Alkalinity can be viewed as excessive numbers of OH\(^-\) ions.
  - Higher numbers on the pH scale.
- A neutral pH is 7.0.

BIOLOGICAL MOLECULES

- Biological molecules are also referred to as organic molecules.
- There are four major categories of biological molecules:
  - Carbohydrates
  - Lipids
  - Proteins
  - Nucleic acids
- All four categories of biological molecules use carbon as their backbone.
BIOLOGICAL MOLECULES

- Carbon atoms can form long chains.
- These chains can have hydrogen or other atoms attached to them.
- The attached atoms can form functional groups, which are involved in chemical reactions.
- The chemical bonds in large organic molecules provide energy to living organisms.

CARBOHYDRATES

- Carbohydrates can be viewed as the most easily used and best source of energy.
- Organisms and cells can break down or build up carbohydrates.
- All carbohydrates contain carbon, oxygen, and hydrogen.

There are three major categories of carbohydrates:

- Monosaccharide – smallest carbohydrate
  - Used to build bigger carbohydrate molecules
- Disaccharide – two monosaccharides
- Polysaccharide – many monosaccharides
CARBOHYDRATES

- A monosaccharide is a carbon chain with several functional groups attached to it.
- The best example of a monosaccharide is glucose.
- Disaccharides and polysaccharides are formed when monosaccharides are linked together by dehydration synthesis.

LIPIDS

- Lipids are a chemically diverse group of substances that includes fats, phospholipids, and steroids.
- They are relatively insoluble in water which makes them very useful as elements of cellular structure.
- Some lipids contain more energy than carbohydrates but are harder to break down.
**LIPIDS: Fats**

- Fats are lipids that contain the three carbon molecule glycerol and one or more fatty acids.
  - Fatty acids form long chains of carbons.
  - Fats are made by dehydration synthesis.
  - Fats are broken down by hydrolysis.

**LIPIDS: Fats**

- Fats are classified based on how many tails are attached
  - Monoacylglycerols – one fatty acid tail
  - Diacylglycerols – two fatty acid chains
  - Triacylglycerols – three fatty acid chains.
LIPIDS: Fats

- Fatty acids can be saturated or unsaturated
  - Saturated fats – contain all of the hydrogens that can possibly be bound
  - Unsaturated fats – have lost hydrogens and formed double bonds at the locations of the missing hydrogens

LIPIDS: Phospholipids and Glycolipids

- Glycolipids are lipids with carbohydrates attached.
- Phospholipids are lipids with phosphates attached.
- Phospholipids form barriers between the water inside the cell and the water outside the cell.

LIPIDS: Steroids

- One of the most important examples of a steroid is cholesterol.
- Cholesterol is found in the cell membranes of some eukaryotic cells.
- Other steroids are found in fungal plasma membrane.
PROTEINS

- Proteins are one of the most important of the biological molecules.
- They are very diverse in both structure and function.
- Each protein has a specific three dimensional shape that is directly related to function.

PROTEINS: Properties

- Proteins are made up of amino acid building blocks.
- Amino acids contain one carboxyl group and one amino group.
- Carboxyl and amino groups combine on different amino acids combine to form a peptide bond through dehydration synthesis.

PROTEINS: Properties
Proteins are made up of long sequences of linked amino acids, called peptides.
- Dipeptide – two amino acids
- Polypeptide – many amino acids
- Some amino acids contain sulphur atoms.
  - These can form disulfide bridges, which are important in protein structure.
The three-dimensional structure of proteins is broken down into four levels:

- **Primary** – sequence of amino acids in the peptide chain
- **Secondary** – folding or coiling of the peptide chain (usually into a helix or pleated sheet)
- **Tertiary** – peptide chain folds upon itself
- **Quaternary** – folded peptide chains join together

The shape is held together by hydrogen and disulfide bonds.

Proteins can be denatured.

- Factors such as pH and temperature can break hydrogen bonds.
- This damage causes changes in shape.
- Changes in shape disrupt function.
**PROTEINS: Types of Protein**

- There are a variety of proteins, but structural proteins and enzymes are among the most important.
- Structural proteins can:
  - Preserve structural integrity
  - Be used for motility
- Enzymatic proteins are involved in many cellular functions such as metabolism.

**PROTEINS: Types of Protein**

- Enzymes lower the energy of activation making metabolic reactions occur faster.
- The active site of an enzyme holds the reactants together during reactions.
- The shape of the active site is critical for function.
NUCLEIC ACIDS

- Nucleic acids are involved with cellular information and also function as energy molecules.
- There are two types of nucleic acid information molecule:
  - DNA – deoxyribonucleic acid
  - RNA – ribonucleic acid

NUCLEIC ACIDS

- Each building block of DNA (a nucleotide) consists of:
  - A nitrogenous base
    - Adenine (A), Guanine (G), Thymine (T), Cytosine (C)
  - A deoxyribose sugar
  - A phosphate
The structure of RNA nucleotides is similar to DNA except they have:
- Ribose sugar
- Uracil instead of thymine

The structure of nucleic acids adheres to the following pattern:
- Long polymeric structures of many nucleotides
- A backbone of alternating sugar and phosphate molecules:
  - Nucleotides are linked together by covalent bonds between the phosphate of one nucleotide and the sugar of the next.
- The ends of the spine are chemically different, giving the spine a direction
- Bases that extend inwards.
**NUCLEIC ACIDS: Structure**

- For most cells and organisms, DNA is double-stranded.
- The strands run in opposite directions (they are anti-parallel).
- Bases of one strand of hydrogen bond to bases of the other strand.
  - This is called complementary base pairing.

**DNA**

- In base pairing, you always find A with T and C with G.
- Base pairing is important for replication and gene expression.
**DNA**

- DNA is a double-stranded molecule.
- DNA is made by the same bonding mechanisms as in RNA.
- It incorporates deoxyribose sugar and not ribose sugar.
- Complementary base pairing occurs with RNA.
- It is involved in transcription and translation.

**RNA**

- RNA is a single-stranded molecule.
- RNA is made by the same bonding mechanisms as in DNA.
- It incorporates ribose sugar and not deoxyribose sugar.
- Complementary base pairing occurs with DNA.
- It is involved in transcription and translation.

**ADENOSINE TRIPHOSPHATE (ATP)**

- The major energy molecule in cells is ATP.
- It contains the nitrogenous base adenosine, a ribose sugar, and a chain of three phosphates bonded to the sugar.
- The bonds between these phosphates are high-energy bonds that when broken yield energy.
  - ATP $\rightarrow$ ADP + energy
- Energy plus phosphate added can rebuild ATP.
  - ADP + P$_i$ + energy $\rightarrow$ ATP