I. Introduction to Organic Compounds

Module 3.1 Life's molecular diversity is based on the properties of carbon.

- Organic compounds contain at least one carbon atom.

- C forms large, diverse molecules.

- C has 4 electrons in the outer shell; t/fore carbon has a strong tendency to fill the shell to 8 by forming covalent bonds with other atoms, particularly H, O, and N.

- The 4 electrons in the outermost shell of carbon allow it to form complex structures (e.g., long, branched chains, ring structures). This is a major reason carbon is the structural backbone of organic compounds.

- A compound composed only of carbon and hydrogen is called a hydrocarbon, which is generally nonpolar.

- A series of covalently attached carbons in a molecule form the backbone, or carbon skeleton.

- sometimes have a DOUBLE bond (Figure 3.1) – it represents 4 shared electrons.

- The way bonding occurs among atoms in molecules determines the overall shape of the molecule.

- Isomers are molecules with the same numbers of each atom but with different structural arrangements of the atoms.

Module 3.2 Functional groups help determine the properties of org. cmpds.

- Functional groups are generally attached to or part of the carbon skeleton of different molecules and exhibit predictable chemical properties.

- Functional groups are the atoms of an organic compound directly participating in chemical reactions. The sex hormones testosterone and estradiol illustrate the power of functional groups.

- Figure 3.2 illustrates five functional groups important to life.

- All of these functional groups have polar characteristics. Therefore, most of the molecules on which they are found are polar molecules.

Module 3.3 Cells make a huge number of large molecules from a small set of small molecules.

- Monomers are the fundamental molecular unit (single units/building blocks)

*** analogy:**

Single unit	**Structure**
brick	wall
carriage	train
tile	mosaic

- monomers link together to form polymers

- Polymers are macromolecules made by linking many of the same kind of fundamental units.

- Types of reactions:

* **dehydration reaction** —molecules synthesized by loss of a water molecule between reacting monomers, the most common way organic polymers are synthesized. *(also called dehydration synthesis or condensation reactions)*

	monosach	+	monosach	➔	disach	+	water
ex.	glucose	+	glucose	➔	sucrose	+	water
	$C_6H_{12}O_6$	+	$C_6H_{12}O_6$	➔	$C_{12}H_{22}O_{11}$	+	H_20

- results in loss of H2O, t/fore called dehydration

*** hydrolysis** —literally, "breaking apart with water"—the most common way organic polymers are degraded.

- when polysachs split apart to form monosachs.

- hydrolysis means water splitting

Have students record opposite of reaction above

- Lactose intolerance results from the inability to hydrolyze lactose due to the absence of the enzyme lactase, thus illustrating the need to be able to perform the correct chemical reactions.

<u>II. Carbohydrates</u>

- ***Monomers = monosaccharide ex. simple sugars such as glucose, fructose***
- ***Polymers = polysaccharides starch, cellulose***

Module 3.4 Monosaccharides are the simplest carbohydrates.

- The word "carbohydrate" indicates that these compounds are made of carbon (carbo, C) and water (hydrate, H_2O).

- The suffix "-ose" indicates that the molecule is a sugar.

- The basic roles of simple sugars are as fuel to do work

Module 3.5 Cells link two single sugars to form disaccharides.

- Two **<u>monosaccharides</u>** are put together to form a disaccharide via a glycosidic bond (Combining two glucose molecules with the removal of water makes maltose.)

- **<u>Disaccharide</u>** formation is an example of a dehydration reaction.

- The most common disaccharide is sucrose (table sugar), which is composed of glucose and fructose.

Module 3.6 Connection: How sweet is sweet?

- There are five taste receptors on the tongue: bitter, salty, sour, sweet, and umami (tastes like chicken!).

- The stronger the binding by a chemical to the sweet receptor, the sweeter the chemical is perceived to be. Fructose is considered 4 times sweeter than sucrose.

Module 3.7 Polysaccharides are long chains of sugar units.

- Different organisms use monosaccharides, such as glucose, to build several different polymers or polysaccharides: starch, glycogen, and cellulose (Figure 3.7)
(Note: Hydrogen atoms and functional groups are not shown in the figure. The hydroxyls functional groups render carbohydrates hydrophilic)

- **<u>Starch</u>** is used for long-term energy storage only in plants. Animals can hydrolyze this polymer to obtain glucose.

- **<u>Glycogen</u>** has the same kind of bond between monomers as starch, but it is highly branched. Glycogen also is used for long-term energy storage, but only in animals. Animals can hydrolyze this polymer to obtain glucose.

- **<u>Cellulose</u>** is the principal structural molecule in the cell walls of plants and algae. Animals cannot hydrolyze this polymer to obtain glucose without the help of intestinal bacteria (only certain bacteria, protozoa, and fungi can hydrolyze cellulose); therefore, it is referred to as **<u>fiber</u>**.

<u>III.   Lipids</u>

- ***Monomers = glycerol and 3 fatty acids***
- ***Polymers = fat, oil, hormones, wax***

- Lipids are compounds of mainly C & H linked by **<u>nonpolar covalent bonds</u>**

- B/c they are non-polar, lipids are not attracted to H_2O molecules, t/fore are **<u>hydrophobic</u>**

- main function of fat is energy storage, but they are also used to cushion organs, insulate body and assist with mobility.

Module 3.8   Fats are lipids that are mostly energy-storage molecules.

- In lipids, carbon and hydrogen predominate; there is very little oxygen, which makes them more or less **hydrophobic**. General molecular formula for fatty acid: $(CH_2)n$.

- Diverse types of lipids have different roles, including energy storage and structural and metabolic functions.

- Fats are polymers of fatty acids (usually three) and one glycerol molecule, formed by dehydration reactions, and are called **<u>triglycerides</u>** (Figure 3.8B, C). Fats are tremendous sources of energy and can store approximately 2 times the equivalent of polysaccharides.

- **<u>Saturated</u>** fatty acids <u>have no double bonds</u> between carbons (the carbons are "saturated" with hydrogen atoms). The molecular backbones are flexible and tend to ball up into tight globules. Saturated fats, such as butter and lard, are solid at room temperature.

- **<u>Unsaturated fats</u>** may include several double bonds between carbons. This causes the molecules to be less flexible, and they do not pack into solid globules. Unsaturated fats, such as olive oil and corn oil, are liquid at room temperature.

- Most plant fats are unsaturated, whereas animal fats are richer in saturated fats.

(NOTE: By "hydrogenating" unsaturated oils, the double bonds are removed and the molecules become more solid at room temperature. These structurally modified (trans) fats are as detrimental as their naturally saturated counterparts in leading to atherosclerotic plaques.)

Module 3.9   Phospholipids, waxes, and steroids are lipids with a variety of functions.

- **<u>Phospholipids</u>** are a major component of cell membranes. They have two fatty acid molecules (instead of three) and a phosphate group.

-<u>Waxes</u> are effective hydrophobic coatings formed by many organisms (insects, plants, and humans) to ward off water. They consist of a single fatty acid linked to an alcohol.

- **<u>Steroids</u>** are lipids with backbones bent into rings. Cholesterol is an important steroid formed by animals. Among other things, cholesterol is the precursor to bile acids that function in the digestion of fats and is the starting material for the synthesis of female and male sex hormones (see Figure 3.2).
NOTE: Despite its reputation, cholesterol plays many vital roles in the body.

- **<u>Phospholipid</u>** containing membranes are polymers of fatty acids and glycerol, but they include a negatively charged PO_4 group in place of one fatty acid. This gives them the unique property of having a hydrophobic "tail" and a hydrophilic "head."

Module 3.10 Connection: Anabolic steroids and related substances pose health risks.

- Anabolic steroids are synthetic and natural variants of the male hormone testosterone, which, among other roles, causes the buildup of muscle and bone mass during puberty in men.

NOTE: Body builders may sometimes be tempted to use steroids, but the medical problems associated with such use, include problems such as testicular atrophy, liver cancer, cardiovascular disease, breast development in males, masculinization of females, and antisocial behavior (steroid rage).

IV. Proteins

- ***Monomers = amino acids***
- ***Polymers = polypeptides - protein such as muscle, hair, nails, skin***

Module 3.11 Proteins are essential to the structures and activities of life.

A. Proteins are constructed from monomers called amino acids.
B. The structure of the protein determines its function.
C. The seven major classes of protein are:
    1. Structural: hair, cell cytoskeleton
    2. Contractile: as part of muscle and other motile cells, produce movement
    3. Storage: sources of amino acids, such as egg white
    4. Defense: antibodies, membrane proteins, complement proteins
    5. Transport: hemoglobin, membrane proteins
    6. Signaling: hormones, membrane proteins
    7. Enzymatic: regulate the speed of a biochemical reaction much like a chemical catalyst is used to speed up a reaction.

Module 3.12 Proteins are made from amino acids linked by peptide bonds.

- **Amino acids** are characterized by having an alpha carbon atom covalently bonded to one hydrogen, one amino group (NH_2), one carboxyl group (COOH), and one functional group symbolized by an R (Figure 3.12A).

- Each naturally occurring amino acid has one of 20 functional groups (Figure 3.12B), which determines the chemical characteristics of each amino acid.

- Amino acids are grouped into two categories based upon the characteristics of the R groups. The two categories are hydrophilic (polar neutral or charged) and hydrophobic (nonpolar). See Appendix 2 for a complete list.

- Organisms use amino acids as the monomer to build polypeptides by dehydration reactions. The bond between each amino acid is called a **peptide bond** (Figure 3.12C). The peptide bond can be broken by hydrolysis, to release free amino acids.

- Polypeptides are from several to more than a thousand amino acids long, and the specific sequence determines the function of the protein (a polypeptide with more than 20 amino acids is classified as a protein). *To illustrate the enormous number of proteins, compare the 20 amino acids used to make proteins to the 26 letters of the alphabet for words.*

Module 3.13 A protein's specific shape determines its function.

- Long polypeptide chains include numerous and various amino acids.

- The final structure of a protein, and thus its potential role, depends on the way these long, linear molecules fold.

- Each sequence of amino acids spontaneously folds in a different way (Figure 3.13A). The folding creates grooves that function as binding sites for other molecules (Figure 3.13B).

- Changes in heat, ionic strength, or salinity can cause proteins to unfold and lose their functionality (this is called **denaturation**).

Module 3.14 A protein's shape depends on four levels of structure.

- Transthyretin (a type of protein) is found in blood and is important in the transport of a thyroid hormone and vitamin A.

- Three-letter abbreviations represent amino acids; each amino acid is in a precise order in the chain (Figure 3.14A).

- Changes in the primary structure of a protein (the amino acid sequence) can affect its overall structure and, thus, its ability to function. Sickle cell disease is an excellent example of a single amino acid defect.

- **Tertiary structure**, which is the overall shape of the polypeptide, results from the clustering of hydrophobic and hydrophilic R groups and bond formation (hydrogen and ionic) between certain R groups along the coils and pleats (Figure 3.14C).

- In transthyretin, the tertiary shape is essentially globular, not fibrous like spider silk. The globular arrangement promotes hydrophilic amino acids to interact with the aqueous environment and forces the hydrophobic amino acids toward the center of the protein, sequestered from the water.

- Many (but not all) proteins consist of more than one polypeptide chain (also known as, subunits) and have quaternary structure.

V. Nucleic Acids

- ***Monomers = nucleotides***
- ***Polymers = DNA & RNA***

Module 3.16 Nucleic acids are information-rich polymers of nucleotides.

- There are two types of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

- Nucleotides are complex molecules composed of three functional parts (Figure 3.16A, B): phosphate group, five-carbon sugar (deoxyribose in DNA, ribose in RNA), and nitrogenous base.

There are five basic types of nitrogenous bases: A, T, G, and C in DNA and A, U, G, and C in RNA (Figure 10.2B, C).

NOTE: DNA nucleotide sequences encode the information required for production of the primary structure of proteins; such sequences are called genes (Modules 10.7 and 10.8).

- Nucleotide monomers join by dehydration reaction between the nucleotide parts (phosphate to sugar) to form polynucleotides with a linear structure of sugar-phosphate repeats (Figures 3.16A, B; Figure 10.2A).

- Hydrogen bonding between nitrogenous bases (A to T and G to C) causes the final structure of the nucleic acid.