24.2

1 FOCUS

Objectives

24.2.1 Identify where glucose is found in nature.

24.2.2 Describe how two simple sugars can be linked.

Guide for Reading

Build Vocabulary L2

Graphic Organizers As you learn the new vocabulary, make a concept map of the relationships among carbohydrates, monosaccharides, disaccharides, and polysaccharides.

Reading Strategy L2

Use Prior Knowledge Remind students of what they know about polymers. As they read this section, they should use this prior knowledge to confirm differences among different types of polysaccharides.

2 INSTRUCT

Connecting to Your World

Chitin is a tough yet lightweight covering that protects many insects. **What is a polymer?** *(a high molar mass molecule formed by the covalent bonding of repeating smaller units, called monomers)* **Where does a cicada get the chemicals to build chitin and other polymers it needs?** *(by eating plant products)*

Monosaccharides

Use Visuals L1

Figure 24.4 Point out that plants are mostly composed of a carbohydrate known as cellulose. Ask, **What are carbohydrates, and what is the general formula of these compounds?** *(Carbohydrates are a group of organic compounds that includes simple and complex sugars. Most carbohydrates have the general formula $C_n[H_2O]_n$.)*

24.2 Carbohydrates

Guide for Reading

Key Concepts

- Where is glucose found abundantly in nature?
- How can the cyclic forms of two simple sugars be linked?

Vocabulary

carbohydrates
monosaccharides
disaccharide
polysaccharides

Reading Strategy

Previewing Before you read this section, skim the section to find out the types of carbohydrates you will be learning about. List the types of carbohydrates and, as you read, write a description of each one.

Connecting to Your World

This cicada is molting—shedding its old exoskeleton and forming a new one. An exoskeleton is the hard protective covering of insects, lobsters, and other arthropods. As an arthropod grows, it must molt to make room for its bigger body. An arthropod's exoskeleton is made of a polymer called chitin, which belongs to a class of organic molecules known as carbohydrates. In this section, you will learn about the structures and functions of carbohydrates.

Monosaccharides

Long-distance runners often prepare for a big race by eating a great deal of bread and pasta, a process known as carbohydrate loading. Breads and pastas are excellent sources of the family of important molecules called carbohydrates. **Carbohydrates** are monomers and polymers of aldehydes and ketones that have numerous hydroxyl groups attached; they are made up of carbon, hydrogen, and oxygen. The name carbohydrate comes from the early observation that many of these compounds have the general formula $C_n(H_2O)_n$ and, as a result, appear to be hydrates of carbon. They are not, in fact, true hydrates.

You would probably call a diet based mainly on bread and pasta a starchy diet. You would be correct. Such foods contain certain carbohydrates called starches. In this section, you will learn about the similarities and differences among some well-known types of carbohydrates.

Carbohydrates are present in most foods, as Figure 24.4 shows. The simplest carbohydrate molecules are called simple sugars, or **monosaccharides.** Glucose and fructose are examples of simple sugars. **Glucose is abundant in plants and animals.** Depending on the source, glucose has also been called corn sugar, grape sugar, or blood sugar. Fructose occurs in a large number of fruits and in honey. Glucose and fructose both have the molecular formula $C_6H_{12}O_6$. However, glucose has an aldehyde functional group, whereas fructose has a ketone functional group. Therefore, they are structural isomers. Both undergo many of the same reactions as ordinary aldehydes and ketones.

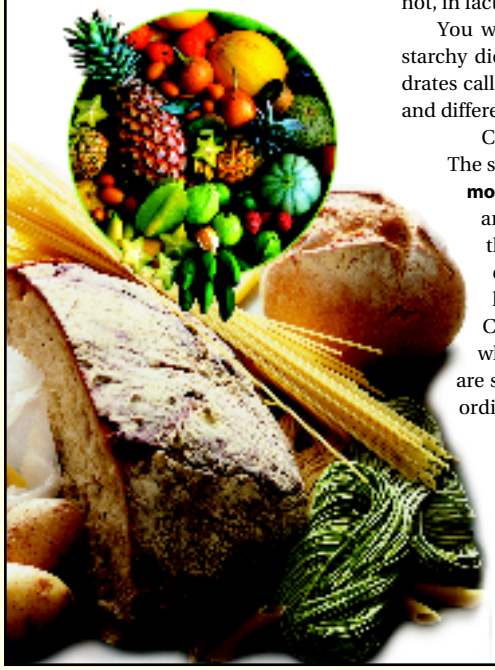


Figure 24.4 Carbohydrates are the most abundant sources of energy in food. Fruits contain simple carbohydrates called sugars. Bread and pasta are good sources of complex carbohydrates called starches.

Section Resources

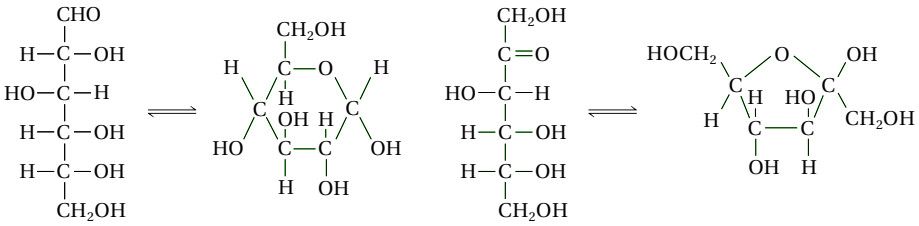
Print

- **Guided Reading and Study Workbook,** Section 24.2
- **Core Teaching Resources,** Section 24.2
- **Transparencies,** T273–T274

Technology

- **Interactive Textbook with ChemASAP,** Assessment 24.2
- **Go Online,** Section 24.2

In aqueous solution, simple sugars such as glucose and fructose exist in a dynamic equilibrium between straight-chain and cyclic forms. The cyclic form predominates. The structures for each sugar in both forms are:



Straight-chain and cyclic forms of glucose

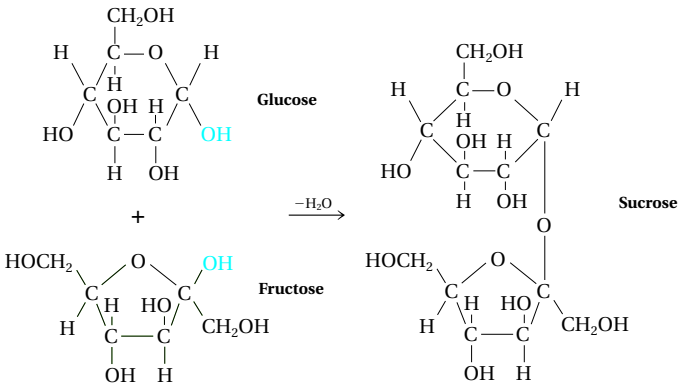
Straight-chain and cyclic forms of fructose

Note the aldehyde functional group (—CHO) on the straight-chain form of glucose and the ketone functional group () on the straight-chain form of fructose.

Checkpoint ***Which form of a simple sugar is favored at equilibrium in aqueous solution?***

Disaccharides and Polysaccharides

Simple sugars form the building blocks of more complex carbohydrates. **The cyclic forms of two simple sugars can be linked by means of a condensation reaction.** For example, the linking of glucose and fructose with the loss of a water molecule produces sucrose—common table sugar. A sugar such as sucrose that forms from two monosaccharides in this way is known as a **disaccharide.** The reaction by which it forms is as follows.



Sucrose is obtained commercially mainly from the juice of sugar cane and sugar beets. The world's production from these sources exceeds 7×10^9 metric tons per year.

The formation of a disaccharide is sometimes the first step in a condensation polymerization reaction that produces extremely large molecules. The polymers produced by the linkage of many monosaccharide monomers are called **polysaccharides.** Starches, the major storage form of glucose in plants, are polysaccharide polymers that consist of glucose monomers. Figure 24.5 shows a portion of a starch molecule.

Word *Origins*

Polysaccharide comes from the Greek words *polys*, meaning "full" or "many," and *sakcharon*, meaning "sugar." A polysaccharide is a compound that is formed by the linking together of many simple sugar molecules. Starches, cellulose, and glycogen are all polysaccharides. **What are the names of some other organic molecules that contain the prefix *poly*-?**

Facts and Figures

Glucose Testing

The ability to detect mono- and polysaccharides is an important function of clinical laboratories and at-home tests for those afflicted with diabetes mellitus. The Benedict's test is one way to test for monosaccharides. It is not specific to glucose, however, but tests the total reducing substance. Available test strips allow more precise measurement of glucose. They combine enzymes that are specific to glucose and indicators that produce colors that vary depending on the concentration of glucose.

Disaccharides and Polysaccharides

TEACHER Demo

Glucose and Fructose Models L2

Purpose To build models of sugars.

Materials Styrofoam balls and toothpicks or molecule kit

Procedure Construct ball-and-stick models of glucose and fructose. Point out the functional groups. Demonstrate the cyclization of the straight-chain forms. Connect the two cyclic forms to form a disaccharide and note the loss of a water molecule. Point out that if this condensation reaction is allowed to continue, many monosaccharide units could join to form a polysaccharide.

TEACHER Demo

Benedict's Test L2

Purpose Students classify sugars as reducing or nonreducing.

Materials hot-water bath, 2–5 mL of 1% carbohydrate solution, 2 test tubes, distilled water, 2–3 mL of Benedict's reagent, dropper, samples of mono- and polysaccharides

Procedure Place 2–5 mL of 1% carbohydrate solution (corn syrup) in one test tube; place distilled water in another test tube as a negative control. Add 2–3 mL of Benedict's reagent to each tube and heat in hot–water bath for a few minutes. The Cu^{2+} ions react with reducing sugars to form a brick-red cuprous oxide (Cu_2O) precipitate. The amount of precipitate formed depends on the amount of sugar present. Have students observe the formation of a red precipitate. Test a number of mono- and polysaccharides and have students classify them as reducing or nonreducing.

Expected Outcome The precipitate indicates presence of a simple sugar.

Word *Origins* L2

Polypropylene, polystyrene, and polyvinyl chloride (PVC).

Answers to....

Checkpoint the cyclic form

Go Online NSTA SCILINKS

Download a worksheet on **Carbohydrates** for students to complete, and find additional teacher support from NSTA SciLinks.

3 ASSESS

Evaluate Understanding L2

Have students describe the structure of mono-, di-, and polysaccharides and give a common example of each. Ask students to specify the types of elements, functional groups, and linkages found in carbohydrates.

Reteach L1

Have students study the structures for the formation of sucrose (page 767). Ask, **What happens in this condensation reaction?** *(Fructose and glucose combine to make sucrose, losing one water molecule.)* Have students describe how polymers form by condensation.

Connecting Concepts

Polyester polyethylene terephthalate (PET) is a condensation polymer of terephthalic acid and ethylene glycol. Nylon is a condensation polymer of 6-aminohexanoic acid.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 24.2.

with ChemASAP

Answers to...

Figure 24.5 Besides writing structural formulas, physical models (such as a ball-and-stick model) could be constructed to show the differences between starch and cellulose.

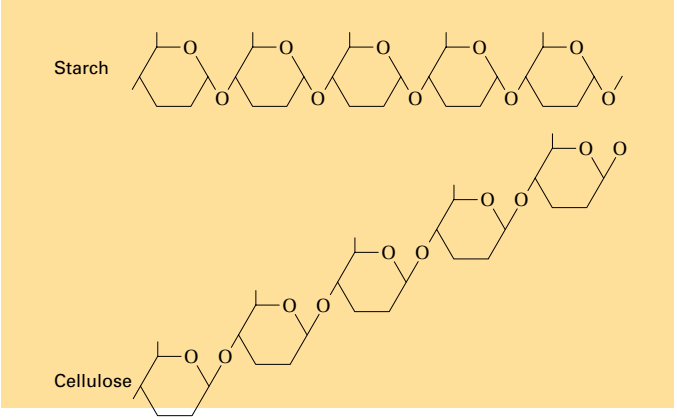


Figure 24.5 Starch and cellulose are similar polymers made up of hundreds of glucose monomers. They differ in the orientation of the bond between the glucose units. Because of this difference, starch is readily digestible, but cellulose is indigestible by most organisms. **Using Models** ***What other types of models could you use to show the structural differences between starch and cellulose?***

A typical linear starch molecule contains hundreds of glucose monomers. Other starches are branched molecules, each branch containing about a dozen glucose units. Glycogen, the energy source stored in the liver and muscle cells of animals, is a more highly branched molecule than plant starches. Glycogen, too, consists of glucose monomers.

Cellulose is probably the most abundant biological molecule on Earth. As you can see in Figure 24.5, cellulose also is a polymer of glucose. The orientation of the bond that links the glucose monomers in cellulose is different, however, from the bond orientation in starch and in glycogen. Starch can be digested by most organisms and is partially soluble in water. Cellulose, however, can be digested by only a few kinds of microorganisms, such as those that live in the digestive tracts of cattle and termites. Cellulose is insoluble in water and is an important structural polysaccharide that provides form, hardness, and rigidity in plants. Plant cell walls are made of cellulose. Cotton is about 80% cellulose.

Go Online NSTA SCILINKS

For: Links on Carbohydrates
Visit: www.SciLinks.org
Web Code: cdn-1242

24.2 Section Assessment

8. Key Concept Where is glucose found in nature?
9. Key Concept How can the cyclic forms of two simple sugars be combined?
10. Distinguish between the important structural features of sucrose, glucose, and fructose.
11. Describe the main characteristics of monosaccharides, disaccharides, and polysaccharides.
12. Starch and cellulose have different properties, but both are composed of glucose units. Explain what makes them different.
13. Name a source for each polysaccharide:
    a. starch **b.** cellulose **c.** glycogen
14. What is the most abundant carbohydrate on Earth and where is it found?

Connecting Concepts

Polymers Starch is a condensation polymer of glucose. Reread Section 23.4, and describe some other examples of molecules that form by condensation polymerization.

Interactive Textbook

Assessment 24.2 Test yourself on the concepts in Section 24.2.

with ChemASAP

Section 24.2 Assessment

8. in plants and animals
9. via a condensation reaction
10. *sucrose:* disaccharide of glucose and fructose; *glucose:* monosaccharide with aldehyde functional group; *fructose:* monosaccharide with ketone functional group.
11. Monosaccharides (simple sugars) can exist in straight-chain or cyclic form. Disaccharides form when two simple sugars condense. Polysaccharides are polymers of monosaccharides.
12. The orientation of the bonds that link the glucose monomers is different.
13. **a.** plants **b.** plant cell walls **c.** liver and muscle cells of animals
14. Cellulose; it is found in plant cell walls.

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