Reading 3.2 – Why do different food molecules provide different amounts of energy?

Getting Started
The following four items have carbohydrate, protein, and fat molecules. Honey has simple sugars. Rice has starch— a complex sugar. Eggs contain protein, and butter contains fats.

			
Honey	Rice	Eggs	Butter

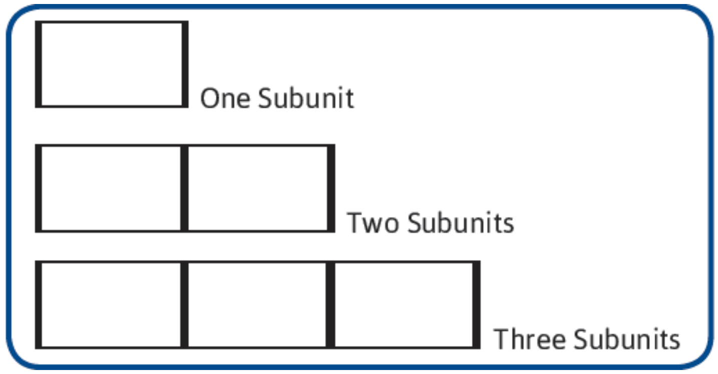
The carbohydrate, protein, and fat molecules in food are similar because they provide the body with both energy and building materials. But these molecules are different from each other as well. You learned that fats can provide the body with more energy per gram than carbohydrates or proteins. In this reading, you will learn about how the structure of fats is different from that of carbohydrates or proteins and why they provide the body with more energy. As you read, compare what you learn about carbohydrate, protein, and fat molecules.

What Makes the Properties of Substances Similar or Different?
You might have learned previously that color, taste, and melting point are properties of a substance. A property is a characteristic or something that describes the substance. The amount of energy per gram that a substance can provide the body is also a property. Fats can provide nine Calories per gram, while carbohydrates and proteins can provide four Calories per gram. This information describes these food molecules.

The properties of a substance are determined by the type, number, and arrangement of atoms in the molecules of that substance. This means that the reason why fats, proteins, and carbohydrates have different properties is because they are made of different types of atoms, they are made of different numbers of atoms, or their atoms are connected differently. To investigate why fats provide the body with more chemical energy than do proteins and carbohydrates, you must study the type, number, and arrangement of atoms in these molecules.

How Do Subunits Build Up to Make Large Molecules?
Food molecules can be simple or complex. In class, you built models of carbohydrate and protein molecules with different numbers of subunits. A subunit is a simple molecule that can be linked together with other similar subunits to make a more complex molecule. The following table shows how subunits can be linked together. Each rectangle represents one subunit.

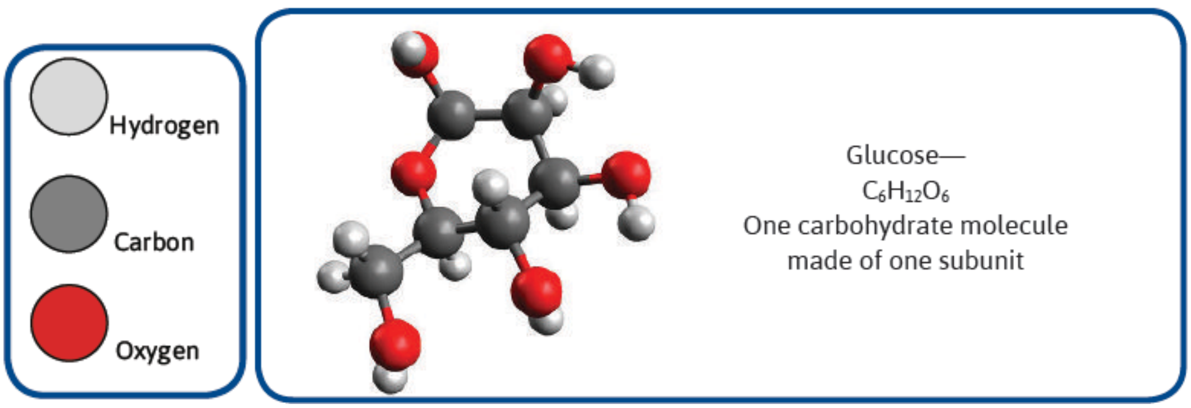
Carbohydrate or protein subunits can link together. This changes the arrangement of atoms and the properties of the substance. For example, carbohydrates with only one subunit taste sweet (like honey), but carbohydrates with long chains of subunits do not (like white potatoes).



Fat molecules do not link together like carbohydrates and proteins do. Instead, the fat molecules are attracted to one another to form a fat droplet. This makes the properties of fats different from proteins and carbohydrates.

What Is the Structure of Carbohydrates?

In your model of carbohydrates in class, the subunit was called glucose. Glucose is found in many sweet foods. The following model shows glucose. Notice that the glucose molecule forms a ring shape.



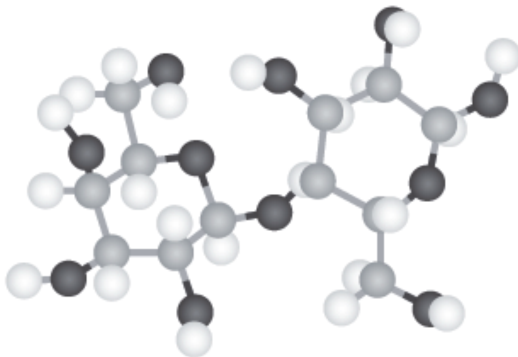
Use the previous model to answer the following questions. (At the end of this reading, you will use this information to compare carbohydrates, proteins, and fats.)

1. What three types of atoms are in a glucose molecule?

2. Compare the number of each type of atom in the glucose molecule.

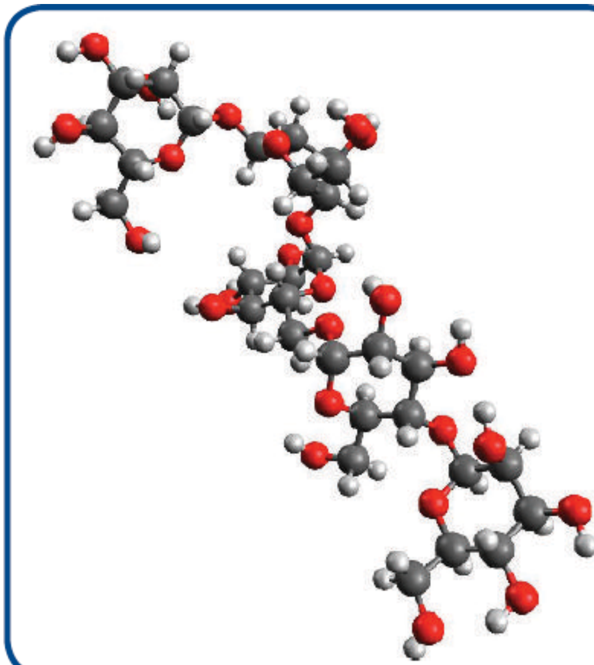
Carbohydrates can also be made of two subunits. A common carbohydrate with two subunits is lactose, the sugar found in milk. You might know someone who is lactose intolerant. This means that he or she cannot digest lactose. The following model shows lactose.

Draw a line between the two subunits in the following molecule.



Lactose—
$C_{12}H_{22}O_{11}$
One carbohydrate molecule
made of two subunits

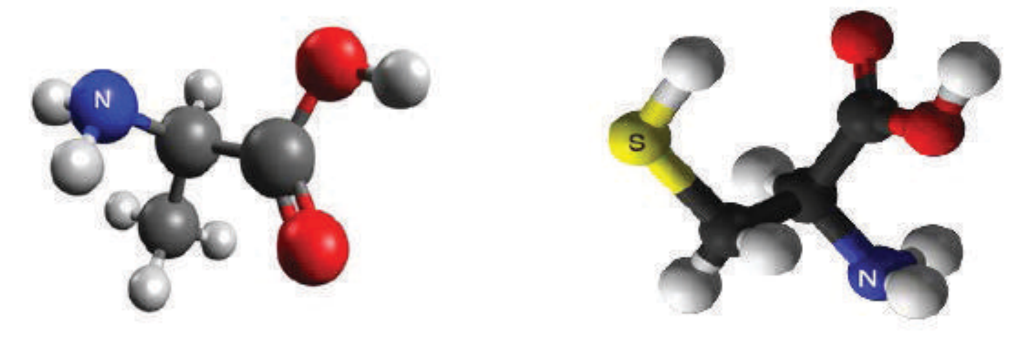
The properties of carbohydrates made of one or two subunits are similar because their structures are both fairly simple. Both types of molecules form crystals, dissolve in water, and have a sweet taste. Honey, fruits, and some vegetables taste sweet because they are made of carbohydrates with one subunit. Milk and table sugar taste sweet because they are made of carbohydrates with two subunits. However, the properties of carbohydrates made of thousands of subunits are very different. These molecules are much more complex than carbohydrates made of one or two subunits. Because the structures of the molecules are different, the substances they make up have different properties. For example, starch cannot be dissolved in water without heating. And if you have tasted rice or white potatoes (which have a lot of starch), you probably know that starch is not sweet.



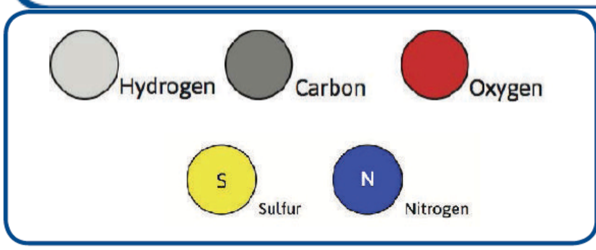
The previous molecule is a starch molecule. This part of starch has five subunits. Some of the rings you can see, but some you cannot because of the way the model is angled. If you were able to rotate the model to look at it from a different direction, you would be able to see other rings in the molecule. An entire starch molecule can be made of thousands of subunits. From this model, you can see that when carbohydrate subunits are joined together, they form a long chain.

What Is the Structure of Proteins?

Like carbohydrates, proteins are also made of many subunits joined together. Protein subunits are called amino acids. There are 20 different amino acids. The following model shows two.



Amino Acid (Alanine)—$C_3H_7NO_2$ Amino Acid (Cysteine)—$C_3H_7NO_2S$



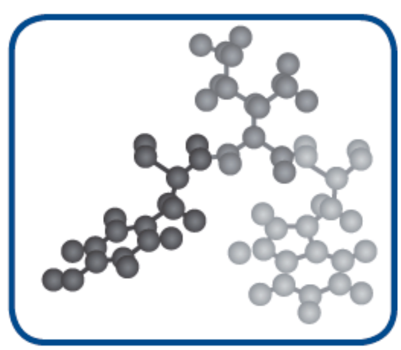
Use the previous model to answer the following questions.

1. What four types of atoms are in all amino acids? What type of atom is in some amino acids and not others?

2. What is different about the types of atoms in carbohydrates and proteins?

3. Compare the number of carbon, hydrogen, and oxygen atoms in an amino acid.

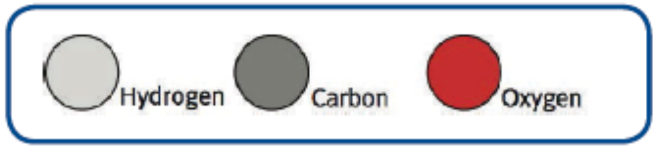
The diagram to the right shows only a part of a protein. It shows three protein subunits joined together, but proteins are formed when hundreds of amino acids are joined together. Proteins are found in many things we eat, like meat, cheese, eggs, and nuts. In the body, proteins are very important, and they do many jobs. For example, some proteins make your muscles contract, while other proteins are a part of your immune system.

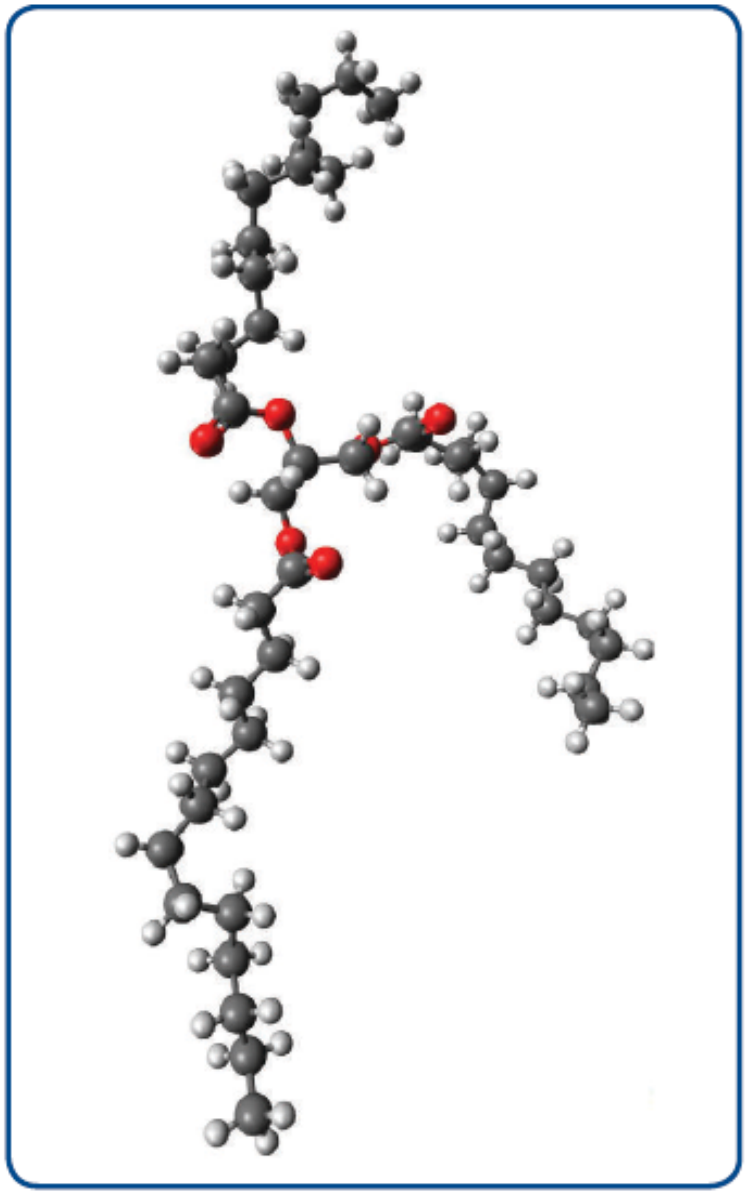


This molecule is made of three amino acid subunits.

What Is the Structure of Fats?

Fats are made up of molecules called triglycerides. Foods like whole milk, butter, and oil contain triglycerides. The following model shows a triglyceride.





Triglyceride—One Fat Molecule—$C_{56}H_{110}O_6$

Use the previous models to answer the following questions.

1. Compare the types of atoms in triglycerides to the types of atoms in carbohydrates and proteins.

2. Compare the number of carbon, hydrogen, and oxygen atoms in a triglyceride.

3. Compare the ratio of carbon, hydrogen, and oxygen atoms in a triglyceride to the ratio in a carbohydrate or protein.

Summary: Carbohydrates, Proteins, Fats, and Energy
In class and in this reading, you noticed many similarities and differences between carbohydrates, proteins, and fats. All of these ideas are summarized below, follow your teacher directions to update your Venn diagram.

Carbohydrates, proteins, and fats are similar because they all provide the body with energy and building materials. They also all contain carbon, hydrogen, and oxygen atoms.

Carbohydrates, proteins, and fats also have differences. If you think back to the beginning of this reading, you may remember that you are trying to explain why fats provide the body with nine Calories per gram, but carbohydrates and proteins provide the body with four Calories per gram. You also know that properties, like amount of energy, are determined by the type, number, and arrangement of atoms in a substance. Since carbohydrates and proteins can provide the same amount of energy to the body, they must have something in common in their structures. Fats must have a structure that is different because they provide the body with more energy.

In addition, you can see that carbohydrates and proteins have about the same number of carbon and oxygen atoms and twice as many hydrogen atoms. For example, glucose, a carbohydrate, has 6 carbon atoms, 6 oxygen atoms, and 12 hydrogen atoms to make $C_6H_{12}O_6$. Fats have very few oxygen atoms compared to carbon atoms. The chemical formula for the triglyceride shown in this reading is $C_{56}H_{110}O_6$. This difference in the numbers of oxygen atoms is the reason fats provide the body with more energy than carbohydrates and proteins. Later in this unit, you will learn why having fewer oxygen atoms allows fats to provide your body with more energy. For now, knowing that fats provide more energy to the body than carbohydrates and proteins because of the number, type, and arrangement of atoms is a good start.

Think about how this idea, that carbohydrates, proteins, and fats provide different amounts of energy, relates to the Driving Question: How Do Food Molecules Provide My Body with Energy? Imagine you wanted to work out to convert the energy in food you ate.

Do you think you would have to work out longer to use the energy that can be released from three grams of carbohydrate, fat, or protein? Why?

You will explore this question in the next activity.