Sugars, Starches, and Fibers Are All Carbohydrates

What are carbohydrates? Today's food advertisements call them “carbs,” but they are not all the same. They are a group of compounds that have some similarities and some differences. Chemically, they are compounds that contain carbon (carbo), as well as hydrogen and oxygen in the same proportion as in water (hydrate). They include sugars, which are also known as **simple carbohydrates**

simple carbohydrates
Carbohydrates known as sugars that include monosaccharides and disaccharides

, and starches and fibers, which together make up the **complex carbohydrates**

complex carbohydrates
Carbohydrates composed of sugar molecules linked together in straight or branching chains. They include starches and fibers.

Sugars are the simplest type of carbohydrate

The basic unit of carbohydrate is a single sugar molecule, a **monosaccharide**

monosaccharide
A single sugar molecule, such as glucose

(*mono* means one). When two sugar molecules combine, they form a **disaccharide**

disaccharide
A sugar formed by linking two monosaccharides

(*di* means two). Monosaccharides and disaccharides are known as simple sugars or simple carbohydrates. The three most common monosaccharides in the diet are **glucose**

glucose
A monosaccharide that is the primary form of carbohydrate used to produce energy in the body. It is the sugar referred to as blood sugar.

fructose
A monosaccharide found in fruit and honey; commonly called fruit sugar

fructose, and galactose. Each contains 6 carbon, 12 hydrogen, and 6 oxygen atoms but differs in their arrangement (Figure 4.4). Glucose is the most important carbohydrate fuel for the body; it is distributed to body cells in the blood and is the sugar we call blood sugar. Glucose is produced in plants by the process of **photosynthesis**

photosynthesis
The metabolic process by which plants trap energy from the sun and use it to make sugars from carbon dioxide and water, which uses energy from the sun to combine carbon dioxide and water (Figure 4.5). Glucose rarely occurs as a monosaccharide in food. It is most often found as part of a disaccharide or starch. Fructose is a monosaccharide that tastes sweeter than glucose. It is found in fruits and vegetables and makes up more than half the sugar in honey. Galactose rarely occurs alone in the food supply; it is most often consumed as a part of **lactose**

lactose
A disaccharide made of glucose linked to galactose that is found in milk, the disaccharide in milk.

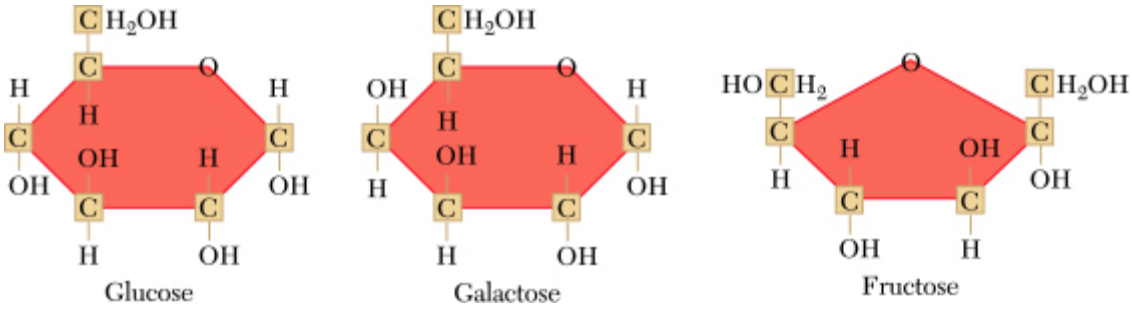

FIGURE 4.4

Common monosaccharides.

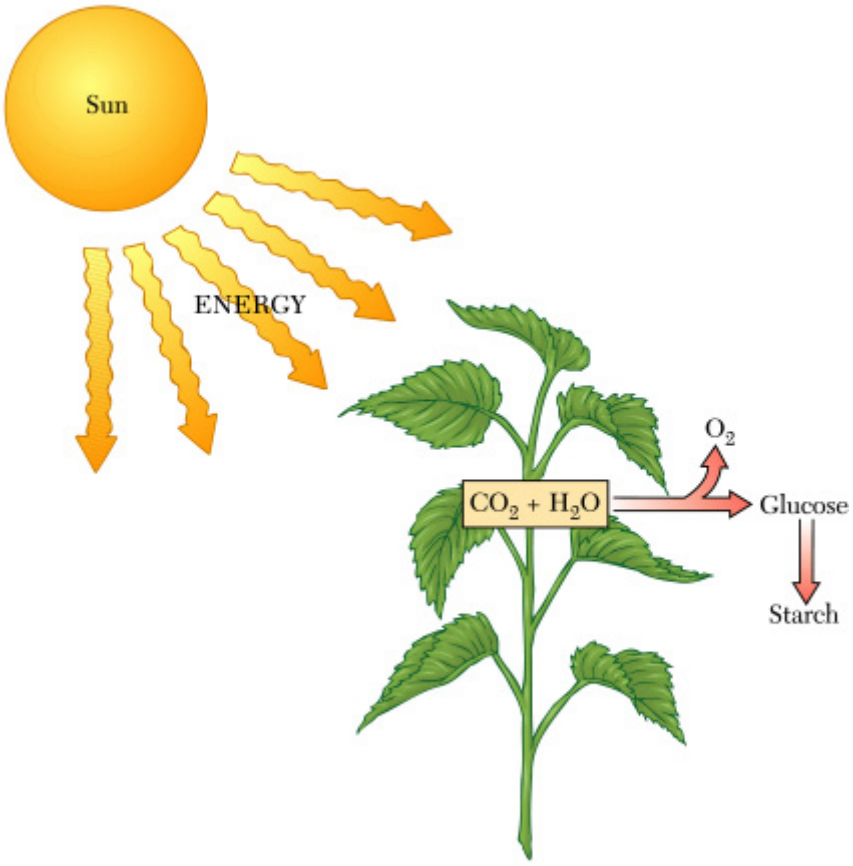

FIGURE 4.5

Photosynthesis uses energy from the sun to synthesize glucose from carbon dioxide and water. Glucose can then be stored as starch.

The most common dissacharides in our diet include maltose, sucrose, and lactose (Figure 4.6). Maltose, which is two glucose molecules linked together, is formed whenever starch is broken down. Maltose gives you that slightly sweet taste you experience when you chew bread and then hold it in your mouth for a few minutes. As the enzyme salivary amylase digests the starch, some sweeter-tasting maltose is formed. **Sucrose**

Sucrose
A disaccharide commonly known as table sugar that is made of glucose linked to fructose

, or common white table or granulated sugar, is the disaccharide made by linking glucose to fructose. It is found in sugar cane, sugar beets, honey, and maple syrup. Sucrose is the only sweetener that can be called “sugar” in the ingredient list on food labels in the United States. Lactose, or milk sugar, is glucose linked to galactose. Lactose is the only sugar found naturally in animal foods. About 30% of the energy in whole cow's milk and about 40% of the energy in human milk comes from lactose.

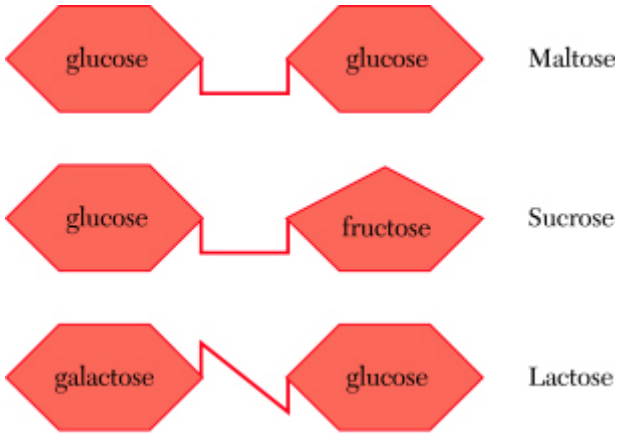

FIGURE 4.6

Common disaccharides.

Complex carbohydrates are many sugars linked together

Complex carbohydrates are made up of many single sugar units linked together in chains. They are generally not sweet to the taste like simple carbohydrates. The length of the chain and how the sugars are linked together affect how the carbohydrates function in our bodies and in our food. Short chains of three to ten monosaccharides are called **oligosaccharides**

oligosaccharides
Short-chain carbohydrates containing 3 to 10 sugar units

. Oligosaccharides are about half as sweet as sucrose. They are found naturally in foods such as onions and legumes. Many cannot be digested by human digestive enzymes but rather are digested by bacteria in the large intestine, causing gas. Longer chains of sugars are called **polysaccharides**

polysaccharides
Carbohydrates containing many sugar units linked together

(*poly* means many). The polysaccharides include **glycogen**

glycogen
A carbohydrate made of many glucose molecules linked together in a highly branched structure. It is the storage form of carbohydrate in animals

in animals, and starches and fibers in plants (Figure 4.7).

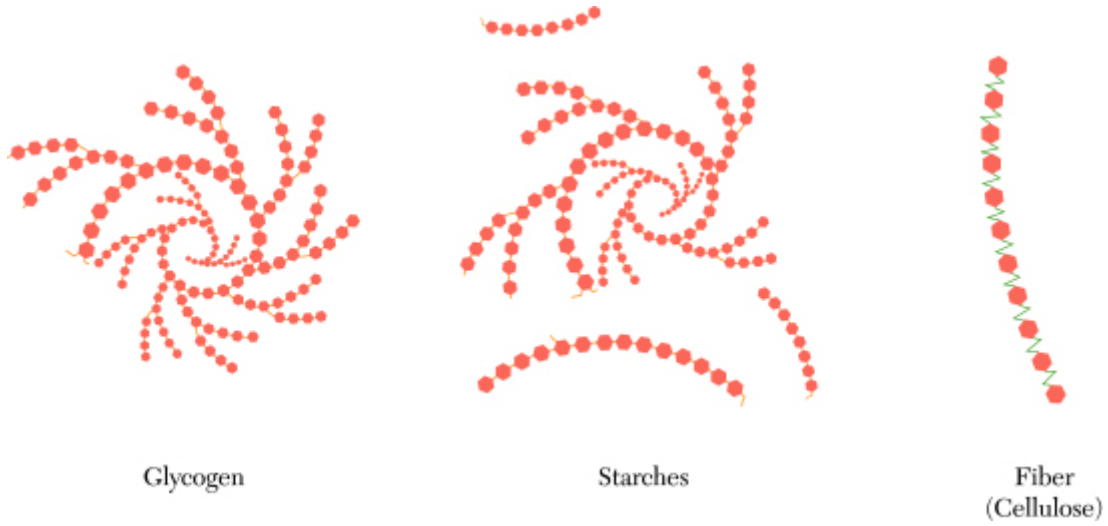

FIGURE 4.7

Complex carbohydrates are made up of straight or branching chains of monosaccharides.

Glycogen is the storage form of carbohydrate in animals

Glycogen is a carbohydrate storage molecule made up of highly branched chains of glucose molecules. Its branched structure allows it to be broken down quickly when glucose is needed. Glycogen is stored in the muscles and in the liver. We don't consume glycogen in our diet because the glycogen in animal muscle tissue is broken down after the animal is slaughtered, but it is made in our bodies from glucose.

Starch is the storage form of carbohydrate in plants

Starch

Starch
A carbohydrate made of many glucose molecules linked together in a highly branched structure. It is the storage form of carbohydrate in animals

is made up of glucose molecules linked together in either straight or branched chains. It is a carbohydrate storage molecule in plants where it provides energy for growth and reproduction. In our diet, we take advantage of these plant energy stores. When we eat potatoes or other tubers, we are eating the energy storage organ of some plants. When we eat sweet potatoes, yams, or cassava, we are eating a starchy root (Figure 4.8). When we eat legumes such as lentils, soybeans, and kidney beans, we are eating a starchy seed from a plant that produces seeds in a pod. When we eat products made from grains like corn, rice, wheat, or oats, we are also eating the starch from a seed.

On the Side

Cassava, which is also called manioc and yucca root, originated in South America. Today it is eaten mostly in Africa, Indonesia, and Southeast Asia. You may think you have never had cassava, but if you have ever had tapioca pudding you have. Tapioca is made from the cassava root. Some varieties of cassava contain high levels of a compound that can be converted into poisonous cyanide in the body. To prevent poisoning, the cassava can be boiled or soaked before it is cooked or made into flour.

FIGURE 4.8

Cassava, seen in the center basket, is a starchy root vegetable that is the staple of the diet in some parts of western and central Africa. (Wolfgang Kaehler/Corbis)

In food preparation and processing, starches are used as thickeners in sauces, puddings, and gravies. Starch thickens food because it swells when heated in water. When a starch-thickened mixture cools, new bonds form between the molecules, creating a gel. Many packaged foods contain a product called modified starch or modified food starch, which is starch that has been treated to cause it to form a more stable gel.

Fiber cannot be digested by human enzymes Fiber is non-digestible carbohydrate; it is not digested by human enzymes, so it cannot be absorbed in the small intestine and it reaches the large intestine unchanged. Despite this, fiber consumed in the diet can have beneficial effects on the gastrointestinal tract and overall health.* Some of the fiber we consume in our diets comes from natural plant sources, this is called dietary fiber. For example, the fiber in an apple or a bowl of oatmeal is classified as dietary fiber. Some of the fiber we consume has been isolated from other sources and added to a food, supplement, or medication for its health benefits; this is called functional fiber. For instance, fiber supplements consumed as laxatives or oat bran added during the processing of a breakfast cereal would be considered functional fiber. Total fiber is the sum of the fiber in a product and therefore includes both dietary fiber and functional fiber.*

Fibers are classified based on how they behave in the GI tract Fiber includes a number of different chemical substances that have different physical and physiological properties. Some fibers dissolve in water and form viscous solutions in the intestine; these are called viscous or **soluble fibers**

soluble fibers
Fiber that forms viscous solutions in water and can be broken down by the intestinal microflora. It includes pectins, gums, and some hemicelluloses

. They hold water in the gastrointestinal tract and increase the weight of the feces. Soluble fibers can be digested by bacteria in the large intestine. This digestion produces gas and short chain fatty acids, small quantities of which can be absorbed into the body. Soluble fibers are found around and inside plant cells. Food sources of soluble fibers include oats, apples, beans, and seaweed. Chemically, they include pectins, gums, and some hemicelluloses. Pectin is found naturally in fruits and vegetables and is added as a thickener when making jams and jellies and other processed foods. Gums are used as thickeners and stabilizers in processed foods because they combine with water to keep solutions from separating. They are used in gravies, pie fillings and puddings. Some gums used in food processing are extracted from shrubs, trees, and seed pods; these include gum arabic, gum karaya, guar gum, locust bean gum, xanthan gum, and gum tragacanth. Agar, carrageenan, and alginates, which come from seaweeds, are also used as thickeners and stabilizers (Figure 4.9). Pectins and gums are also used in reduced-fat products to mimic the texture of fat.

FIGURE 4.9

Modified starch, pectin, and gums are used as stabilizers and thickeners in these processed foods. (Charles D. Winters)

Fibers that cannot be digested by bacteria in the large intestine add bulk to the fecal matter. These are called **insoluble fibers**

insoluble fibers
Fiber that, for the most part, does not dissolve in water and cannot be broken down by bacteria in the large intestine. It includes cellulose, some hemicelluloses, and lignin

because they do not dissolve in water. These fibers pass through the gastrointestinal tract without being changed and increase the amount of material in the intestine. Insoluble fibers are primarily derived from the structural parts of plants, such as the cell walls. Food sources include wheat bran, rye bran, and vegetables such as broccoli and celery. Chemically, they include cellulose, some hemicelluloses, and lignins, substances that are not carbohydrates but are considered fiber.

Some starch resists digestion In addition to substances classically defined as fiber, there is some starch that resists digestion in the human gastrointestinal tract. This **resistant starch**

resistant starch
Starch that escapes digestion in the small intestine of healthy people

escapes digestion for a number of reasons. In some cases it is not digested because the natural structure of the grain protects it; in other cases cooking and processing can

alter digestibility. For instance, heating makes potato starch more digestible but cooling the cooked potato reduces its digestibility. When resistant starch reaches the large intestine it is fermented like soluble fiber. Resistant starch helps prevent constipation by increasing the moisture content and bulk of the feces. Foods high in resistant starch include legumes, unripe bananas, and cold cooked potatoes, rice, and pasta.