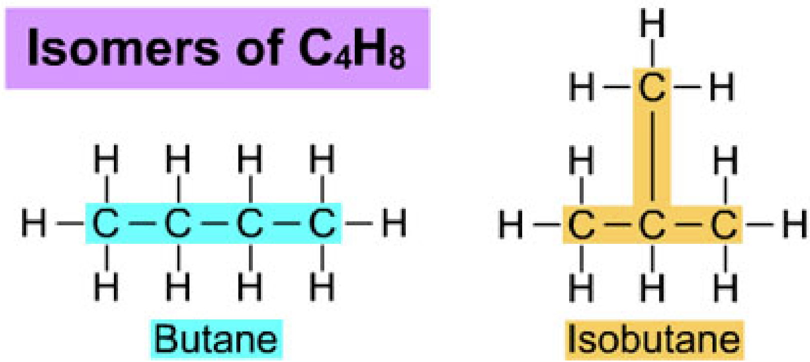
CHAPTER 3: ORGANIC COMPOUNDS, CARBOHYDRATES, & LIPIDS

Carbon's Properties

Carbon is an element that is essential to living things. Due to its valence shell electron configuration , carbon can form 4 bonds. Additionally, carbon has an intermediate electronegativity, and therefore is most likely to form covalent bonds with other atoms.

There are different names for the various subsets of molecules that contain carbon. Substances that contain carbon and are synthesized by cells are referred to as ***organic compounds***. Substances that contain only carbon and hydrogen are referred to as ***hydrocarbons***. Finally, long chains of carbon-carbon bonds in organic molecules are referred to as ***carbon skeletons***.

Although two molecules may contain the same number of carbon and hydrogen molecules, they may look very different. Molecules with the same chemical formula, but different chemical structures are called ***isomers***. For example, consider C_4H_8:



In the example above, two structures are possible depending on whether the carbon skeleton is unbranched (butane) or branched (isobutane). For molecules with double or triple bonds, a change in the location of the multiple bond can create an isomer.

Functional Groups

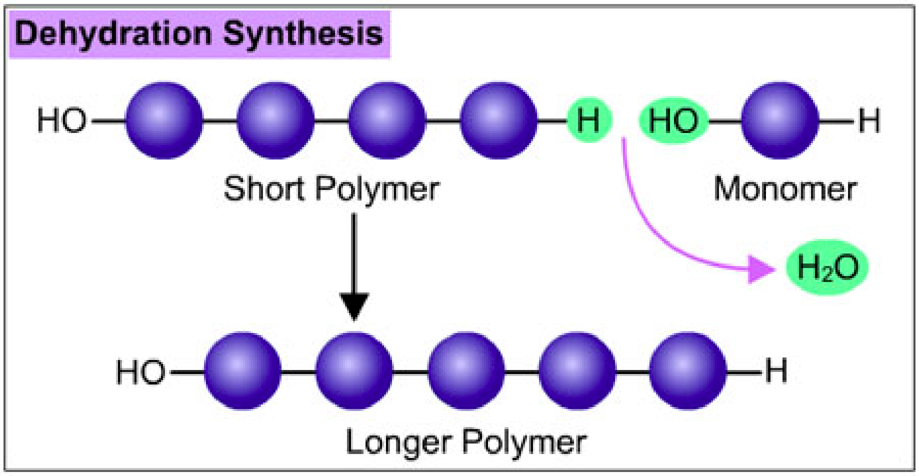
The properties of organic compounds depend heavily on groups of atoms attached to the carbon skeleton called ***functional groups***. All of these functional groups are polar, due to the high electronegativities of oxygen and nitrogen. Both the oxygen and nitrogen atoms exert a strong pull on the shared electrons in a bond, leading to polar groups. Molecules containing these polar functional groups are therefore called ***hydrophilic*** (water-loving) because they are soluble in water, which is also polar. The various functional groups are listed below with their chemical formulas.

Functional Group	General Formula	Name of Compounds
Hydroxyl	—O—H	Alcohols
Carbonyl	—C(=O)—H	Aldehydes
	—C(=O)—	Ketones
Carboxyl	—C(=O)—OH	Carboxylic Acids
Amino	—N(H)—H	Amines

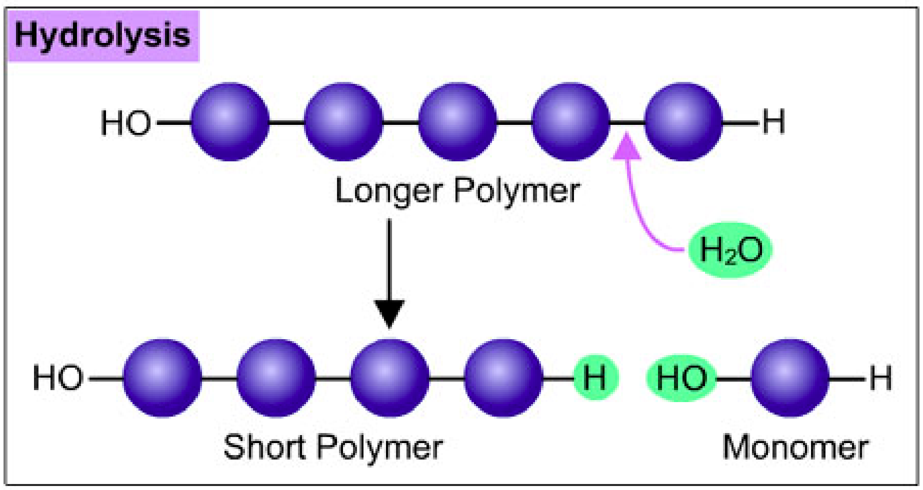
Macromolecules, Monomers, and Polymers

Macromolecules are very large molecules that may consist of thousands of covalently connected atoms. There are four important classes of macromolecules: proteins, nucleic acids (including DNA), carbohydrates, and lipids (including fats). Most macromolecules are made by joining many identical or smaller molecular units, called ***monomers***, together to form chains called ***polymers***. A vast number of unique polymers can be made from a relatively small number of different monomers.

Monomers are joined together by cells to form polymers during a process called ***dehydration synthesis***. During dehydration synthesis, a hydroxyl (OH) group is removed from one monomer and a hydrogen is removed from the other to join them together to form a polymer. During this process, water is produced (see below).



Cells also have the ability to break down polymers using a process called ***hydrolysis***. During hydrolysis, a water molecule is added to the polymer to break it apart (See below).



Carbohydrates & Monosaccharides

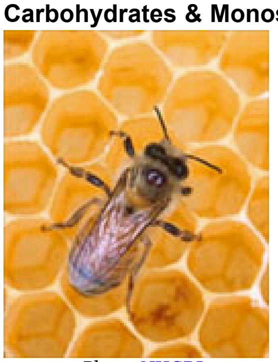


Photo: NHGRI

Carbohydrates are molecules composed of sugar monomers. They can range from single unit sugars, called ***monosaccharides***, to longer polymers of sugar units, called ***polysaccharides***. Monosaccharides, such as glucose and fructose (found in honey), generally have chemical formulas that are some multiple of CH2O. For example, both glucose and fructose have the chemical formula C6H12O6, and differ only in their arrangement of atoms. Monosaccharides provide the main fuel source for cellular work. Those that are not used right away are often incorporated into disaccharides and polysaccharides.

Disaccharides & Polysaccharides

A ***disaccharide*** is a molecule consisting of two monosaccharides. It is formed by dehydration synthesis. A polysaccharide is a polymer consisting of a few hundred to a few thousand monosaccharides. Like disaccharides, polysaccharides are formed by dehydration synthesis. ***Starch*** is a common polysaccharide that plants use to store sugar energy. When the stored energy is needed, starch is broken down into glucose via the process of hydrolysis.

In animals, excess sugar is stored in the form of the polysaccharide ***glycogen***. Glycogen is very similar to starch, although it contains many more branches. Glycogen stores are hydrolyzed when energy is needed.

Other polysaccharides such as ***cellulose*** can provide structural support for organisms. Cellulose fibrils help make wood strong enough to support trees that are hundreds of feet high. Most animals cannot hydrolyze cellulose, and therefore it passes through our digestive tract unchanged. Cellulose is commonly known as fiber.

Lipids: Fats

Lipids are molecules composed mainly of carbon and hydrogen atoms. Bonds between carbon and hydrogen atoms are nonpolar. Therefore, lipids are ***hydrophobic*** (water-fearing) and do not mix with water. A ***fat*** is a type of large lipid molecules that consists of a combination of glycerol and fatty acids. Dehydration synthesis links three fatty acids to a glycerol molecule to form a ***triglyceride***, or fat molecule.

Photo: Microsoft Office Online

There are two main types of fats: saturated and unsaturated. When double bonds are present in a fatty acid, it is prevented from bonding with
the maximum number of hydrogen atoms. Such a fat is called an ***unsaturated*** fat since it has less than the maximum number of hydrogen atoms. Unsaturated fats are "good" fats. The double bonds present in unsaturated fast cause kinks in the fatty acid chains, which prevent the fat molecules from packing closely together and solidifying at room temperature. Most fats derived from plants, such as corn oil and olive oil, are unsaturated. Most of the fat found in foods such as nuts and avocados is also unsaturated.

Saturated fats are fats with the maximum number of hydrogens. Saturated fats are primarily animal fats, and are considered "bad" fats. Saturated fats may contribute to cardiovascular disease by promoting the accumulation of plaque along the inside walls of blood vessels, reducing blood flow.

Phospholipids, Waxes, & Steroids

In addition to fats, there are three other important types of lipids: phospholipids, waxes, and steroids. Although ***phospholipids*** are very similar to fats, they only have two fatty acids and contain the element phosphorous. Phospholipids are a major component of cell membranes.

Waxes are molecules that consist of one fatty acid connected to an alcohol. Waxes are even more hydrophobic than fats, and often form a coat over fruits and even insects to help keep them from drying out.

Steroids are lipids with four fused carbon rings. Cholesterol is an example of a steroid, and is used by the body as the starting material for making female and male sex hormones such as testosterone. We often hear about athletes and steroids. The steroids that we hear about associated with athletics are called anabolic steroids. Anabolic steroids are synthetic variants of testosterone. By taking these steroids, an athlete can quickly build muscle mass with little work. However, the health hazards of these steroids are numerous. Possible side effects include:

- Reduced sperm count
- Development of breasts in men
- Shrinking of the testicles
- Facial hair growth in women
- Deepened voice in women
- Acne
- Rapid weight gain
- Liver Damage

For these reasons, and many others, anabolic steroids are banned from athletics. For more information on anabolic steroids, visit the web links for this chapter.