

## Chapter 3

### Topic: Biomolecules

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#### Main concepts:

- In chemistry, the word **organic** refers to molecules that are made up of carbon and hydrogen. (The term “organically grown” or “organic” on food labels refers to agricultural practices.)
  - Plants and other photosynthetic organisms synthesize small organic molecules, referred to as **monomers**, from **inorganic** compounds. Some examples of monomers include simple sugars and amino acids. This is why photosynthetic organisms are called **producers**.
  - All organisms, including producers and consumers, break monomers down for energy or assemble them into longer molecules called **polymers** to build tissues. Some examples of polymers include proteins (chains of amino acids) and complex carbohydrates (chains of simple sugars).
  - Monomers are assembled into polymers through a process called **dehydration synthesis**. Polymers are broken down into monomers through a process called **hydrolysis** (hydro = water, lyse = to break).
  - Biologically important molecules are grouped into four classes: carbohydrates, lipids, proteins, and nucleic acids.
  - Polymers are large molecules made up of smaller molecules, referred to as monomers. Dehydration synthesis links monomers into polymers. Hydrolysis breaks polymers apart into monomers.
  - **Carbohydrates** include both monomers and polymers. Notice that the names of most carbohydrates end in “-ose.”
    - Monomers include the **monosaccharides** (mono=single, saccharide=sugar). Glucose is the most common monosaccharide in living organisms. Other important monosaccharides include fructose (fruit sugar), ribose (found in RNA), and deoxyribose (found in DNA).
    - **Disaccharides** are sugars made of two monosaccharides linked together by dehydration synthesis. Sucrose (table sugar) is a common disaccharide, composed of glucose and fructose. Lactose (milk sugar) is composed of glucose and galactose.
    - **Polysaccharides** are long chains of single sugars. Some important polysaccharides include starch (also called amylose), glycogen (a polysaccharide that vertebrate animals store in their livers), and cellulose (found in plant cell walls, the “fiber” that you see on food labels).
  - **Lipids** include the fats, waxes, oils, phospholipids, and steroid hormones. Lipids are made up of **fatty acids**, which are long chains of carbons with hydrogens attached, and glycerol.
    - If the carbons in a fatty acid chain are linked to as many hydrogens as is possible, the fatty acid is **saturated**. Saturated fats tend to be solid at room temperature. If there is a double bond between two of the carbon atoms, the fatty acid is **unsaturated** at that point. Unsaturated fats are liquid at room temperature.
    - Unsaturated fats can be artificially saturated, or “hydrogenated,” to produce solid fats such as shortening or margarine. Hydrogenation can produce a configuration of carbons and hydrogens called **trans** configuration. *Trans* fat consumption has been associated with health problems.
    - **Phospholipids** are fats that make up cell membranes.
    - **Steroids** are fats that include rings of carbons. Many hormones are steroids. Cholesterol is also a steroid.
  - **Nucleic acids** are polymers that are made up of individual units called **nucleotides**. Nucleotides are in turn made up of a base, a sugar (either ribose or deoxyribose), and a phosphate group. DNA and RNA are nucleic acids. We will learn more about the structure and function of nucleic acids when we get to genetics.
  - **Proteins** are polymers made up of **amino acids**. There are twenty different amino acids. Specific proteins are made up of hundreds or thousands of specific amino acids linked together in a particular order.
    - The order of amino acids in a protein is encoded in the genes in our DNA. The amino acid chain is folded into the final protein, which has a certain shape that helps it carry out its particular function (job). If the gene that codes for the protein is incorrect (a “mutation”), the order of amino acids will be wrong, and the protein may not have the correct shape. This is what causes genetic disorders.
    - Different proteins have specific functions, including structure, movement, defense, storage, communication, or assisting in chemical reactions.
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- Proteins have up to four levels of structure. **Primary structure** is the order of the amino acids. **Secondary structure** is a repeating structure caused by hydrogen bonds between amino acids. Secondary structure usually takes the form of a helix (spiral) or a pleated sheet. **Tertiary structure** is when the helix or pleated sheet folds back on itself to form twisted or knot-like structures. This is caused by hydrogen bonding, and special bonds called disulfide bridges that form between amino acids. **Quaternary structure** is where multiple proteins are linked together into one large structure. Hemoglobin, for example, is formed by four separate proteins.
- **Enzymes** are special proteins that assist in (**catalyze**) chemical reactions. Each enzyme has one specific job, and can carry out that job over and over again.

### Common misconceptions:

- Until students memorize which monomers each polymer is made up of, students have difficulty with questions asking what products would be produced if a given polymer is broken down by an enzyme. This causes problems for students during the enzyme lab.
- Because students associate fats and sugars with weight gain, many students believe that sugar contains fat or vice versa.
- Students hear confusing messages about diets and dieting, and may believe that all fats or all carbohydrates are unhealthy, or that eating lots of protein will make you lose weight or gain muscle.
- Most beginning biology students think of “protein” as a single substance, perhaps because it is listed that way on food labels. However, there are thousands of different proteins, each of which has a different function. Some proteins, such as keratin (in hair, horn, and feathers), are not digestible.
- Many students believe that the primary function of protein is to supply energy, and that carbohydrates are a less desirable form of energy. Students also believe that it’s harder to get energy out of fats.

### Chapter study guide:

Polymer class	Monomers	Functions
Complex carbohydrates		
Lipids		
Proteins		
Nucleic acids		

- In the table above, list the monomers that make up the four classes of polymers, and state the general functions of each polymer class. (Technically, a lipid is not a polymer because it is not a chain made up of a single kind of subunit. We will, however, consider it among the polymers because lipids are large molecules made up of smaller molecules.) Be sure to *look up this information*, rather than fill it in based on your prior understanding. (See the misconceptions list, above.)
- Define **organic molecule** and **inorganic molecule**. Explain why there is such a huge variety of carbon-based molecules.
- Define **functional group**, and list some of the properties (characteristics) that functional groups may give to molecules.
- Define **monomer** and **polymer**. Describe, in general terms, what happens in **dehydration synthesis** and **hydrolysis**. Note where a molecule of water is given off during dehydration synthesis, and where one is used during hydrolysis. You may find the animation “Dehydration Synthesis and Hydrolysis” (listed below) useful in understanding these two processes.
- List the things that each of these do in living things: simple sugars, cellulose, starch, glycogen.
- Explain why we can digest starch, but not cellulose.
- List the three major groups of lipids. Explain why a gram of lipids contains more calories than a gram of sugar. Explain why it is more advantageous for animals to store food energy as fat instead of carbohydrates.
- Define **triglyceride** and describe its structure. Describe the difference between saturated and unsaturated fatty acids, and the structure of a *trans* fat.

- Explain the difference between “good” cholesterol and “bad” cholesterol, and where cholesterol in the body comes from.
- Describe the structure of a **phospholipid** and a **steroid**.
- List the three units that make up a **nucleotide**. Name the two important **nucleic acids** that are the hereditary molecules.
- List other functions of nucleotides in the body.
- Explain why there is such a huge variety of **proteins**. List several proteins named in the text and their functions.
- Describe how proteins are formed from **amino acids**. Describe the four levels of structure in a protein and give examples of proteins that show secondary, tertiary, and quaternary structure.
- Genes (in DNA) code for the amino acid sequence of a protein. Explain, using examples, why the order of amino acids is important, and what could happen if the code in a gene for a protein is incorrect.
- Explain what a **denatured** protein is. Give some examples of ways that proteins are denatured.

### Useful websites:

- “Dehydration Synthesis and Hydrolysis” <http://science.nhmccd.edu/biol/dehydrat/dehydrat.html> is a simple animation to help you remember these two reversible processes.
  - “The Basics of Life, Lesson 2: Class and Characteristics of Macromolecules in Cells” [http://www.sci.uidaho.edu/bionet/biol115/t2\\_basics\\_of\\_life/lesson02/lesson2\\_mod1.htm](http://www.sci.uidaho.edu/bionet/biol115/t2_basics_of_life/lesson02/lesson2_mod1.htm) has very useful animations in which you can construct the four classes of polymers (macromolecules) from their monomers. Click on the links in the “Lesson 2 Modules” box at the right, and read the material. At the right of each page will be a box titled “Learning Materials.” This will have a link to the animation. Follow the instructions for building the molecules. You may have to rotate some of the monomers to make them fit. When the monomers link together correctly, a drop of water will be given off, representing dehydration synthesis.
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