MINISTRY OF EDUCATION

SECONDARY ENGAGEMENT PROGRAMME

GRADE 11

CHEMISTRY

WEEK 12 **LESSON 2**

Topic: **Macromolecules**

Sub-topic: Natural Polymers – Additional Reading

Objectives: Given the handout, students will accurately answer questions based on the topic.

Content

Monosaccharides

What's on your mind?

The brain is a marvelous organ. And it's a hungry one, too. The major fuel for the brain is the carbohydrate glucose. The average adult brain represents about 2% of our body's weight, but uses 25% of the glucose in the body. Moreover, specific areas of the brain use glucose at different rates. If you are concentrating hard, (taking a test, for example) certain parts of the brain need a lot of extra glucose while other parts of the brain only use their normal amount. Something to think about.

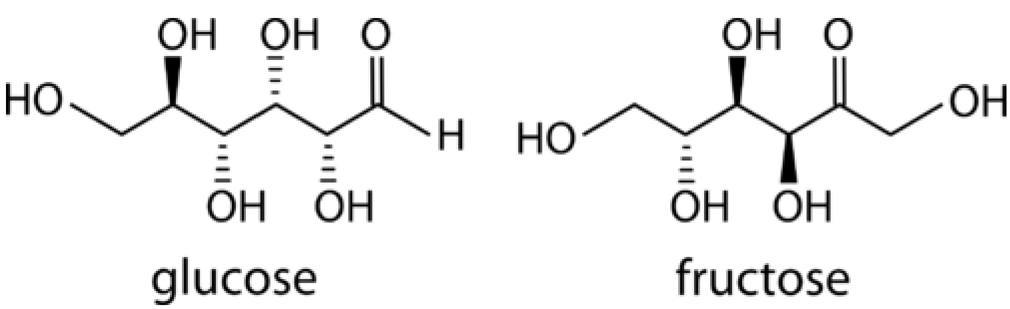
Monosaccharides

Some foods that are high in carbohydrates include bread, pasta, and potatoes. Because carbohydrates are easily digested, athletes often rely on carbohydrate rich foods to enable a high level of performance.

Foods that serve as carbohydrate sources.

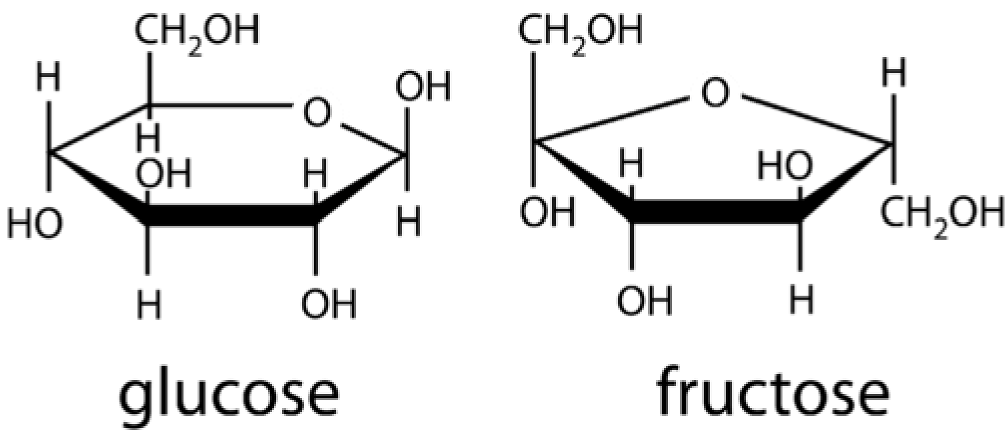
The term carbohydrate comes from the fact that the majority contain carbon, hydrogen, and oxygen in a ratio of 1:2:1, making for an empirical formula of CH_2O. This is somewhat misleading because the molecules are not actually hydrates of carbon at all. **Carbohydrates** are monomers and polymers of aldehydes and ketones that have multiple hydroxyl groups attached.

Carbohydrates are the most abundant source of energy found in most foods. The simplest carbohydrates, also called simple sugars, are plentiful in fruits. A **monosaccharide** is a carbohydrate consisting of one sugar unit. Common examples of simple sugars or monosaccharides are glucose and fructose. Both of these monosaccharides are referred to as hexoses since they have six carbons. Glucose is abundant in many plant sources and makes up sweetners such as corn sugar or grape sugar. Fructose occurs in a great many fruits and is also found in honey. These sugars are structural isomers of one another, with the difference being that glucose contains an aldehyde functional group whereas fructose contains a ketone functional group.



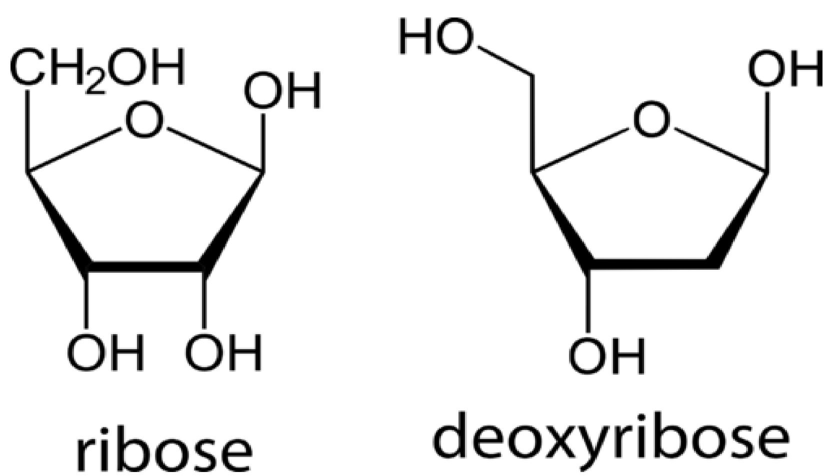
Glucose and fructose are monosaccharides, or simple sugars

Glucose and fructose are both very soluble in water. In aqueous solution, the predominant forms are not the straight-chain structure shown above. Rather, they adopt a cyclic structure (see **Figure** below). Glucose is a six-membered ring, while fructose is a five-membered ring. Both rings contain an oxygen atom.



The cyclic form of sugars is the favored form in aqueous solution

Another important group of monosaccharides are the pentoses, containing five carbons in the chain. Ribose and deoxyribose are two pentoses that are components of the structures of DNA and RNA.

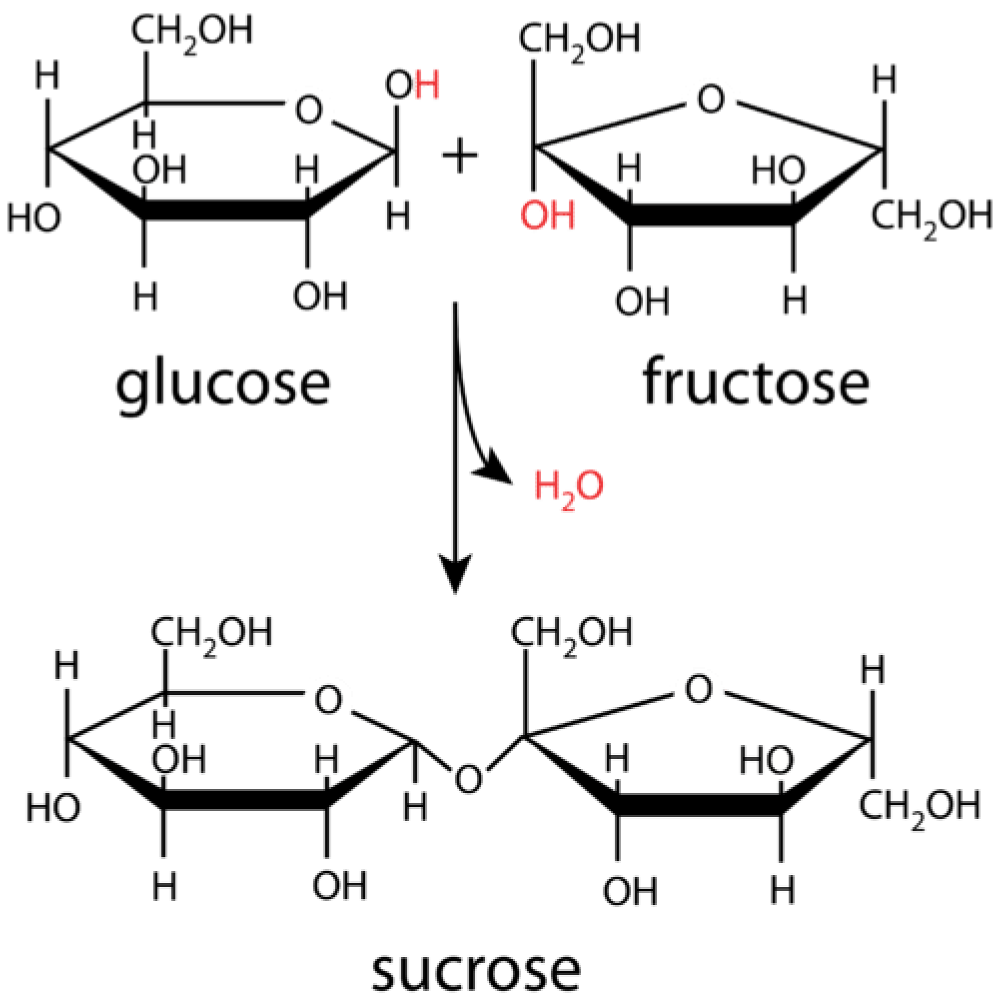


Disaccharides

Milk is one of the basic foods needed for good nutrition, especially for growing children. It contains vitamins and minerals necessary for healthy development. Unfortunately, milk and other dairy products also contain lactose, a carbohydrate that can make some people very ill. Lactose intolerance is a condition in which the lactose in milk cannot be digested well in the small intestine. The undigested lactose then moves into the large intestine where bacteria attack it, forming large amounts of gas. Symptoms of lactose intolerance include bloating, cramps, nausea, and vomiting. Often, the individual will outgrow this problem. Avoidance of foods containing lactose is recommended for people who show signs of lactose intolerance. Since dairy products can provide many vital nutrients, tablets can be taken that provide the needed digestive materials in the small intestine. Lactose-free milk is also readily available.

Disaccharides

The simple sugars form the foundation of more complex carbohydrates. The cyclic forms of two sugars can be linked together by means of a condensation reaction. The figure below shows how a glucose molecule and a fructose molecule combine to form a sucrose molecule. A hydrogen atom from one molecule and a hydroxyl group from the other molecule are eliminated as water, with a resulting covalent bond linking the two sugars together at that point.

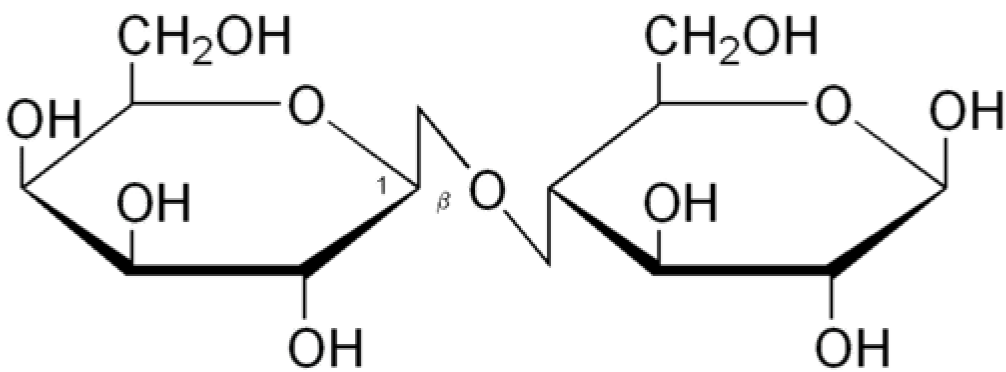


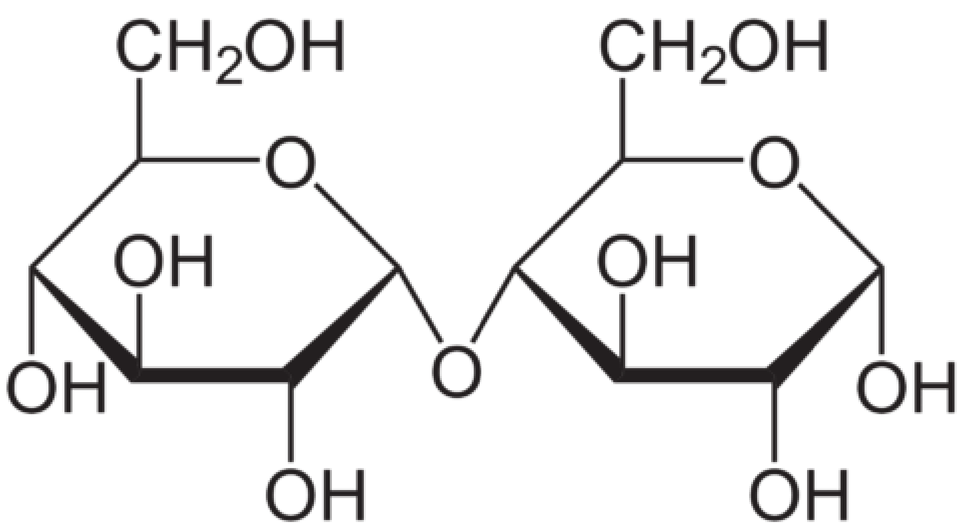
Glucose and fructose combine to produce disaccharide sucrose in condensation

Sucrose, commonly known as table sugar, is an example of a disaccharide. A **disaccharide** is a carbohydrate formed by the joining of two monosaccharides. Other common disaccharides include lactose and maltose. Lactose, a component of milk, is formed from glucose and galactose, while maltose formed from two glucose molecules.

During digestion, these disaccharides are hydrolyzed in the small intestine to form the component monosaccharides, which are then absorbed across the intestinal wall and into the bloodstream to be transported to the cells.

Lactose



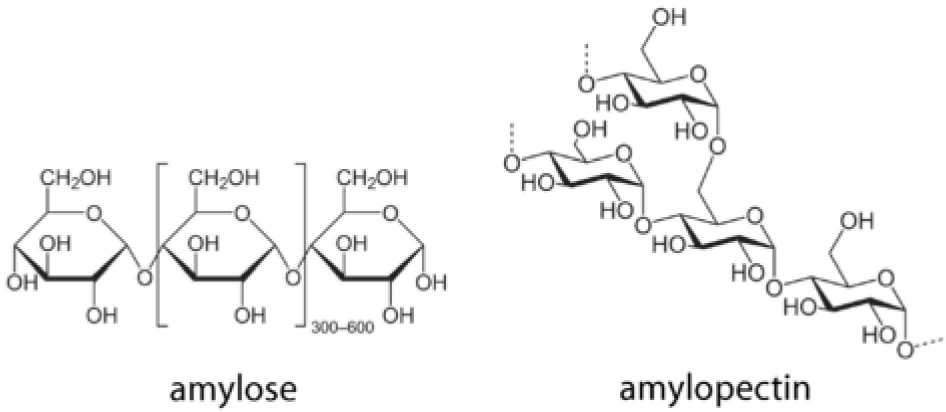


Maltose

Polysaccharides

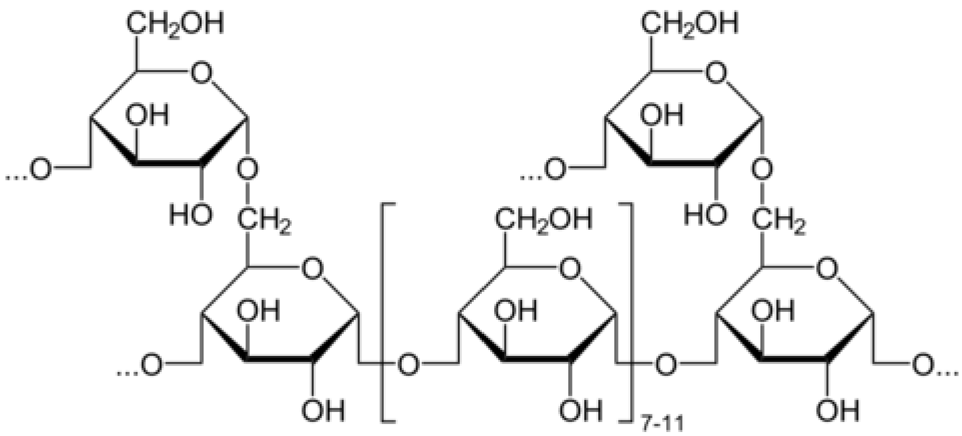
Polysaccharides

Many simple sugars can combine by repeated condensation reactions until a very large molecule is formed. A **polysaccharide** is a complex carbohydrate polymer formed from the linkage of many monosaccharide monomers. One of the best known polysaccharides is starch, the main form of energy storage in plants. Starch is a staple in most human diets. Foods such as corn, potatoes, rice, and wheat have high starch contents. Starch is made of glucose monomers and occurs in both straight-chain and branched forms. Amylose is the straight-chain form and consists of hundreds of linked glucose molecules. The branched form of starch is called amylopectin. In the small intestine, starch is hydrolyzed to form glucose. The glucose can then be converted to biochemical energy or stored for later use.



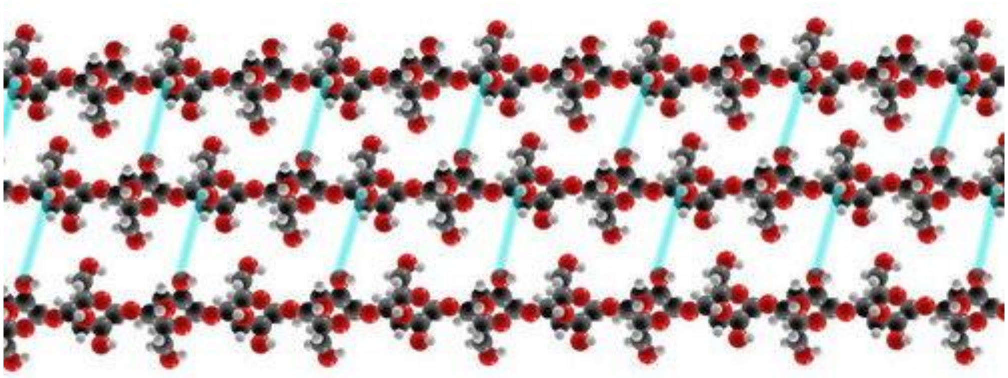
Amylose and amylopectin are the two most common components of naturally occurring starch. Both consist of many glucose monomers connected into a polymer. Starch serves as energy storage in plants

Glycogen is an even more highly branched polysaccharide of glucose monomers that serves a function of energy storage in animals. Glycogen is made and stored primarily in the cells of the liver and muscles.



Glycogen is a branched polymer of glucose and serves as energy storage in animals

Cellulose is another polymer of glucose, consisting of anywhere from hundreds to over ten thousand monomers. It is the structural component of the cell walls of green plants and is the single most common organic molecule on Earth. Roughly 33% of all plant matter is cellulose. The linkage structure in cellulose is different than that of starch, and cellulose is indigestible except by a few microorganisms that live in the digestive tracts of cattle and termites. The figure below shows a triple strand of cellulose. There is no branching and the fibers adopt a very stiff rod-like structure with numerous hydrogen bonds between the fibers adding to its strength. Cellulose is the main component of paper, cardboard, and textiles made from cotton, linen, and other plant fibers.



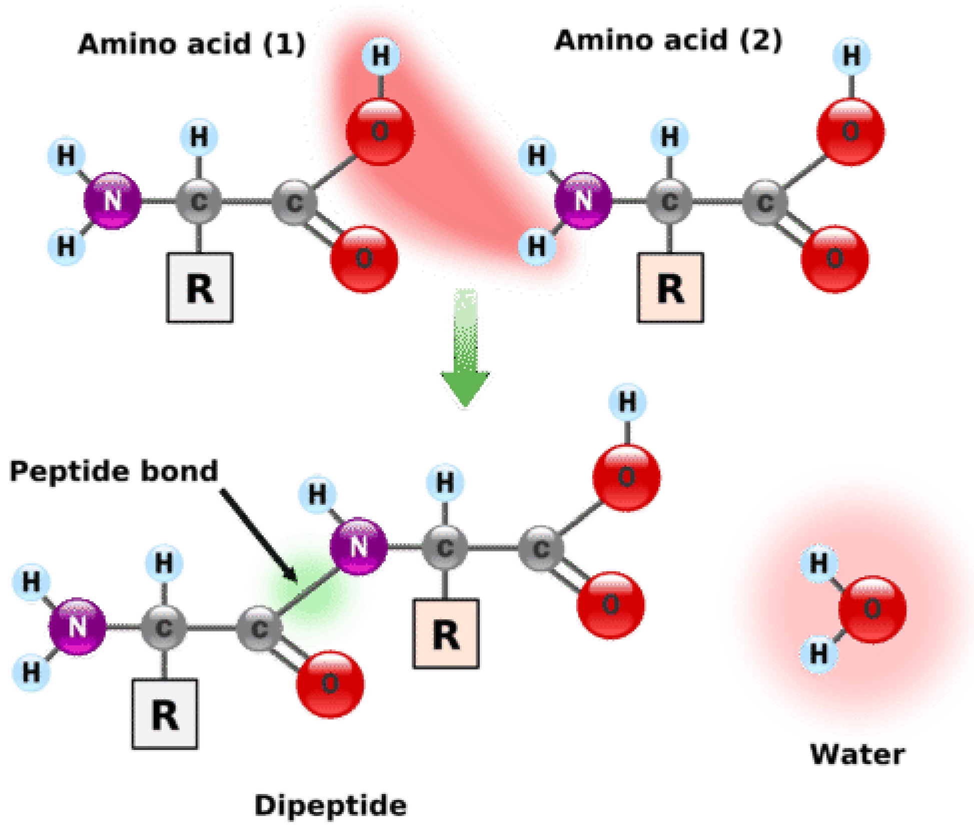
Cellulose is composed of very long strands of glucose monomers that are hydrogen bonded to one another. Cellulose is largely indigestible and comprises the cell walls of plants

Peptides

Cells in our bodies have an intricate mechanism for the manufacture of proteins. Humans have to use other techniques in order to synthesize the same proteins in a lab. The chemistry of peptide synthesis is complicated. Both active groups on an amino acid can react and the amino acid sequence must be a specific one in order for the protein to function. Robert Merrifield developed the first synthetic approach for making proteins in the lab, a manual approach which was lengthy and tedious (and, he won the Nobel Prize in Chemistry in 1984 for his work). Today however, automated systems can crank out a peptide in a very short period of time.

Peptides

A **peptide** is a combination of amino acids in which the amino group of one amino acid has undergone a reaction with the carboxyl group of another amino acid. The reaction is a condensation reaction, forming an amide group (CO–N), shown below.



Amino acids join together to form a molecule called a dipeptide. The C–N bond is called a peptide bond. The order of amino acids is by convention shown with the free amino group on the left and the free carboxyl group on the right

A **peptide bond** is the amide bond that occurs between the amino nitrogen of one amino acid and the carboxyl carbon of another amino acid. The resulting molecule is called a dipeptide. Notice that the particular side chains of each amino acid are irrelevant since the R groups are not involved in the peptide bond.

The dipeptide has a free amino group on one end of the molecule and a free carboxyl group on the other end. Each is capable of extending the chain through the formation of another peptide bond. The particular sequence of amino acids in a longer chain is called an amino acid sequence. By convention, the amino acid sequence is listed in the order such that the free amino group is on the left end of the molecule and the free carboxyl group is on the right end of the molecule. For example, suppose that a sequence of the amino acids glycine, tryptophan, and alanine is formed with the free amino group as part of the glycine and the free carboxyl group as part of the alanine. The amino acid sequence can be easily written using the abbreviations as Gly-Trp-Ala. This is a different sequence from Ala-Trp-Gly because the free amino and carboxyl groups would be on different amino acids in that case.

LIPIDS

You've probably seen dozens of nutrition facts labels like the one in the opening image. The labels show the nutrients that foods contain. Many people read nutrition facts labels to see how much fat there is in particular foods. That's because eating too much fat, especially saturated fat, can be unhealthy and contribute to weight gain. Fats are a type of biochemical compound called lipids.

What Are Lipids?

Lipids are one of four classes of biochemical compounds, which are compounds that make up living things and carry out life processes. (The other three classes of biochemical compounds are carbohydrates, proteins, and nucleic acids.) Living things use lipids to store energy. Lipids are also the major components of cell membranes in living things. Types of lipids include fats and oils.

- Fats are solid lipids that animals use to store energy.
- Oils are liquid lipids that plants use to store energy.

Q: Can you name some lipids that are fats? What are some lipids that are oils?

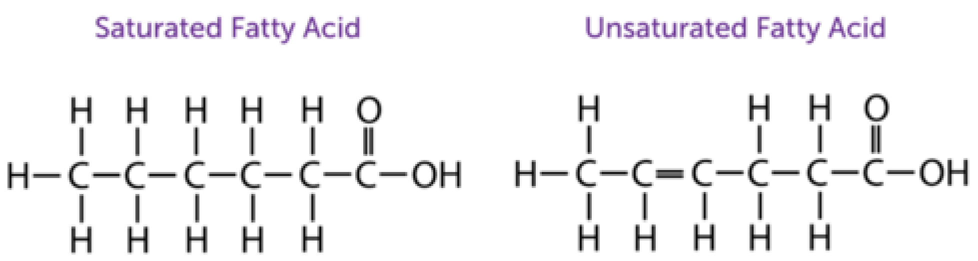
A: Lipids that are fats include butter and the fats in meats. Lipids that are oils include olive oil and vegetable oil. Examples of both types of lipids are pictured in the **Figure** below.

(A) The white bands on these lamb chops are fat. (B) The yellow liquid in this bottle is olive oil

Fatty Acids

Lipids consist only or mainly of carbon, hydrogen, and oxygen. Both fats and oils are made up of long chains of carbon atoms that are bonded together. These chains are called fatty acids. Fatty acids may be saturated or unsaturated. In the **Figure** below you can see structural formulas for two small fatty acids, one saturated and one unsaturated.

- Saturated fatty acids have only single bonds between carbon atoms. As a result, the carbon atoms are bonded to as many hydrogen atoms as possible. In other words, the carbon atoms are saturated with hydrogens. Saturated fatty acids are found in fats.
- Unsaturated fatty acids have at least one double bond between carbon atoms. As a result, some carbon atoms are not bonded to as many hydrogen atoms as possible. They are unsaturated with hydrogens. Unsaturated fatty acids are found in oils.



Q: Both of these fatty acid molecules have six carbon atoms and two oxygen atoms. How many hydrogen atoms does each fatty acid molecule contain? What else is different about the two molecules?

A: The saturated fatty acid molecule has 12 hydrogen atoms. This is as many hydrogen atoms as can possibly be bonded to carbon atoms in this molecule. The unsaturated fatty acid molecule has

10 hydrogen atoms, or two less than the maximum possible number. The saturated fatty acid has only single bonds between its carbon atoms. The unsaturated fatty acid has a double bond between two of its carbon atoms.