chapter 5

Carbohydrates

Chapter | Outline

Case | Scenario

Myeshia is a 19-year-old African American female who recently read about the health benefits of calcium and decided to increase her intake of dairy products. To start, she drank 1 cup of 1% milk at lunch. Not long afterward, she experienced bloating, cramping, and increased gas production. She suspected that the source of this pain was the milk she consumed, especially since her parents and her sister complain of the same problem. She wanted to try to determine if the milk was, in fact, the cause of her gastrointestinal discomfort. So the next day she substituted a cup of yogurt for the glass of milk at lunch. She had heard that yogurt is easier to tolerate than milk for some people. Subsequently, she did not have any pain. What has Myeshia discovered? What component of milk is likely causing the problem?

Refresh | Your Memory

As you begin your study of carbohydrates in Chapter 5, you may want to review:

- The health claims on food labels for various carbohydrates in Chapter 2.
- The anatomy and physiology of digestion and absorption in Chapter 3.
- The processes of glycolysis, gluconeogenesis, and ketosis in Chapter 4.

Boost | Your Study

Check out the ***Perspectives in Nutrition: Online Learning Center*** **www.mhhe.com/wardlawpers6** *for quizzes, flash cards, activities, and web links designed to further help you learn about carbohydrates.*

Chapter | Objectives

Chapter 5 is designed to allow you to:

1. Identify the basic structures and food sources of the major carbohydrates—monosaccharides, disaccharides, polysaccharides (e.g., starches), and fiber.
2. List the functions of carbohydrate in the body and the problems that result from not eating enough carbohydrate.
3. Outline the beneficial effects of fiber on the body.
4. State the RDA for carbohydrate and various guidelines for carbohydrate intake.
5. Describe food sources of carbohydrate and list some alternate sweeteners.
6. Describe the regulation of blood glucose and the nutrients that can become blood glucose.
7. Identify the consequences of lactose maldigestion and diabetes, and explain appropriate dietary measures to take to reduce these health problems.

What did you eat to obtain the energy you are using right now? The next three chapters will examine this question by focusing on the nutrients the human body uses for fuel. These energy-yielding nutrients are mainly carbohydrates (on average, 4 kcal/g) and fats and oils (on average, 9 kcal/g). Little of the other common fuel—protein (on average, 4 kcal/g)—is used for that purpose by the body. Most people know that potatoes have carbohydrates and steak has fat and protein, but few people, besides scientists and registered dietitians, know what those terms signify.

It is likely that you have recently consumed fruits, vegetables, dairy products, cereal, breads, and pasta. All these foods supply carbohydrates.[4] Unfortunately, the benefits of these foods are often misunderstood. Many people think carbohydrate-rich foods are fattening—they are not. Pound for pound, carbohydrates are much less fattening than fats and oils. Furthermore, carbohydrates, especially fiber-rich foods such as fruits, vegetables, whole grains, and legumes, have been promoted by many experts for the important health benefits these foods supply.[8, 10, 13] Some people think sugars necessarily cause diabetes or hyperactivity—not so, according to well-designed scientific investigations. Almost all carbohydrate-rich foods, except pure sugars, provide essential nutrients and should constitute 45 to 60% of our daily energy intake.[6] Let's take a closer look at carbohydrates.

Carbohydrates—An Introduction

Carbohydrates are a primary fuel source for some cells, such as those in the nervous system and red blood cells. Muscles also rely on a dependable supply of carbohydrate in order to support intense physical activity. Yielding on average 4 kcal/g, carbohydrates are a readily available fuel for all cells in the form of blood glucose and stored in the liver and muscles as glycogen. Carbohydrate stored in the liver can be used to maintain blood glucose availability in times when the diet does not supply enough. Regular intake of carbohydrate is important, because liver glycogen stores are exhausted in about 18 hours if no carbohydrate is consumed. After that point, the body is forced to produce its own carbohydrate from body and food protein; this eventually leads to health problems.[6]

We have sensors on our tongues that recognize sweet carbohydrates. Researchers surmise that this sweetness indicated a safe energy source to early humans, and so carbohydrate became an important energy source. The returning Crusaders brought sugar from the Holy Land to Europe. Columbus introduced sugarcane to the Americas. The French later exploited sugar beets as a source of sugar.

Primarily choosing the healthiest carbohydrate sources, while moderating intake of those that are less healthful, contributes to a well-planned diet. It is difficult to eat so little carbohydrate that body needs are not met, but it is easy to overconsume the carbohydrates that can contribute to health problems.[6] Let's explore this concept further as we look at carbohydrates in detail.

Fruits such as peaches are an excellent source of carbohydrate for a diet.

Structures and Functions of Simple Carbohydrates

Most forms of carbohydrates are composed of carbon, hydrogen, and oxygen in the ratio of 1:2:1, respectively. The general formula is $(CH_2O)n$, where n represents the number of times the ratio is repeated. The chemical formula for glucose is $C_6H_{12}O_6$, or $(CH_2O)_6$. The simpler forms of carbohydrates are called **sugars** and often take the form of single or double sugars, called **monosaccharides** and **disaccharides,** respectively. The more complex forms of carbohydrates are **polysaccharides,** typically either **starches** or **fibers.**[6]

Plants use carbon dioxide, water, and energy (from the sun) to produce the carbohydrates we eat. This complex process is called **photosynthesis.**

$$CO_2 + H_2O \rightarrow (CH_2O)n + O_2$$

Monosaccharides: Glucose, Fructose, and Galactose

The common monosaccharides (*mono* meaning "one" and *saccharide* meaning "sugar") are glucose, fructose, and galactose. Glucose is the principal monosaccharide in the body. Other names for glucose are *dextrose* or *blood sugar.* In Figure 5-1, the chemical structure of glucose is shown in both its linear and ring forms. Glucose exists in the body in the ring form. Because it is a six-carbon monosaccharide, glucose is called a **hexose** (*hex* meaning "six," for six carbons; *ose* is the standard word ending for carbohydrates).[3]

Fructose is related to glucose. It is a hexose and can form either a five- or six-member ring (see Fig. 5-1). Fructose, also called levulose, is found in

- Fruit
- Honey (about half fructose, half glucose)
- **High-fructose corn syrup,** which is used in the production of soft drinks, frozen desserts, and confections. The presence of fructose in these products makes it a major sugar in our diets. In most North American diets, fructose accounts for about 8 to 10% of total energy intake.

sugar A simple carbohydrate with the chemical composition $(CH_2O)n$. Most sugars form ringed structures when in solution. Generally refers to monosaccharides and disaccharides.

monosaccharide A class of simple sugars, such as glucose, which is not broken down further during digestion.

disaccharides A class of sugars formed by the chemical bonding of two monosaccharides.

polysaccharides Carbohydrates containing many glucose units, from 10 to 1000 or more.

starch A carbohydrate made of multiple units of glucose attached together in a form the body can digest; also known as *complex carbohydrate.*

fiber Substances in plant foods that are not digested by the processes that take place in the stomach or small intestine. These add bulk to feces. Fibers naturally found in foods are also called dietary fiber.

hexose A general term describing a carbohydrate containing six carbons.

fructose A monosaccharide with six carbons that form a five-membered or six-membered ring with oxygen in the ring; found in fruits and honey.

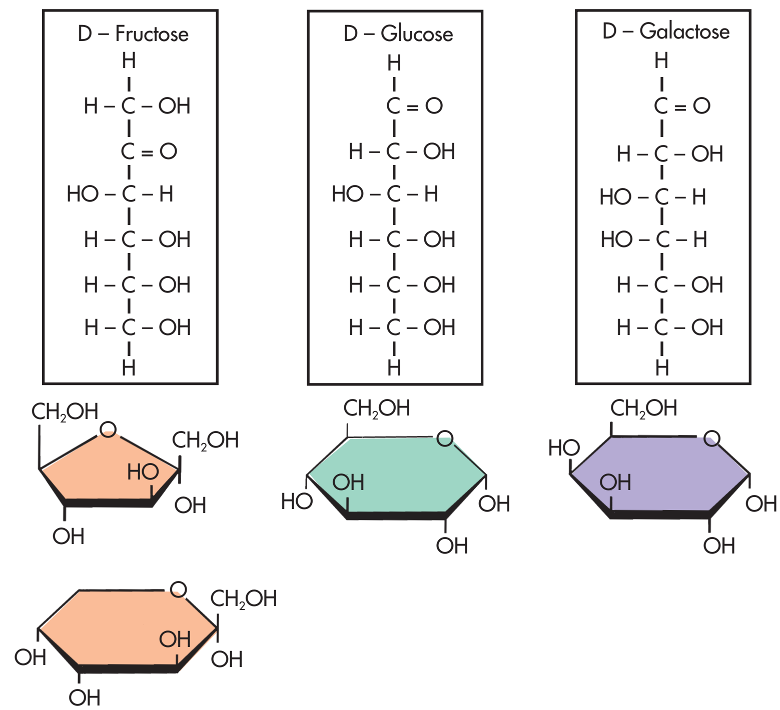
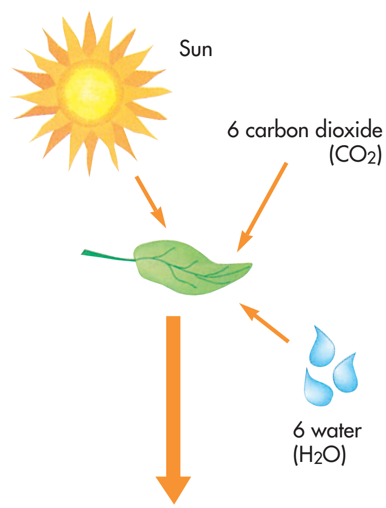


Figure 5-1 Forms of the D-isomer of the six-carbon monosaccharides—fructose, glucose, and galactose—shown in the linear form and in the ring form where each corner represents a carbon atom unless otherwise indicated. Hydrogen atoms are also omitted. (Appendix A reviews this shortcut notation.) This ring structure is the predominant form when in solution. Only the D-isomer forms are metabolized by the body. Appendix A also reviews the concepts of isomers.
Illustration by William Ober.



A summary of photosynthesis. Glucose is stored in the leaf but can also undergo further metabolism to form starch and fiber in the plant.

Fructose, after absorption by the small intestine and transport to the liver, is almost all metabolized to glucose or to intermediates in the glycolysis pathway. Some fructose is then converted to glycogen, **lactic acid,** or fat, depending on the amount consumed. Synthesis of lactic acid and fat is stimulated by fructose intakes that are two or more times typical intakes.

Galactose is the third major monosaccharide of nutritional importance. Comparison of the structure of this simple sugar with that of glucose shows that the two structures are almost identical, except that the hydrogen (–H) and the hydroxyl group (–OH) on carbon-4 are reversed (review Fig. 5-1). Galactose is not usually found free in nature in large quantities but, rather, combines with glucose to form a disaccharide called *lactose* (present in milk and other dairy products). Once absorbed into the body, galactose is converted into glucose in the liver, which is used to provide immediate energy or is stored as *glycogen*.

Another monosaccharide found in nature is **ribose,** a five-carbon sugar (or pentose; *penta* means "five"). This is present in a cell's genetic material. Very little ribose is present in our diet; we produce this sugar from other foods we eat.

Finally, a few sugar alcohols are present in foods and will be discussed later in this chapter, in the section on nutritive sweeteners in foods. Currently, the major sugar alcohol used in the manufacture of edible products is **sorbitol.**

Once you are familiar with the chemical forms of the sugars, it is much easier to understand how they are interrelated, combined, digested, metabolized, and synthesized.

Disaccharides: Maltose, Sucrose, and Lactose

Carbohydrates containing two sugar units are called disaccharides (*di* means "two"). These are formed when two monosaccharides combine. The three most common disaccharides found in nature are **maltose, sucrose,** and **lactose.** All contain glucose (Fig. 5-2).[6]

One carbon on each participating monosaccharide is chemically bound together by oxygen. Two forms of this C—O—C bond exist in nature, called **alpha (α) bonds** and **beta (β) bonds,** and are depicted slightly differently. As shown in Figure 5-2, maltose and sucrose contain the alpha form, whereas lactose contains the beta form. Many

lactic acid A three-carbon acid, also called lactate, that is formed during anaerobic cell metabolism; a partial breakdown product of glucose.

galactose A six-carbon monosaccharide; an isomer of glucose.

sorbitol An alcohol derivative of glucose that yields about 3 kcal/g but is slowly absorbed from the small intestine. It is used in some sugarless gums and dietetic foods.

maltose Glucose bonded to glucose.

sucrose Fructose bonded to glucose; table sugar.

lactose A sugar composed of glucose linked to another sugar called galactose.

alpha (α) bond A type of bond that can be digested by human intestinal enzymes; drawn as C⌞O⌟C.

beta (β) bond A type of bond that cannot be broken by human intestinal enzymes during digestion when it is part of a long chain of glucose molecules (e.g. cellulose) drawn as C⌜O⌟C.

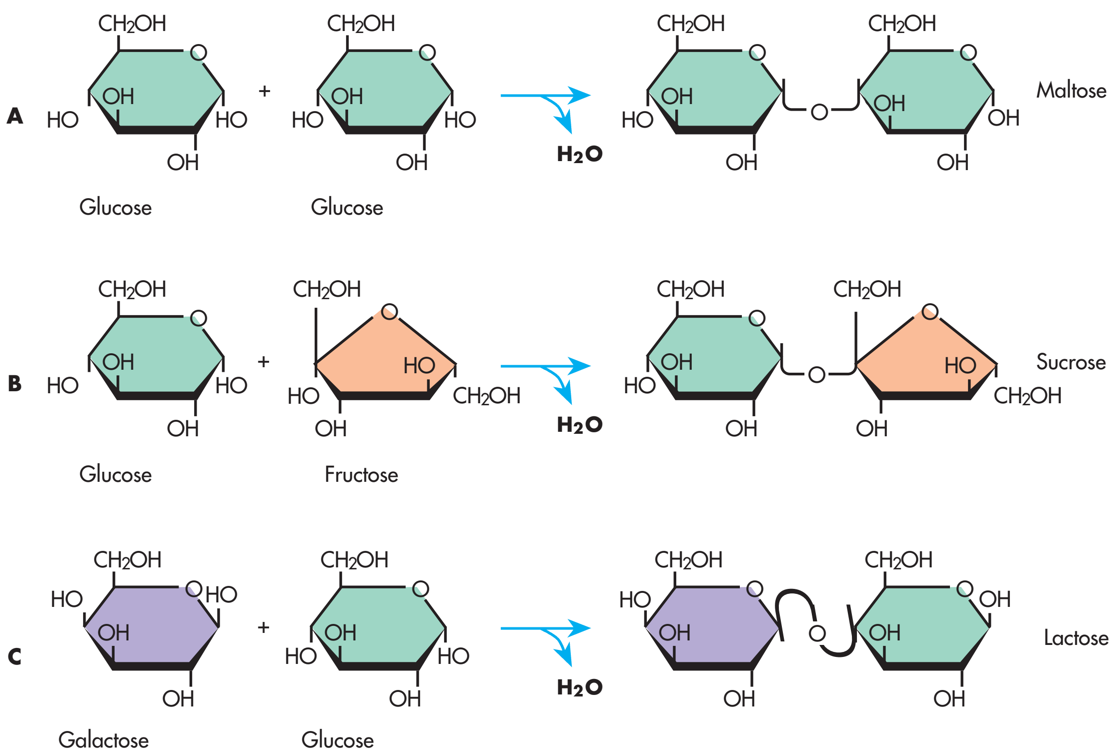


Figure 5-2 Joining of two monosaccharides forms a disaccharide. (*A*) Maltose is made up of two glucose molecules and is formed in germinating grains. (*B*) Sucrose, or common table sugar, is made up of glucose and fructose. (*C*) Lactose, or milk sugar, is made up of glucose and galactose. Note that lactose contains a different type of bond (beta, or β) from that of maltose and sucrose (alpha, or α), a property that makes lactose difficult to digest for individuals who show a low activity of the enzyme lactase.
Illustration by William Ober.

carbohydrates contain glucose polymers with the individual molecules bonded together by either alpha or beta bonds. Humans can digest such carbohydrates only if the glucose molecules are linked by alpha bonds.[3] This topic will be covered later in this chapter, when fiber is discussed.

Maltose consists of two glucose molecules joined by an alpha bond. When seeds sprout, they produce enzymes that break down the polysaccharides (starch) to sugars such as maltose and glucose. It is this sugar that provides the energy for the plant to initiate growth. In a process called malting, the sprouting process is stopped by heat. This is the first step in the production of alcoholic beverages such as beer. Yeast in the absence of oxygen converts most of the carbohydrates to ethanol (alcohol) and carbon dioxide in a process called **fermentation.** There will be more about the production of alcoholic products in Chapter 8. Few other food products and beverages contain maltose. In fact, most maltose that we ultimately digest in the small intestine is produced during the digestion of starch (see a later section on digestion in this chapter).

Sucrose, common table sugar, is composed of glucose and fructose linked via an alpha bond. Large amounts of sucrose are found only in plants, such as sugarcane, sugar beets, and maple syrup. The sucrose from these sources may be purified to various degrees. Brown, white, and powdered sugars are common forms of sucrose sold in grocery stores.

Lactose, the primary sugar in milk and milk products, consists of glucose joined to galactose via a beta bond. As discussed in a later section of this chapter, many people are unable to digest large amounts of lactose because they don't produce enough of the enzyme lactase that is capable of breaking its beta bond. This can cause intestinal gas, bloating, cramping, and discomfort as the unabsorbed lactose is metabolized into acids and gases by bacteria in the large intestine.[17]

fermentation The conversion, without the use of oxygen, of carbohydrates to alcohols, acids, and carbon dioxide.

A common misconception is that honey contains vitamins and minerals. You can prove to yourself that honey is no more nutritious than sucrose by consulting Appendix N. Only the sweetener molasses, a by-product of sucrose production, contains any appreciable amount of minerals. However, our consumption of molasses is very low.

Simple	**Monosaccharides**
	Glucose, fructose, galactose
	Disaccharides
	Sucrose, lactose, maltose
	Oligosaccharides
	Raffinose, stachyose
	Polysaccharides
	Starches (amylose and amylopectin), glycogen
Complex	Most fibers

You are likely to encounter many different words referring to the monosaccharides and disaccharides just discussed or products containing these simple sugars. Note that all of the terms listed in Table 5-7 later in the chapter are names for sugars either naturally present in food products or added during their manufacture. These monosaccharides and disaccharides are often referred to as *simple sugars* because they contain only one or two sugar units and, therefore, have a simple chemical structure. Food labels lump all these sugars under one category, listing them as "sugars."

Concept | Check

Monosaccharides are single sugars. From a nutritional standpoint, important monosaccharides are glucose, fructose, and galactose. Disaccharides are double sugars. The major disaccharides in the diet are sucrose (glucose bonded to fructose), maltose (glucose bonded to glucose), and lactose (glucose bonded to galactose). The disaccharides have either alpha or beta bonds. Our bodies are unable to break down most of the beta bonds. Once absorbed into the body, most carbohydrates are ultimately transformed into glucose by the liver.

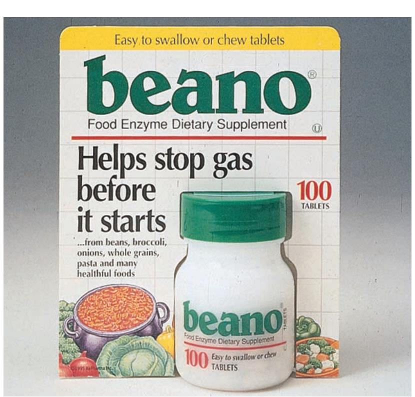
Oligosaccharides: Raffinose and Stachyose

raffinose An indigestible oligosaccharide made of three monosaccharides (galactose-glucose-fructose).

stachyose An indigestible oligosaccharide made of four monosaccharides (galactose-galactose-glucose-fructose).

From a nutritional standpoint, oligosaccharides contain 3 to about 10 single sugar units (*oligo* means "scant").[6] (Chemists and biochemists, however, often lump disaccharides in the oligosaccharide category as well.[3]) Two oligosaccharides of nutritional importance are **raffinose** and **stachyose,** which are found in beans and other legumes. These are constructed of typical monosaccharides but are bonded together in such a way that digestive enzymes cannot break them apart. Thus, when we consume beans and other legumes, raffinose and stachyose remain undigested on reaching the large intestine. There, bacteria metabolize them, producing gas and other by-products.

Many people have no trouble digesting beans and other legumes, but others experience unpleasant side effects from intestinal gas. An enzyme preparation called Beano®, which prevents these side effects, can help such people if taken right before a meal. Once consumed, the enzyme preparation breaks down many of the indigestible oligosaccharides in legumes and other vegetables in the gastrointestinal tract before they reach the large intestine. Beano® is made from mold, so persons sensitive to molds may react allergically and should avoid it or use with caution. For more information or free samples, contact the manufacturer (800-257-8650).



Beano® can be used to reduce intestinal gas produced by bacterial metabolism of oligosaccharides in the large intestine.

Structures and Functions of the More Complex Carbohydrates

The polysaccharides, often referred to as *complex carbohydrates,* include some that are digestible (e.g., starch) and some that are largely indigestible, such as fiber.

Digestible Polysaccharides: Starch and Glycogen

amylose A straight-chain type of starch composed of glucose units.

amylopectin A branched-chain type of starch composed of glucose units.

Polysaccharides are polymers containing many monosaccharide units, up to 1000 or more. Most polysaccharides of nutritional importance are synthesized from glucose, as when vegetables turn glucose into starch during maturation. This makes peas and corn sweetest when they are young. Starch, the major digestible polysaccharide in our diet, is the storage form of energy in plants. There are two types of plant starch—**amylose** and **amylopectin**—both of which are a source of energy for plants and animals.

Both amylose and amylopectin contain many glucose units linked by alpha (digestible) bonds. The primary difference between the two types of starch is that amylose

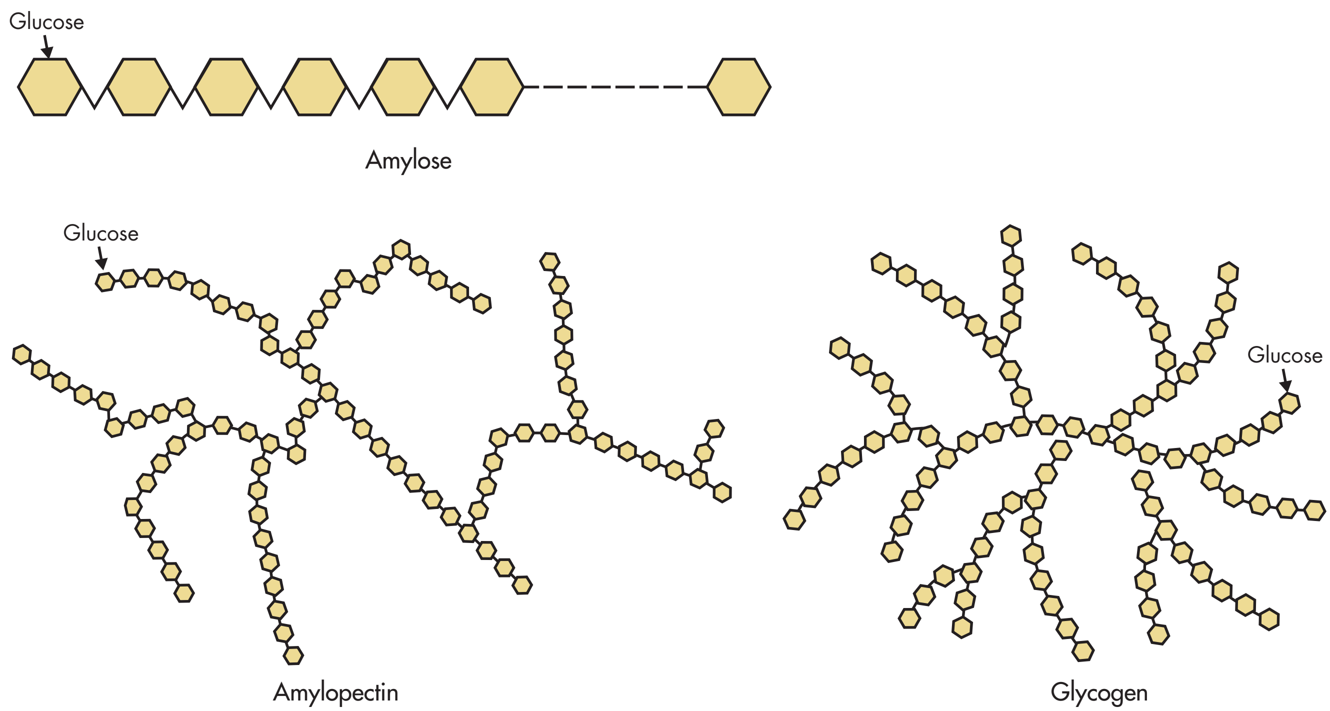


Figure 5-3 Some common starches. We consume essentially no glycogen. All glycogen found in the body is made by our cells, primarily in the liver and muscles.

is a straight-chain polymer, whereas amylopectin is highly branched (Fig. 5-3). Cooking increases the digestibility of these starches by making them more soluble in water and thus more available for attack by digestive enzymes. Amylose and amylopectin are found in potatoes, beans, breads, pasta, rice, and other starchy products, typically in a ratio of about 1:4. Amylopectin raises blood glucose much more readily than amylose, since its numerous branches provide many areas for digestive enzyme activity. The enzymes act only at the ends of the glucose chains. The more numerous the branches of a starch, the more sites (ends) are available for enzyme action (see the discussion of glycemic index in a later section of this chapter).[6]

The branches in amylopectin also allow it to form a very stable starch gel, enabling it to retain water and resist water seepage. Food manufacturers commonly use starches rich in amylopectin in sauces and gravies for frozen foods because they remain stable over a wide temperature range. Manufacturers may also use processes to bond the starch molecules to one another, further increasing their stability. The resulting product, called **modified food starch,** is used in baby foods, salad dressings, and instant puddings.

Glycogen, the storage form of carbohydrate in humans and other animals, is a glucose polymer with alpha bonds and numerous branches. The amount of carbohydrate in a diet greatly influences the glycogen stored. The structure of glycogen is similar to that of amylopectin, but the branching patterns are more complicated (review Fig. 5-3). As with amylopectin, because glycogen is so highly branched, it is quickly broken down by enzymes in body cells in which it is stored.[6] The liver and muscles are the major storage sites for glycogen. Because only about 120 kcal of glucose are available as such in body fluids, muscle and liver storage sites for carbohydrate energy—amounting to about 1800 kcal—are extremely important. As noted in this chapter's introduction, the 400 kcal of liver glycogen can be turned into blood glucose, while the 1400 kcal of muscle glycogen cannot. Still, glycogen in muscles supplies glucose for muscle use, especially during high-intensity and endurance exercise. (See Chapter 14 for a detailed discussion of carbohydrate use during physical activity.)

As some vegetables age, their sugars are converted to starches.

modified food starch A product consisting of chemically linked starch molecules that is more stable than normal, unmodified starches.

dietary fiber Fiber found in food.

functional fiber Fiber added to foods that has shown to provide health benefits.

cellulose A straight-chain polysaccharide of glucose molecules that is undigestible because of the presence of beta bonds; part of insoluble fiber.

hemicellulose A dietary fiber containing xylose, galactose, glucose, and other monosaccharides bonded together.

pectin A dietary fiber containing chains of galacturonic acid and other monosaccharides; characteristically found between plant cell walls.

gums A dietary fiber containing chains of galactose, glucuronic acid, and other monosaccharides; characteristically found in exudates from plant stems.

mucilages A dietary fiber consisting of chains of galactose, mannose, and other monosaccharides; characteristically found in seaweed.

lignins An insoluble fiber made up of a multiringed alcohol (noncarbohydrate) structure.

whole grains Grains containing the entire seed of the plant, including the bran, germ, and endosperm (starchy interior).

insoluble fibers Fibers that mostly do not dissolve in water and are not generally metabolized by bacteria in the large intestine. These include cellulose, some hemicelluloses, and lignins. More formally called poorly fermented fibers.

Indigestible Polysaccharides: Fibers

Folklore surrounding fiber has been a part of American culture since the 1800s. In the 1820s and 1830s, a minister named Sylvester Graham traveled up and down the East Coast extolling the virtues of fiber. He left us a legacy—the graham cracker. However, today's graham cracker bears little resemblance to the whole-grain product he promoted. The next wave of fiber frenzy crested in the mid-1870s with Dr. John Harvey Kellogg and his brother William, of breakfast cereal fame. Dr. Kellogg became the first person to earn a million dollars from "health foods." One of his patients was Charles W. Post, who followed the Kelloggs' lead and started the Post Toasted Cornflakes Company. In 1901 alone, Post netted $1 million from his Grape-Nuts cereal and other products. As you will see, present-day scientific evidence supports this early promotion of fiber as part of a total diet.

The definition of fiber has recently been expanded to include both the **dietary fiber** that is found naturally in foods, and other forms of fiber that may be added to foods. This second category is called **functional fiber;** any of these fibers must show beneficial effects in humans to be included in the category. **Total fiber** (or just the term *fiber*) is then the combination of dietary fiber and functional fiber in the food product.[6] Currently the Nutrition Facts label only includes the category dietary fiber; the label has yet to be updated to reflect the latest definition of fiber by the Food and Nutrition Board.

In terms of their chemical composition, fibers are composed primarily of the nonstarch polysaccharides **cellulose, hemicelluloses, pectins, gums,** and **mucilages.** The only noncarbohydrate components of dietary fibers are **lignins,** which includes complex alcohol derivatives (Table 5-1). Almost all forms of fiber come from plants and, as a group, none are digested in the human stomach or small intestine.[6]

Cellulose is a straight-chain glucose polymer similar to amylose; however, unlike amylose, which contains alpha bonds, the glucose units in cellulose are linked by beta bonds. As noted earlier, glucose molecules joined by beta bonds are not broken down by human digestive enzymes. Thus, cellulose is not digestible by humans and is classified as a dietary fiber, not a starch. Because the long glucose chains of cellulose are linear, they can pack closely together, forming fibrous structures of great strength. Overall, cellulose, hemicelluloses, and lignins form the structural part of the plant. A cotton ball is pure cellulose. Bran fiber is rich in hemicelluloses. Since bran layers form the outer covering of all grains, **whole grains** are good sources of this fiber (Fig. 5-4). The woody fibers in broccoli are partly lignins. As a class, these undigestible dietary fibers generally do not dissolve in water and thus are called **insoluble fibers** (or poorly fermented fibers).

Table 5-1 Classification of Dietary Fibers

Type	Component(s)	Examples	Physiological Effects	Major Food Sources
Insoluble (Poorly Fermented)				
Noncarbohydrate	Lignins	Wheat bran	Increases fecal bulk; estrogen-like effects	Whole grains
Carbohydrate	Cellulose Hemicelluloses	Wheat products Brown rice	Increases fecal bulk Decreases intestinal transit time	All plants Wheat, rye, rice, vegetables
Soluble (Viscous)				
Carbohydrate	Pectins, gums, mucilages, some hemicelluloses	Apples, bananas, oranges, carrots, barley, oats, kidney beans	Delays gastric emptying; slows glucose absorption; can lower blood cholesterol	Citrus fruits, oat products (beta-glucan in particular), beans, thickeners added to foods

Pectins, gums, and mucilages are found inside and around plant cells. They help "glue" plant cells together (review Fig. 5-4). These dietary fibers either dissolve or swell when put into water and thus are called **soluble fibers** (or viscous fibers). Some forms of hemicellulose also fall into this soluble-fiber category. Soluble fibers such as gum arabic, guar gum, locust bean gum, and various pectins are present in numerous food products, especially salad dressings, inexpensive ice creams, jams, and jellies. Other rich sources of soluble fibers include fruits and vegetables in general, soybean fiber, rice bran, and **psyllium** seeds (found in many commercial fiber laxatives).

soluble fibers Fibers that either dissolve or swell in water and are metabolized (fermented) by bacteria in the large intestine. These include pectins, gums, and mucilages. More formally called viscous fibers.

psyllium A mostly soluble type of dietary fiber found in the seeds of the plantain plant.

One workable definition of fiber is the foodstuffs that remain undigested as they enter the large intestine. There is really no common property that characterizes various fibers, except their ability to resist digestion in the small intestine. Since some fibers—especially the soluble fibers—are fermented by bacteria in the large intestine, it is not accurate to say that fiber is simply that found in the feces.

Bacteria in the large intestine ferment soluble fibers into products such as short-chain fatty acids (e.g., acetic acid, butyric acid, and propionic acid) and gases, such as hydrogen (H_2) and methane (CH_4). These acids, especially butyric acid, provide fuel for the cells in the large intestine and enhance their health. All these products can also be absorbed into the bloodstream. As a result of bacterial metabolism, soluble dietary fibers yield about 1.5 to 2.5 kcal/g on average, although the actual value is still in question.[6] Thus, high-fiber foods should not be looked at as calorie-free, though they are often lower in energy content per serving than low-fiber alternatives.

When intake of fiber is high, its breakdown by bacteria can cause methane and hydrogen to increase in the breath. This is not harmful. In addition, the body tends to adapt over time to a high-fiber intake, leading to less gaseous symptoms and adjusting to the increased pressure in the large intestine.

Currently food labels use the term *soluble fiber,* rather than the more formal *viscous fiber.* We will use soluble fiber in this and other chapters since it is still the term found on the Nutrition Facts label. It is likely that the term *soluble* will be phased out in the future and replaced with the term *viscous.*

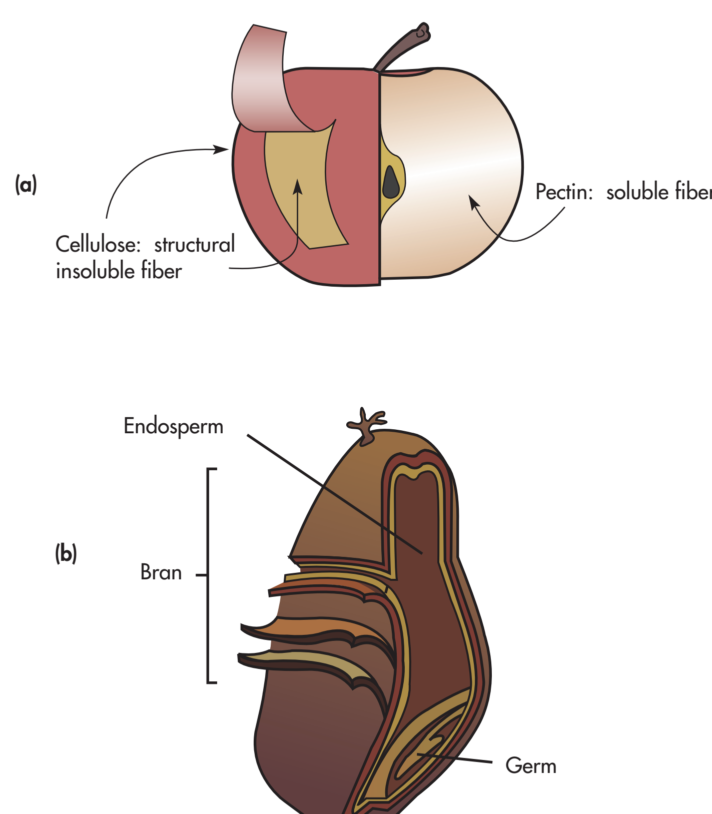


Figure 5-4 Various forms of fiber. (*a*) The skin of an apple consists of the insoluble (also called poorly fermented) fiber cellulose, which provides structure for the fruit. The soluble (also called viscous) fiber pectin "glues" the fruit cells together. (*b*) The outside layer of a wheat kernel is made of layers of bran—insoluble fiber—making this whole grain a good source of fiber. Fruits, vegetables, whole grains, and legumes such as beans are rich in fiber.

Critical | Thinking

Celia decides to go on a diet and buys over-the-counter pills. You look at the ingredients and note that the pills contain psyllium, a word you recognize from the nutrition course you're taking. What advice can you give Celia about the wisdom of using these diet pills?

An outmoded term used for fiber is *crude fiber*. This term arose during the early 1900s to reflect the amount of indigestible foodstuff present in animal feed. The animal feed was boiled for 1 hour in acid and for another hour in an alkaline solution. The remains of that chemical digestion was called crude fiber; it consisted mostly of cellulose and lignins. All other types of fiber were destroyed by the chemical action.

Concept Check

Amylose, amylopectin, and glycogen are all storage forms of glucose, called polysaccharides. Amylose and amylopectin combine in varying proportions to form food starch, such as that found in potatoes and bread. Glycogen is a storage form of glucose in humans. Liver glycogen yields a ready source of blood glucose.

Fiber is essentially the portion of ingested food that remains undigested as it enters the large intestine. Fiber components include cellulose, hemicelluloses, lignins, pectins, gums, and mucilages. There are two general classes of fiber: insoluble and soluble. Insoluble fibers (or poorly fermented fibers) are mostly made up of cellulose, hemicelluloses, and lignins. Soluble fibers (or viscous fibers) are made up mostly of pectins, gums, and mucilages. Both insoluble and soluble fibers are resistant to human digestive enzymes, but bacteria in the large intestine can break down soluble fibers.

In the search for fiber sources, berries are often overlooked. Just ½ cup contains up to 3 g of fiber.

amylase Starch-digesting enzyme from the salivary glands or pancreas.

Carbohydrate Digestion and Absorption

Food preparation can be viewed as the start of carbohydrate digestion because cooking softens the tough fibrous tissue of plants, such as broccoli stalks. When starches are heated, the starch granules swell as they soak up water, making them much easier to digest. All these effects of cooking generally make these foods easier to chew, swallow, and break down during digestion.

Digestion

The enzymatic digestion of starch begins in the mouth, when the saliva, which contains an enzyme called salivary **amylase,** mixes with the starchy products during the chewing of the food. This amylase breaks down starch into many smaller units (e.g., disaccharides, such as maltose) (Fig. 5-5). You can observe this conversion while chewing a saltine cracker. Prolonged chewing of the cracker causes it to taste sweeter as some starch breaks down into the sweeter sugars, such as maltose. Still, food is in the mouth for such a short amount of time that this phase of digestion is negligible. In addition, once the food moves down the esophagus and reaches the stomach, the acidic environment (pH 1-2) inactivates salivary amylase.

After the carbohydrates have reached the small intestine—where the pH of 7 or more is well suited for further carbohydrate digestion—the pancreas releases enzymes, such as pancreatic amylase. The original carbohydrates in a food are present in the small intestine as monosaccharides (mostly any glucose and fructose present as such in food), as well as disaccharides (maltose from starch breakdown, lactose mainly from dairy products, and sucrose from food and that added at the table).

The polysaccharides in the food that were first acted on in the mouth are then digested further by pancreatic amylase. The disaccharides are digested to their monosaccharide units once they reach the wall of the small intestine, where the specialized enzymes on the mucosal cells digest each disaccharide into the monosaccharide components. The enzyme maltase acts on maltose to produce two glucose molecules. Sucrase acts on sucrose to produce glucose and fructose. Lactase acts on lactose to produce glucose and galactose. When considering carbohydrate digestion, you should remember that the key digestive enzymes come from the pancreas and the cells of the intestinal wall.[6]

Intestinal diseases can interfere with the efficient digestion of the sugars maltose, lactose, and sucrose. Some of the carbohydrates therefore escape digestion and are not absorbed. When these unabsorbed carbohydrates eventually reach the large intestine, the bacteria there use the sugars for energy needs, producing acids and gases as by-products

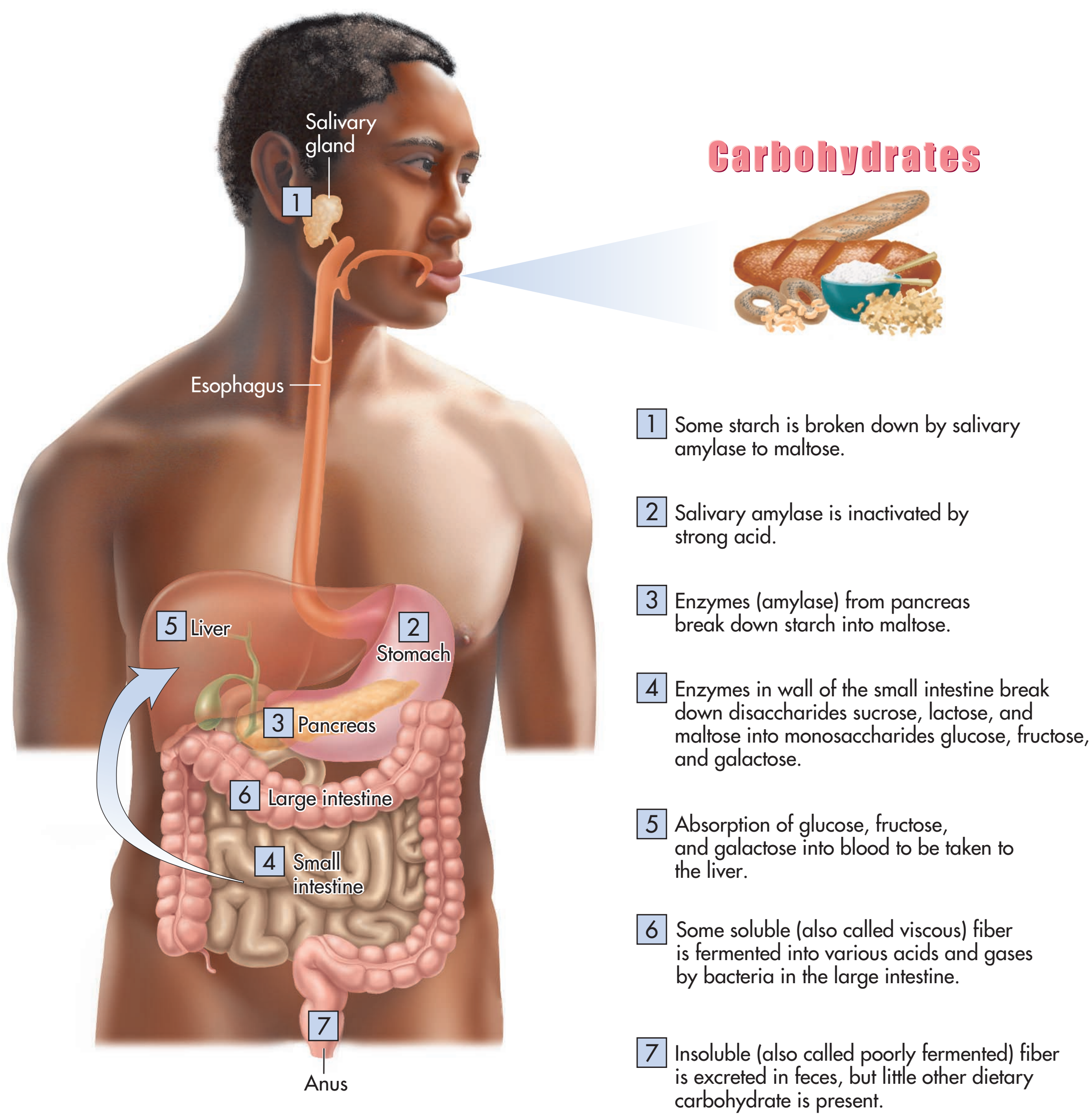


Figure 5-5 Carbohydrate digestion and absorption. Enzymes made by the mouth, pancreas, and small intestine participate in the process of digestion. Most carbohydrate digestion and absorption take place in the small intestine. Note that Chapter 3 covered the physiology of digestion and absorption in detail.

(review Fig. 5-5). If produced in large amounts, these gases can cause abdominal discomfort. People recovering from intestinal disorders, such as diarrhea or bacterial infections, may need to avoid lactose for a few weeks if temporary lactose malabsorption is experienced. A few weeks is sufficient time for the small intestine to resume producing enough lactase enzyme to allow for more complete lactose digestion.

Absorption

Simple sugars found naturally in foods and those formed as by-products of earlier starch digestion in the mouth and small intestine follow an active absorption process (except fructose). Recall from Chapter 3 that this is a process that requires a specific carrier and energy input in order for the substance to be taken up by the absorptive cells in the small intestine. Glucose and its close relative, galactose, undergo active absorption. They are

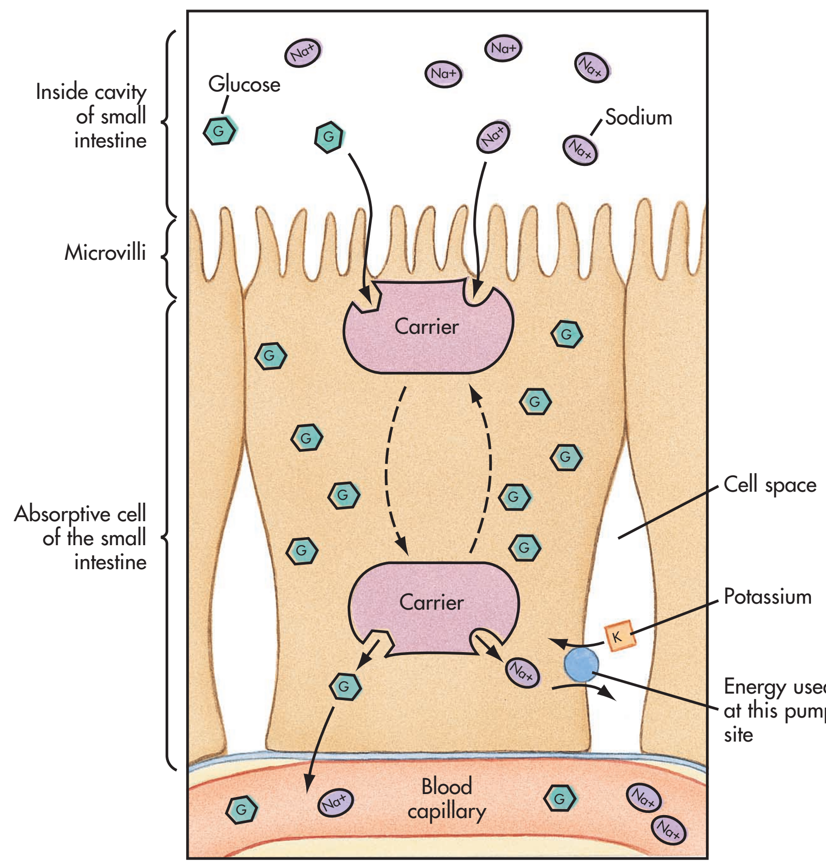


Figure 5-6 Active absorption of glucose. Glucose and sodium pass across the cell membrane of the intestinal absorptive cell in a carrier-dependent, energy-requiring process. The energy is used for maintaining a low concentration of sodium in the cell. Once inside the absorptive cell, glucose can exit by facilitated diffusion down its concentration gradient and enter the bloodstream.

pumped into the absorptive cells along with sodium (Fig. 5-6).[6] The ATP energy used in the process is actually needed to pump the sodium ion back out of the absorptive cell.

Fructose on the other hand is taken up by the absorptive cells via facilitated diffusion. In this case, a carrier is used, but no energy input is needed. This absorptive process is slower than that seen with glucose or galactose. Thus, large doses of fructose are not readily absorbed and can contribute to diarrhea as they remain in the small intestine and attract water via osmosis. (Chapter 11 will discuss osmosis in detail.)

Once glucose, galactose, and fructose enter the intestinal cells, some fructose is metabolized to glucose. The single sugars in the absorptive cells are then transported via the portal vein that goes directly to the liver. The liver then exercises its metabolic options:

- transforming the monosaccharides into glucose and releasing it directly into the bloodstream for transport to organs such as the brain, muscles, kidneys, and adipose tissues
- producing the storage form of carbohydrate: glycogen
- producing fat

Of these three options, producing fat is the least likely.[6]

A small portion of starch (about 10%) escapes digestion. This type of starch is called *resistant starch,* as it resists digestion. The reason for the lack of digestion varies depending on the specific type of resistant starch in a food. This travels down to the large intestine and is fermented there by bacteria. Then some of the starch is absorbed in the form of acids and gases produced by bacterial metabolism, as is true for undigested lactose. As mentioned before, scientists suspect that some of these products actually promote the health of the large intestine by providing a source of energy.

Concept | Check

Carbohydrate digestion is the process of breaking down larger carbohydrates into their absorbable components. The enzymatic digestion of starches begins in the mouth with salivary amylase. Enzymes made by the pancreas and small intestine complete the digestion of carbohydrates to single sugars in the small intestine. Primarily following an active absorption process, the single sugars (glucose and galactose)—either resulting from the digestive process or present in the meal—are taken up by absorptive cells in the intestine. Fructose undergoes facilitated diffusion; once in the absorptive cell most is metabolized to glucose. All the monosaccharides then enter the portal vein and travel to the liver. The liver finally exercises its metabolic options, primarily producing glucose and glycogen from the monosaccharides.

Functions of Glucose and Other Sugars in the Body

Glucose yields energy, but it has many other functions as well. Since the other sugars can generally be converted to glucose, and more complex carbohydrates (e.g., starches) are broken down to yield glucose, the functions described here apply to most carbohydrates.

Glucose is also used to synthesize the ribose and deoxyribose sugars used in RNA and DNA synthesis, respectively.

Yielding Energy

The main function of glucose is to act as a source of energy to body cells. Certain tissues, such as the red blood cells and most parts of the brain, derive almost all of their energy from glucose. In fact, except when the diet contains almost no carbohydrates, the brain and the rest of the **central nervous system** use mostly glucose for fuel. Glucose can also fuel muscle cells and other body cells, but many of these cells usually use fat to meet energy needs.

central nervous system (CNS) The brain and spinal cord portions of the nervous system.

Sparing Protein from Use as an Energy Source

Glucose is protein sparing. That is, dietary protein can be used to make body tissues and to perform other vital processes only when carbohydrate intake provides enough glucose for body needs. Therefore, if you do not consume enough carbohydrate to yield that glucose, your body is forced to make it from other nutrients, such as proteins found in muscle tissue. This process is termed **gluconeogenesis,** which means "production of new glucose" (review Chapter 4 for details). If the process continues for weeks, these organs can become partially weakened. Generally, North Americans consume adequate sources of protein, so sparing protein is not an essential function of carbohydrate in the diet under such conditions. It does become important in some energy-reduced diets and in starvation. (Chapters 7 and 20 discuss specific effects of starvation and famine.)

gluconeogenesis The production of new glucose by metabolic pathways in the cell. Amino acids derived from protein usually provide the carbons for this glucose.

The life-threatening wasting of protein that occurs during long-term fasting (or starvation) has prompted companies that produce products used for rapid weight loss, such as Optifast, to include enough carbohydrate to supply 100 g/day or more. This significantly decreases protein breakdown and thus helps protect vital tissues and organs, including the heart, during rapid weight loss.

Preventing Ketosis

An adequate intake of carbohydrates—glucose, other sugars, or starch—is necessary for the complete metabolism of fats to carbon dioxide (CO_2) and water (H_2O) in the body. A low carbohydrate intake, with the resulting decline in release of the hormone **insulin,**

insulin A hormone produced by beta cells of the pancreas. Insulin increases the synthesis of glycogen in the liver and the movement of glucose from the bloodstream into muscle and adipose cells, among other processes.

Expert Opinion

The Benefits of a High-Carbohydrate Diet

William E. Connor, M.D.

The great civilizations of the world developed and flourished consuming high-carbohydrate diets. The classic examples are the Chinese civilization, based on rice; the Egyptian and Babylonian cultures, which consumed wheat; and, in the Americas, the Maya, Inca, and Aztec peoples, whose staples were corn and beans. Except for the affluent countries of the Western world, the majority of the world's population continues to consume a high-carbohydrate diet derived from cereals, legumes, vegetables, and fruits. Indeed, typical amounts of carbohydrates consumed are large, in the range of 400 to 500 g/day, predominantly as starch or other polysaccharides, and constituting from 75 to 80% of the total energy intake. An example of a culture that my colleagues and I have studied is the Tarahumara Indians of Mexico; they have consumed a high-carbohydrate diet for generations, with the principal foods being corn, beans, and wild plants. Their diet contains ample protein and is nutritionally adequate.

Ecologically, a high-carbohydrate diet makes better use of the world's resources. Cereal crops and legumes require about one-fifth of the resources needed to yield the same energy that beef would require. Thus, the available resources of the world would not be sufficient to produce the high-animal-fat diet of North America for everyone.

Historically (and today) a high-carbohydrate diet has been based largely on plant foods that contain starch as the carbohydrate source. The only plant exception is fruit, in which the carbohydrates are glucose, fructose, and sucrose, as well as pectin, a fiber. Even nuts, which contain about 50% fat in terms of total energy content, also contain a considerable amount of carbohydrate, 20 to 30% of total energy. Foods derived from animals, on the other hand, contain very little or no carbohydrate, instead being composed of protein and fat.

Some hunter-gatherers of the past consumed very little carbohydrate because plant foods were simply not available. The Eskimo of the Arctic are the classic example; most of their calories were derived from seal, fish, whale, caribou, and other land animals. However, for most humans, the only time in life when a high-carbohydrate diet is not consumed is during infancy, when the diet of human milk or infant formulas contains about 50% of the energy from fat and is fairly low in carbohydrate, about 40% of the energy content. Even in the United States, adults consume 45 to 50% of the total energy as carbohydrate. For children and adults, practical high-carbohydrate diets usually contain from 60 to 65% of total energy, an amount suggested by the Coronary Heart Disease Prevention Group at the Oregon Health Sciences University. Such an alternative diet would contain protein as 15% of energy, fat as 20 to 25% of energy, and cholesterol intake of 100 mg/day or less. This high-carbohydrate diet is designed to prevent not only cardiovascular disease but also other diseases associated with an affluent lifestyle, such as cancer.

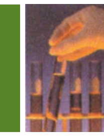
From the health point of view, a high-carbohydrate diet consisting largely of plant foods is a diet that is rich in fiber, minerals, vitamins, saponins (a phytochemical; see Chapter 2), sitosterol (see Chapter 6 for details), and essential fatty acids. It is thus a diet high in bulk from fiber and, so, weighs considerably more than a low-carbohydrate diet. It is a diet rich in antioxidants, such as vitamin E, ascorbic acid, and carotenoids, especially lutein and zeaxanthin. These are important in preventing cardiovascular disease and cancer, and in delaying the aging process. A high-carbohydrate diet is also rich in folate; this is sometimes in short supply in the highly purified

leads to release of fatty acids from adipose cells and subsequent incomplete breakdown of the fatty acids in the liver. This then results in formation of ketone bodies—acetoacetic acid and its derivatives. Chapter 4 covered this condition in detail, called ketosis.

In starvation, people do not consume enough carbohydrate, so ketone bodies soon appear in the blood. Again, this is the normal metabolic response to a fuel shortage. Over time, part of the brain and other tissues can use these ketone bodies for fuel. In fact, the use of ketone bodies by the brain and other organs, such as the heart, is an important adaptive mechanism for survival during starvation. If part of the brain could not use ketone bodies, the body would be forced to produce much more glucose from protein to support the brain's energy needs. The resulting self-cannibalization would rapidly break down the muscles, heart, and other organs, severely limiting the body's ability to tolerate starvation.

In untreated **type 1 diabetes,** excessive production of ketone bodies can occur, partly because there is not enough insulin to allow for normal glucose metabolism. In

type 1 diabetes A form of diabetes in which the person with the disease is prone to ketosis and requires insulin therapy.



North American diet. Folate helps control abnormal homocysteine levels—an emerging cardiovascular risk factor. Since it comes from plant foods, the high-carbohydrate diet has another advantage in that it is typically low in fat, low in saturated fat, and low in cholesterol content. This means that populations that consume a high-carbohydrate diet have low blood cholesterol and LDL-cholesterol, as well as a low incidence of cardiovascular disease. A lower-fat diet would reduce the amount of fat in the bloodstream after a meal; this fat contains particles that can contribute to atherosclerosis (see Chapter 6 for details).

Fiber includes several carbohydrates that are largely indigestible by the human gut, such as cellulose, hemicellulose, lignin, pectin, and beta-glucans. Fiber is found only in plants and is common in unprocessed cereals, legumes, vegetables, and fruits. In ruminant animals, fiber is completely digested and is used as a source of energy. In humans, fiber contributes little to the energy content of the diet but promotes satiety through its bulk and promotes proper functioning of the colon and rectum. Fiber may help prevent certain diseases of the colon and rectum, such as appendicitis, hemorrhoids, and diverticulitis.

Sugar is a conspicuous component of the North American diet, perhaps now even increasing from the usual amount of about 20% of total energy intake. Sugar, of course, includes sucrose, fructose, and glucose. Fruits are natural sources of sugars but would supply only a small amount of sugars vis-à-vis the total energy intake and would contribute valuable nutrients. The addition of large quantities of sucrose and fructose to processed food, baked goods, and candies would supply only energy, without the other nutritive benefits of fruit consumption. In the high-carbohydrate diet I recommend, most of the carbohydrate would be supplied by starch. The consumption of sugar would even be reduced from the current 20% of energy to 10 to 15% of energy intake. It would be expected that incidence of dental caries then would be reduced as sugar intake declined.

A high-carbohydrate diet should emphasize whole grains within the breads, cereals, rice, and pasta group of the Food Guide Pyramid.

Another advantage of a high-carbohydrate diet based on plant foods is in the prevention of obesity. There is good evidence that North Americans lose weight more easily with a high-carbohydrate diet and are less inclined to gain weight than are those whose carbohydrate intake is lower and fat intake is higher. The energy cost of metabolizing a high-starch source of carbohydrate (e.g., corn or beans) is much higher than the energy expenditure necessary to metabolize a dense nutrient, such as meat, or the fat from french fries or even olive oil. Finally, the advantages of a high-carbohydrate, lower-fat diet apply in the control of hypertension.

Given all these benefits, a reexamination of the relative amount of carbohydrate in one's diet is warranted. Much research supports the recommendation to increase complex carbohydrates from vegetables, whole grains, beans, and fruits.

Dr. Connor is a professor of medicine in the Division of Endocrinology, Diabetes, and Clinical Nutrition at the Oregon Health Sciences University, Portland, Oregon. He is a former president of the American Society for Clinical Nutrition and a former member of the Food and Nutrition Board of the National Academy of Sciences.

such patients, the resulting ketosis can cause numerous complications (see the Nutrition Perspective at the end of this chapter for further discussion of diabetes).

Functions of Fiber

Fiber supplies mass to the feces, making elimination much easier. This is especially true for insoluble fibers. When enough fiber is consumed, the stool is large and soft because many types of plant fibers attract water. The larger size stimulates the intestinal muscles, which aids elimination. Consequently, less pressure is necessary to expel the stool.

When too little fiber is eaten, the opposite can occur: the stool may be small and hard. Constipation may result, which can force one to exert excessive pressure in the large intestine during defecation. This high pressure can force parts of the large intestine (colon) wall out from between the surrounding bands of muscle, forming small

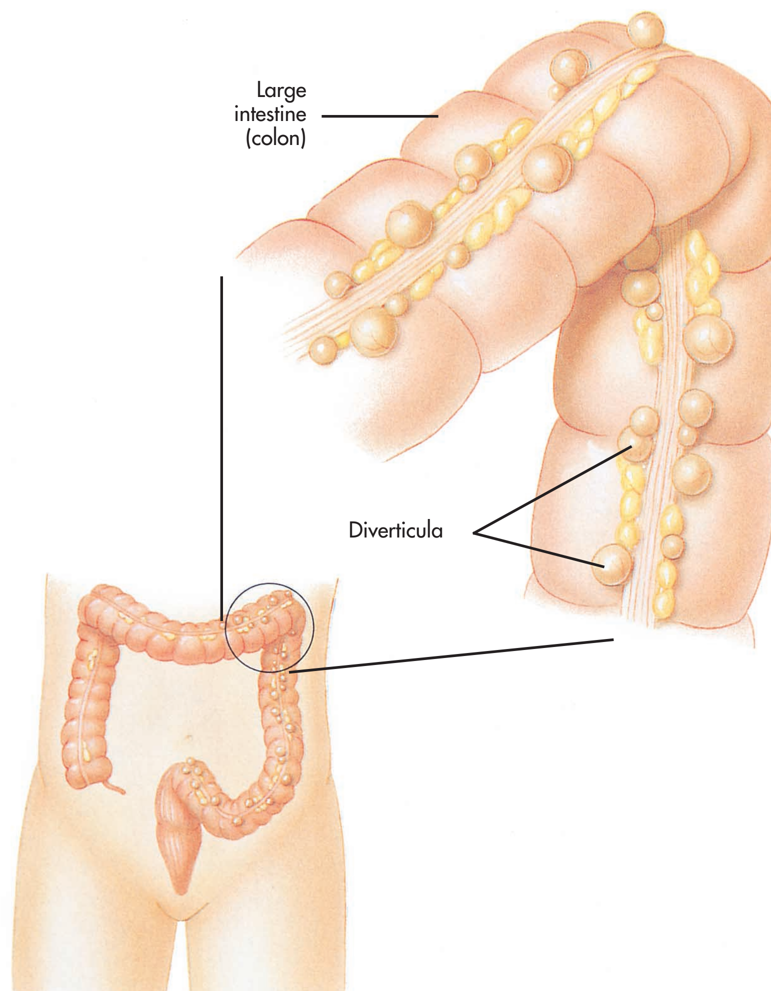


Figure 5-7 Diverticula in the colon. A low-fiber diet increases the risk of developing diverticula. About ⅓ of people over age 45 have the disease, while ⅔ of people over 85 do.
Illustration by William Ober.

diverticula Pouches that protrude through the exterior wall of the large intestine.

hemorrhoid A pronounced swelling of a large vein, particularly veins found in the anal region.

diverticulosis The condition of having many diverticula in the large intestine.

diverticulitis An inflammation of the diverticula caused by acids produced by bacterial metabolism inside the diverticula.

Critical | Thinking

Karla has a family history of colon cancer, and at age 20 she is curious about the lifestyle factors she can employ to prevent developing the disease. What advice would you provide her?

pouches called **diverticula.** Multiple diverticula are normally present (Fig. 5-7). **Hemorrhoids** may also result from excessive straining during defecation (see Chapter 3).

Diverticula are asymptomatic in about 80% of affected people; that is, they are not noticeable. The asymptomatic form of this disease is called **diverticulosis.** If the diverticula become filled with food particles, such as hulls and seeds, they may eventually become inflamed, a condition known as **diverticulitis.** Intake of fiber then should be reduced to limit further bacterial activity. Once the inflammation subsides, a high-fiber diet is resumed to ease stool elimination and reduce the risk of a future attack.

Additional health benefits can accrue from the consumption of fiber. A diet high in fiber likely aids weight control and reduces the risk of developing obesity.[10] The bulky nature of high-fiber foods fills us up without yielding much energy. Increasing intake of foods rich in fiber is one strategy for remaining satisfied after a meal (review the discussion on energy density in Chapter 2).

Over the past 30 years, many population studies have shown a link between increased fiber intake and a decrease in colon cancer development. However, recent research has questioned the relationship between intake of fiber and colon cancer development.[6] Currently, most of the research on colon cancer is focusing on the potential preventive effects of vegetable intake; regular exercise; the use of aspirin and related pain medications; and adequate folate, selenium, and calcium intakes. Smoking, obesity in men, and processed red meat intake are under study as potential causative factors.[15] Overall, the health benefits to the colon that stem from a high-fiber diet are probably due mostly to the nutrients that are commonly part of high-fiber foods, such as vitamins, minerals, phytochemicals, antioxidants, and in some cases essential fatty acids. Thus it is more advisable to increase fiber intake using fiber-rich foods, rather than mostly relying on fiber supplements.

When consumed in large amounts, soluble fibers slow glucose absorption from the small intestine, and so contribute to better blood glucose regulation.[14] This effect can be helpful in the treatment of diabetes. In fact, adults whose main carbohydrate source is low-fiber foods are much more likely to develop diabetes than those who have high-fiber diets (see the Nutrition Perspective at the end of this chapter).[8]

A high intake of soluble fiber also inhibits absorption of cholesterol and bile acid (cholesterol-rich) from the small intestine, thereby reducing blood cholesterol and possibly reducing the risk of cardiovascular disease and gallstones.[6, 13] The short-chain fatty acids resulting from bacterial degradation of soluble fiber (e.g., proprionic acid) also probably reduce cholesterol synthesis in the liver. In addition, the slower glucose absorption that occurs with diets high in soluble fiber is linked to a decrease in insulin release. Since insulin stimulates cholesterol synthesis in the liver, this reduction in insulin may contribute to the ability of soluble fiber to lower blood cholesterol. Overall, a fiber-rich diet containing fruits, vegetables, beans, and whole grains (including whole-grain breakfast cereals) is advocated as part of a strategy to reduce cardiovascular disease (coronary heart disease and stroke) risk.[1, 6]

Oatmeal is a rich source of soluble (also called viscous) fiber, namely beta-glucan. FDA allows a health claim for the benefits of oatmeal to lower blood cholesterol that arise from the effects of this soluble fiber.

Concept | Check

Carbohydrates provide glucose for the energy needs of red blood cells and parts of the brain and central nervous system. Eating little carbohydrates forces the production of glucose (via gluconeogenesis), using carbons from amino acids. These amino acids are derived from the breakdown of proteins in body organs. An inadequate carbohydrate intake also inhibits efficient fat metabolism, which in turn can lead to ketosis.

Fiber forms a vital part of the diet by adding mass to the stool, which eases elimination. It also helps in weight control and reduces the risk of developing obesity and cardiovascular disease. Soluble fiber can also be useful for controlling blood glucose in patients with diabetes and in lowering blood cholesterol. Whole grains, vegetables, beans, and fruits are excellent sources of fiber.

Recall from Chapter 2 that FDA has approved the following claim: "Diets rich in whole-grain foods and other plant foods and low in total fat, saturated fat, and cholesterol may decrease the risk for cardiovascular (heart) disease and certain cancers."

Carbohydrate Needs

The RDA for carbohydrates is 130 g/day for adults. This is based on the amount needed to supply adequate glucose for the central nervous system, without having to rely on partial replacement of glucose by ketone bodies. Exceeding this amount somewhat is fine; the Food and Nutrition Board recommends that carbohydrate intake should range from 45 to 65% of total energy intake.[6] North Americans consume about 180 to 330 g of carbohydrates per day. The top five carbohydrate sources for U.S. adults are white bread, soft drinks, cookies and cakes (including doughnuts), sugars/syrups/jams, and potatoes. Clearly, many of us (teenagers included) should take a closer look at our main carbohydrate sources and strive to improve these from a nutritional standpoint.[12]

In North America, carbohydrates supply about 50% of dietary energy intake for adults. Worldwide, however, carbohydrates account for about 70% of all energy consumed. In some countries, carbohydrates account for up to 80% of the energy consumed.

Advice from the Dietary Guidelines regarding carbohydrates is:

- Choose a variety of grains daily, especially whole grains.
- Choose a variety of fruits and vegetables daily.
- Choose beverages and foods that limit your intake of sugars.

How Much Fiber Do We Need?

The Adequate Intake for fiber for adults is 25 g/day for women and 38 g/day for men. This is based on a goal of 14 g/1000 kcal in a diet. The rationale for the Adequate Intake is the ability of fiber to reduce risk of cardiovascular disease (and likely many cases of diabetes). The Daily Value used for fiber on food and supplement labels is 25 g for a 2000

Figure 5-8 Reading the Nutrition Facts on food labels helps us choose more nutritious foods. Based on the information from these nutrition labels, which cereal is the better choice for breakfast? Consider the amount of fiber in each cereal. Do the ingredient lists give you any clues? (Note: Ingredients are always listed in descending order by weight on a label.) When choosing a breakfast cereal, it is generally wise to focus on those that are rich sources of fiber. Simple sugar content can also be used for evaluation. However, sometimes this number does not reflect added sugar but simply the addition of fruits, such as raisins, complicating the evaluation.

Nutrition Facts

Serving Size 1 cup (55g/2.0 oz.)
Servings Per Container 10

Amount Per Serving	Cereal	Cereal with ½ Cup Vitamins A & D Skim Milk
Calories	170	210
Calories from Fat	10	10
		% Daily Value**
Total Fat 1.0g*	**2%**	**2%**
Sat. Fat 0g	**0%**	**0%**
Cholesterol 0mg	**0%**	**0%**
Sodium 300mg	**13%**	**15%**
Potassium 340mg	**10%**	**16%**
Total Carbohydrate 43g	**14%**	**16%**
Dietary Fiber 7g	**28%**	**28%**
Sugars 16g		
Other Carbohydrate 20g		
Protein 4g		
Vitamin A	15%	20%
Vitamin C	20%	22%
Calcium	2%	15%
Iron	65%	65%
Vitamin D	10%	25%
Thiamin	25%	30%
Riboflavin	25%	35%
Niacin	25%	25%
Vitamin B_6	25%	25%
Folate	30%	30%
Vitamin B_{12}	25%	35%
Phosphorus	20%	30%
Magnesium	20%	25%
Zinc	25%	25%
Copper	10%	10%

*Amount in cereal. One half cup skim milk contributes an additional 40 calories, 65mg sodium, 6g total carbohydrate (6g sugars), and 4g protein.
**Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Potassium		3,500mg	3,500mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Wheat bran with other parts of wheat, raisins, sugar, corn syrup, salt, malt flavoring, glycerin, iron,niacinamide, zinc oxide, pyridoxine hydrochloride (vitamin B_6), riboflavin (vitamin B_2), vitamin A palmitate, thiamin hydrochloride (vitamin B_1), folic acid, vitamin B_{12}, and vitamin D.

Nutrition Facts

Serving Size: 1 Cup (40g/1.5 oz.)
Servings Per Package: About 14

Amount Per Serving	1 Cup Cereal	Cereal With ½ Cup Skim Milk
Calories	160	200
Calories from Fat	0	5
		%Daily Value**
Total Fat 0g*	**0%**	**1%**
Saturated Fat 0g	**0%**	**1%**
Cholesterol 0mg	**0%**	**1%**
Sodium 55mg	**2%**	**4%**
Potassium 80mg	**2%**	**8%**
Total Carbohydrate 35g	**9%**	**11%**
Dietary Fiber 1g	**4%**	**4%**
Sugars 20g		
Other Carbohydrate 14g		
Protein 2g		
Vitamin A	25%	30%
Vitamin C	0%	2%
Calcium	0%	15%
Iron	10%	10%
Vitamin D	10%	20%
Thiamin	25%	25%
Riboflavin	25%	35%
Niacin	25%	25%
Vitamin B6	25%	25%
Folate	25%	25%
Vitamin B12	25%	30%
Phosphorus	4%	15%
Magnesium	4%	8%
Zinc	10%	10%
Copper	2%	2%

*Amount in Cereal. One-half cup skim milk contributes an additional 65mg sodium, 6g total carbohydrate (6g sugars), and 4g protein.
**Percent Daily Values are based on a 2000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Potassium		3,500mg	3,500mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Wheat, Sugar, Corn Syrup, Honey, Caramel Color, Partially Hydrogenated Soybean Oil, Salt, Ferric Phosphate, Niacinamide (Niacin), Zinc Oxide, Vitamin A (Palmitate), Pyridoxine Hydrochloride (Vitamin B6), Riboflavin, Thiamin Mononitrate, Folic Acid (Folate),Vitamin B12 and Vitamin D.

Whole grains are an excellent source of fiber.

Healthy People 2010 has the following goals related to carbohydrate intake:

- Increase the proportion of persons age 2 years and older who consume at least six daily servings of grain products, with at least three being whole grains.
- Increase the proportion of persons age 2 years and older who consume at least two daily servings of fruit.
- Increase the proportion of persons age 2 years and older who consume at least three daily servings of vegetables, with at least one-third being dark green or orange vegetables.

kcal diet. In North America, the average whole-grain intake is less than one serving per day; fiber intake averages 13 g/day for women and 17 g/day for men. This low intake is attributed to the lack of knowledge on the benefits of whole grains, as well as the lack of ability to recognize whole-grain products at the time of purchase. Thus, most of us should increase our fiber intake. At least three servings of whole grains per day is recommended. Eating a high-fiber cereal ($\geq$ 3 g of fiber per serving) for breakfast is one easy

Table 5-2 Sample of Menus Containing 1600 kcal and 25 g of Fiber, and 2000 kcal and 38 g of Fiber*

	25 g Fiber			38 g Fiber		
Menu	**Serving Size**	**Carbohydrate Content (g)**	**Fiber Content (g)**	**Serving Size**	**Carbohydrate Content (g)**	**Fiber Content (g)**
Breakfast						
Orange juice (with pulp)	1 cup	28	0.5	1 cup	28	0.5
Wheaties	¾ cup	17	2	¾ cup	17	2
2% milk	½ cup	6	—	½ cup	6	—
Whole-wheat toast	1 slice	13	2	1 slice	13	2
Margarine	1 tsp	—	—	1 tsp	—	—
Coffee		1	—		1	—
Lunch						
Lean ham	2 oz	—	—	2 oz	—	—
Whole-wheat bread	2 slices	26	4	2 slices	26	4
Mayonnaise	2 tsp	2	—	2 tsp	2	—
Lettuce	¼ cup	—	0.2	¼ cup	—	0.2
Cooked white beans	⅓ cup	15	4	1 cup	45	12
Pear (with skin)	½	12	2	1	25	4
1% milk	½ cup	6	—	½ cup	6	—
Snack						
Carrot (as carrot sticks)	1	8	2	1	8	2
Dinner						
Broiled chicken (no skin)	3 oz	—	—	3 oz	—	—
Baked potato (large, with skin)	½	15	1.5	1	30	3
Margarine	1½ tsp	—	—	1½ tsp	—	—
Cooked green beans	1 cup	10	4	1 cup	10	4
Margarine	½ tsp	—	—	½ tsp	—	—
1% milk	1 cup	12	—	1 cup	12	—
Apple (with peel)	½	16	1.8	1	32	3.7
Snack						
Raisin bagel	1	39	1.2	1	39	1.2
Total		226 g	25 g		300 g	38 g

*The overall diet pattern is based on the Food Guide Pyramid. Breakdown of approximate energy content: carbohydrate, 55%; protein, 20%; fat, 25%.

way to increase fiber intake (Fig. 5-8). As mentioned before, whole-food sources such as cereals, not bran supplements, are preferable because foods provide a broader variety of nutrients. This is especially true for many natural high-fiber foods—whole grains, fruits, vegetables, and beans.

Table 5-2 shows a diet containing 25 and 38 g of fiber within a very moderate energy intake. Diets to meet the fiber recommendations are possible if you like whole-wheat bread, fruits, vegetables, and beans. Use Table 5-3 to estimate the fiber content of your diet. What is *your* fiber score?

Table 5-3 Estimate Your Fiber Intake

To roughly estimate your daily fiber consumption, determine the number of servings of each food category listed below that you consumed yesterday. Multiply the serving amount by the value listed and then add up the total amount of fiber. How does your total fiber intake for yesterday compare with the general recommendation of 25 to 38 g of fiber per day for women and men, respectively?

Food	Servings	Grams
Vegetables (serving size: 1 cup raw leafy greens or 1/2 cup other vegetables)	______ × 2	
Fruits (serving size: 1 whole fruit; ½ grapefruit; ½ cup berries or cubed fruit; ¼ cup dried fruit)	______ × 2.5	
Beans, lentils, split peas (serving size: ½ cup cooked)	______ × 7	
Nuts, seeds (serving size: ¼ cup; 2 tbsp peanut butter)	______ × 2.5	
Whole grains (serving size: 1 slice whole-wheat bread; ½ cup whole-wheat pasta, brown rice, or other whole grain; ½ each bran or whole-grain muffin)	______ × 2.5	
Refined grains (serving size: 1 slice bread, ½ cup pasta, rice, or other processed grains; and ½ each refined bagels or muffins)	______ × 1	
Breakfast cereals (serving size: check package for serving size and amount of fiber per serving)	______ × grams fiber per serving	
Total Grams of Fiber =	____________	

Adapted from Fiber: Strands of protection. *Consumer Reports on Health,* p. 1, August 1999.

Currently, recommendations for carbohydrate intake vary widely in the scientific literature and popular press. Aside from the low intakes used to induce ketosis as part of a plan for quick weight loss (note that this diet is not recommended for long term use; see Chapter 13), recommendations vary from 45 to 60% of energy intake by the Food and Nutrition Board to more than 70% in the *Pritikin Program* and *Eat More, Weigh Less* plan. The Nutrition Facts panel on food labels uses 60% of energy intake as the standard for recommended carbohydrate intake. In addition, one recommendation on which almost all experts agree is that one's carbohydrate intake should be base primarily on fruits, vegetables, whole grains, and beans, not mostly on refined grains and sugar.[2] Dr. William Connor discussed this in detail in the Expert Opinion on page 150.

Only when a person's blood triglycerides are high is a carbohydrate-rich diet not recommended. (This will be covered further in Chapter 6 with respect to the **Metabolic Syndrome,** also called Syndrome X. Note that about 25% of North American adults have this condition.[7]) Actually, the chief culprits in this case are not carbohydrates as a class of nutrients but excessively large meals full of foods both rich in simple sugars and refined starches and low in fiber, coupled with little physical activity.[7] These practices should not form the basis of daily habits, but unfortunately, they do for many adults.[12]

Metabolic Syndrome A condition in which the person has insulin resistance, hypertension, increased blood triglycerides, and decreased HDL cholesterol levels. This condition is usually accompanied by obesity, lack of physical activity, and a diet high in refined carbohydrates. Also called Syndrome X.

Note that manufacturers list enriched white (refined) flour as wheat flour on food labels. Most people think that if "wheat bread" is on the label, they are buying a whole-wheat product. Not so. If the label does not list "whole-wheat flour" first, then the product is not primarily a whole-wheat bread and thus does not contain as much fiber as it could. Careful reading of labels is important in the search for more fiber—look especially for whole grains.

Keep in mind, however, that any nutrient can lead to health problems when consumed in excess, including carbohydrate and fiber. High carbohydrate, high fiber, and low fat does not mean zero calories. Carbohydrates help moderate energy intake in comparison with fats, but the contribution of high-carbohydrate foods to total energy intake still has to be accounted for.

Problems with High-Fiber Diets

Very high intakes of fiber—for example, 60 g/day—can pose some health risks and, so, require close physician supervision if used. A high fiber intake especially requires a high fluid intake. Not consuming enough fluid with the fiber can leave the stool very hard and make it difficult and painful to eliminate. Large amounts of fiber provide certain components that may also bind essential minerals, such as zinc and iron (see Chapter 12).[6]

High-fiber diets often contribute to intestinal gas and occasionally to the production of fiber balls, called **phytobezoars,** in the stomach. These have been found in diabetic patients and in older adults who consume large amounts of fiber. Phytobezoars can lead to blockage of intestinal flow. Fiber may also contribute to blockages in the intestine when intake is high and sufficient fluid is not consumed. Finally, large amounts of fiber may add such an excess of bulk to a child's diet that energy intake is reduced; fiber fills the stomach before food intake meets energy needs.

phytobezoars Pellets of dietary fiber, characteristically found in the stomach.

Moderating Intake of Simple Sugars Is Important for Many of Us

The sweetness of sugars improves the taste of many foods, such as grapefruit (Table 5-4). A small amount of sugars in the diet is fine. In addition, sugars provide certain functional properties to foods, such as texture, body, and browning capacity.[6] Nutrition experts suggest that sugars added to foods should provide no more than about 10% of total energy intake daily, with an upper limit of 25%.[6] Beyond this limit diet quality typically declines, such as with calcium intake. The more moderate intake corresponds to a maximum of about 50 g (or 12 teaspoons) of sugars per day, based on a 2000 kcal diet. On average, North Americans eat about 82 g of added sugars daily, amounting to about 16% of energy intake. Added sugars are defined as sugars and syrups that are added to foods during processing or preparation. Major sources of added sugars include soft drinks, cakes, cookies, fruit punch, and dairy desserts. The specific sugars added include white sugar, brown sugar, corn syrup, fructose, and other sources. Not included are sugars that naturally occur in foods such as lactose in milk and fructose in fruit. Table 5-5 suggests ways to reduce intake of sugars. For many of us, this would be a healthful practice.

Most of the sugars that we eat come from foods and beverages to which sugar has been added during processing and/or manufacture. The major sources are soft drinks, candy, cakes, cookies, pies, fruitades, and dairy desserts, such as ice cream. The rest of the sugar in our diets is present naturally in foods, such as fruits, or comes from the sugar bowl. During food processing, the sugar content is often increased. The more processed the food, generally the higher the simple-sugar content.

In the United States, a *juice* is defined as a fruit or vegetable beverage with no added sugars. Some fruits, such as cranberries and grapefruits, are so tart that sugar is added to make them palatable as a beverage. For example, cranberry juice *cocktail* technically isn't a juice because of the sugar added during manufacturing. Its sugar content is comparable to true juices, though, but is still very nutritious.

Problems with High-Sugar Diets

The main problem with consuming an overabundant amount of sugar is that it provides empty calories; this translates to a decline in the nutritional value of a diet.

There are many forms of sugar on the market. Used in many foods, together they contribute to our daily intake of approximately 82 g (20 tsp) of added sugars in our diets.

Stevia comes from a South American shrub; it is 100 to 300 times sweeter than sucrose and provides zero calories. This is a sweetener that has been used in small amounts by the Japanese since the 1970s. FDA has not approved the use of stevia in foods, but stevia can be purchased at health-food stores as a dietary supplement.

There is a widespread notion that high sugar intake by children causes hyperactivity, typically part of the syndrome called *attention deficit hyperactive disorder (ADHD)*. However, most researchers find that sucrose may actually have the opposite effect.[6] A high-carbohydrate meal, if also low in protein and fat, has a calming effect and induces sleep; this effect may be linked to changes in the synthesis of certain neurotransmitters in the brain, such as serotonin (see Chapter 13). If there is a problem, it is probably the excitement or tension in situations in which high sugar-rich foods are served, such as at birthday parties and on Halloween.

Table 5-4 The Sweetness of Sugars and Alternative Sweeteners

Type of Sweetener	Relative Sweetness* (Sucrose = 1)	Typical Sources
Sugars		
Lactose	0.2	Dairy products
Maltose	0.4	Sprouted seeds
Glucose	0.7	Corn syrup
Sucrose	1.0	Table sugar, most sweets
Invert sugar†	1.3	Some candies, honey
Fructose	1.2–1.8	Fruit, honey, some soft drinks
Sugar Alcohols		
Sorbitol	0.6	Dietetic candies, sugarless gum
Mannitol	0.7	Dietetic candies
Xylitol	0.9	Sugarless gum
Alternative Sweeteners		
Cyclamate	30	Not currently in use in the United States
Aspartame	180	Diet soft drinks, diet fruit drinks, sugarless gum, powdered diet sweetener
Acesulfame-K	200	Sugarless gum, diet drink mixes, powdered diet sweeteners, puddings, gelatin desserts
Saccharin (sodium salt)	300	Diet soft drinks
Sucralose	600	Diet soft drinks, tabletop use, sugarless gums, jams, frozen desserts
Neotame	7000 to 13,000	Tabletop sweetener, baked goods, frozen desserts, jams and jellies

From the American Dietetic Association, 1993, and other sources.

*On a per gram basis

†Sucrose broken down into glucose and fructose

Diet Quality

Overcrowding the diet with sweet treats can leave little room for important, nutrient-dense foods, such as fruits and vegetables. Children and teenagers are at the highest risk for overconsuming empty calories in place of nutrients that are essential for growth. Many children and teenagers are drinking an excess of sugared soft drinks and other sugar-containing beverages and much less milk than ever before. Milk contains calcium and vitamin D, both of which are essential for bone health; therefore, this exchange of soft drinks for milk can compromise bone health.

Supersizing beverages is also a growing problem; for example, in the 1950s a typical serving size of soft drink was a 6½ oz bottle, and now a 20 oz plastic bottle is a typical serving. This one change contributes 170 extra kcal to the diet. Most convenience stores now offer cups that will hold 64 oz of soft drinks. Filling up on sugared soft drinks in place of foods is not a healthy practice, but enjoying an occasional soft drink or limiting intake to one 12 oz serving a day is generally fine. Switching to diet soft drinks would spare the simple sugar calories, but still lacks in nutritional value, except for the fluid.

The sugar found in cakes, cookies, and ice cream supplies many extra calories that promote weight gain, unless an individual is physically active. Today's low-fat and fat-

Table 5-5 Suggestions for Reducing Simple-Sugar Intake

At the Supermarket
• Read ingredient labels. Identify all the added sugars in a product. Select items lower in total sugar when possible.
• Buy fresh fruits or fruits packed in water, juice, or light syrup, rather than those packed in heavy syrup.
• Buy fewer foods that are high in sugar, such as prepared baked goods, candies, sugared cereals, sweet desserts, soft drinks, and fruit-flavored punches. Substitute vanilla wafers, graham crackers, bagels, English muffins, and diet soft drinks, for example.
• Buy reduced-fat microwave popcorn to replace candy for snacks.
In the Kitchen
• Reduce the sugar in foods prepared at home. Try new recipes or adjust your own. Start by reducing the sugar gradually until you've decreased it by one-third or more.
• Experiment with spices such as cinnamon, cardamom, coriander, nutmeg, ginger, and mace to enhance the flavor of foods.
• Use home-prepared items (with less sugar) instead of commercially prepared ones that are higher in sugar.
At the Table
• Use less of all sugars. This includes white and brown sugars, honey, molasses, and syrups.
• Choose fewer foods high in sugar, such as prepared baked goods, candies, and sweet desserts.
• Reach for fresh fruit instead of a sweet for dessert or between-meal snacks.
• Add less sugar to foods—coffee, tea, cereal, and fruit. Get used to using half as much; then see if you can cut back even more.
• Cut back on the number of sugared soft drinks, punches, and fruit juices you drink. Substitute water, diet soft drinks, and whole fruits rather than fruit juice.

Modified from USDA *Home and Garden Bulletin* No. 232-5, 1986.

Many foods we enjoy are sweet. These should be eaten in moderation.

free snack products usually contain lots of added sugar to produce a product with an acceptable taste. The result is to produce a high-calorie food that is equal to or greater in energy content than the high-fat food product it was designed to replace. Following the recommendation of having no more than 10% of added sugars is easier if sweet desserts such as cakes, cookies, and ice cream (full and reduced fat) are consumed sparingly.[12]

Dental Caries

Sugars in the diet (and starches that are readily fermented in the mouth, such as crackers and white bread) also increase the risk of developing **dental caries.**[6] Caries are formed when sugars and other carbohydrates are metabolized into acids by bacteria that live in the mouth (Fig. 5-9). These acids dissolve the tooth enamel and underlying structure. Bacteria also use the sugars to make plaque, a sticky substance that both adheres bacteria to teeth and diminishes the acid-neutralizing effect of saliva.

dental caries Erosion in the surface of a tooth caused by acids made by bacteria as they metabolize sugars.

The worst offenders in terms of dental caries are sticky and gummy foods high in sugars, such as caramel, because they stick to the teeth and supply the bacteria with a long-lived carbohydrate source. These long-lived carbohydrates are termed **cariogenic** (*cario* means "cavity"). Although liquid sugar sources (e.g., fruit juices) are not as potent at causing dental caries as sticky and gummy foods, they still warrant consideration. Some experts caution that sports drinks may also lead to dental caries due to their acid content.

cariogenic Literally, "caries-producing"; a substance, often carbohydrate-rich (such as caramel), that promotes dental caries.

Snacking regularly on sugary foods is also likely to cause caries because it gives the bacteria on the teeth a steady source of carbohydrate from which to continually make

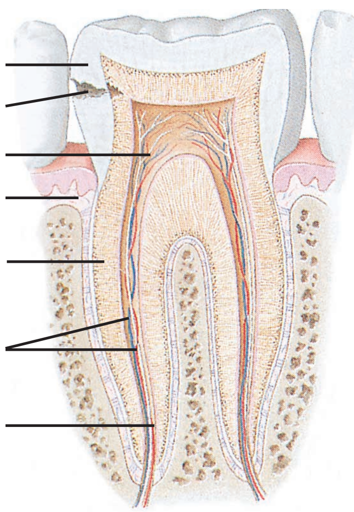


Figure 5-9 Dental caries. Bacteria can collect in various areas on a tooth. Using simple sugars such as sucrose, bacteria then create acids that can dissolve tooth enamel, leading to caries. If the caries process progresses and enters the pulp cavity, damage to the nerve and resulting pain are likely. The bacteria also produce plaque whereby they adhere to the tooth surface.

acid. Sugared gum chewed between meals is a prime example of a poor dental habit. Still, sugar-containing foods are not the only foods that allow acid production by the bacteria in the mouth. As mentioned, if starch-containing foods (e.g., crackers and bread) are held in the mouth for a long time, they can be acted on by enzymes in the mouth that break down the starch to sugars; bacteria can then produce acid from these sugars. Overall, the sugar and starch content of a food and its retentive ability largely determine its cariogenicity.

Fluoridated water and toothpaste have contributed to fewer dental caries in North American children over the past 20 years due to the mineral's tooth-strengthening effect (see Chapter 12). Research has also indicated that certain foods—such as cheese, peanuts, and sugar-free chewing gum—can actually help reduce the amount of acid on teeth. In addition, rinsing the mouth after meals and snacks reduces the acidity in the mouth. Certainly, good nutrition, habits that do not present an overwhelming challenge to oral health (e.g., chewing sugar-free gum), and routine visits to the dentist all contribute to improved dental health.

High Glycemic Index and Glycemic Load

Many foods high in sugar and starch produce a high **glycemic index (GI)** and resulting high **glycemic load (GL)** in the body. Glycemic index is defined as the blood glucose response to a given food, compared to a standard (typically, glucose or white bread) (Table 5-6).[14] Glycemic index is influenced by starch structure, fiber content, food processing, physical structure, and macronutrients in the meal, such as fat. Foods with particularly high glycemic index values are baking potatoes (not seen as much with red potatoes, as these are low in amylopectin), mashed potatoes (due to greater surface area exposed), short grain white rice, honey, and jelly beans.

Another way of looking at how different foods affect blood glucose and insulin levels is the glycemic load. The glycemic load actually better reflects a food's effect on one's blood glucose than either the amount of carbohydrate or glycemic index alone.[20] To calculate the glycemic load of a food, the amount of carbohydrate found in a food is multiplied by the glycemic index of that carbohydrate. For example, vanilla wafers have a glycemic index of 77, which is considered high. On the other hand, when calculating the glycemic load of vanilla wafers by multiplying the glycemic index by 15 grams of carbohydrate (a small serving), the result is a very low glycemic load of only 12 ($0.77 \times 15 = 12$).

Nutritionists are concerned about the effect of high glycemic load carbohydrates on blood glucose because these foods especially increase insulin output from the pancreas. Chronically high insulin output leads to many deleterious effects on the body: high blood triglycerides; smaller **low-density lipoprotein (LDL)** particles, which are more prone to lead to cardiovascular disease; increased fat deposition in adipose tissue; increased tendency for blood to clot; increased fat synthesis in the liver; and a more rapid return of hunger after a meal (insulin rapidly lowers the macronutients in the blood as it stimulates their storage). Over time, this increase in insulin output may actually cause the muscles to become resistant to the action of insulin, creating a state of insulin resistance and eventually type 2 diabetes in some people.[13]

There are many ways to address this problem of high glycemic load foods. The most important is to not overeat these foods at any one meal. This greatly minimizes their effects on blood glucose and the related increased insulin release. Consider substituting at least once per meal a food which has a low glycemic load for one with a higher value, such as long grain rice or spaghetti for short grain white rice. Combining a low glycemic load food, such as an apple, kidney beans, milk, or salad with dressing, with a high glycemic load food also reduces the effect on blood glucose. In addition, maintaining a healthy body weight and performing regular physical activity further reduces the effects of a high glycemic load diet.

As you will see in the Nutrition Perspective at the end of the chapter, a focus on low glycemic load helps in the treatment of diabetes; Chapter 14 discusses the use of foods with different glycemic load values in planning diets for athletes.

glycemic index (GI) The blood glucose response of a given food, compared to a standard (typically, glucose or white bread). Glycemic index is influenced by starch structure, fiber content, food processing, physical structure, and macronutrients in the meal, such as fat.

glycemic load (GL) The amount of carbohydrate in a food multiplied by the glycemic index of that carbohydrate.

low-density lipoprotein (LDL) The lipoprotein in the blood, containing primarily cholesterol; elevated LDL cholesterol is strongly linked to cardiovascular disease risk.

Table 5-6 Glycemic Index (GI) and Glycemic Load (GL) of Common Foods

Reference food glucose = 100				
Low GI foods—below 55		Low GL foods—below 15		
Intermediate GI foods—between 55 and 70		Intermediate GL foods—between 15 and 20		
High GI foods—more than 70		High GL foods—more than 20		
	Serving Size (g)	**Glycemic Index (GI)**	**Carbohydrate (g)**	**Glycemic Load (GL)**
Pastas/Grains				
Brown rice	1 cup	55	46	25
White, long grain	1 cup	56	45	25
White, short grain	1 cup	72	53	38
Spaghetti	1 cup	41	40	16
Vegetables				
Carrots, boiled	1 cup	49	16	8
Sweet corn	1 cup	55	39	21
Potato, baked	1 cup	85	57	48
New (red) potato, boiled	1 cup	62	29	18
Dairy Foods				
Milk, whole	1 cup	27	11	3
Milk, skim	1 cup	32	12	4
Yogurt, low-fat	1 cup	33	17	6
Ice cream	1 cup	61	31	19
Legumes				
Baked beans	1 cup	48	54	26
Kidney beans	1 cup	27	38	10
Lentils	1 cup	30	40	12
Navy beans	1 cup	38	54	21
Sugars				
Honey	1 tsp	73	6	4
Sucrose	1 tsp	65	5	3
Fructose	1 tsp	23	5	1
Lactose	1 tsp	46	5	2
Breads and Muffins				
Bagel	1 small	72	30	22
Whole-wheat bread	1 slice	69	13	9
White bread	1 slice	70	10	7
Croissant	1 small	67	26	17
Fruits				
Apple	1 medium	38	22	8
Banana	1 medium	55	29	16
Grapefruit	1 medium	25	32	8
Orange	1 medium	44	15	7
Beverages				
Apple juice	1 cup	40	29	12
Orange juice	1 cup	46	26	13
Gatorade	1 cup	78	15	12
Coca-Cola	1 cup	63	26	16
Snack Foods				
Potato chips	1 oz	54	15	8
Vanilla wafers	5 cookies	77	15	12
Chocolate	1 oz	49	18	9
Jelly beans	1 oz	80	26	21

Source: Foster-Powell K and others: International table of glycemic index and glycemic load. *American Journal of Clinical Nutrition* 76:5, 2002.

Carrots, much maligned in the popular press for having a high glycemic index (which isn't even true), actually contribute a low glycemic load to a diet.

Moderation in Lactose Intake Is Important for Some People

lactose maldigestion (primary and secondary) Primary lactose maldigestion occurs when lactase production declines for no apparent reason. Secondary lactose maldigestion occurs when a specific cause, such as long-standing diarrhea, results in a decline in lactase production. When noticeable symptoms develop after lactose intake, it is then called lactose intolerance.

Lactose maldigestion (when noticeable symptoms develop after lactose intake it is then called lactose intolerance) is a normal pattern of physiology that often begins to develop after early childhood, about ages 3 to 5 years.[17] It can lead to symptoms of abdominal pain, gas, and diarrhea after consuming lactose, generally when eaten in large amounts. This *primary* form of lactose maldigestion is estimated to be present in about 75% of the world's population, although not all of these individuals experience symptoms.

Another form of the problem, *secondary* lactose maldigestion, is a temporary condition in which lactase production is decreased in response to an underlying disease, such as intestinal diarrhea. The bloating and gas in lactose maldigestion are caused by bacterial fermentation of lactose in the large intestine. The diarrhea is caused by undigested lactose in the large intestine as it draws water from the circulatory system into the large intestine (osmotic effect; see Chapter 11 for more on osmosis).

In North America, approximately 25% of adults show signs of decreased lactose digestion in the small intestine, many of whom are Asian Americans, African Americans, and Hispanic Americans, especially as they age. Still, many of these individuals can consume moderate amounts of lactose with minimal or no gastrointestinal discomfort because of eventual lactose breakdown by bacteria in the large intestine, in turn reducing the osmotic effect. Thus, it is unnecessary for these people to greatly restrict their intake of lactose-containing foods. These calcium-rich food products are important for maintaining bone health. Obtaining enough calcium and vitamin D from the diet is much easier if milk and milk products are included.

It is hypothesized that approximately 3000 to 5000 years ago, a genetic mutation occurred in regions that relied on milk and dairy foods as a main food source, allowing those individuals (mostly in northern Europe, pastoral tribes in Africa, and the Middle East) to retain the ability to maintain high lactase output for their entire lifetime. This was not seen in other populations in the world, and so such digestive capability was not retained.

Recent studies have shown that nearly all individuals with decreased lactase production can tolerate ½ to 1 cup of milk with meals, and that most individuals adapt to intestinal gas production resulting from the breakdown of lactose by bacteria in the large intestine.[6] Combining lactose-containing foods with other foods also helps because certain properties of foods can have positive effects on rates of digestion. For example, fat in a meal slows digestion, leaving more time for lactase action. Hard cheese and yogurt also are more easily tolerated than milk. Much of the lactose is lost in the production of cheese, and the active bacteria cultures in yogurt digest the lactose when these bacteria are broken apart in the small intestine and release lactase. In addition, an array of products, such as low-lactose milk and lactase pills, are available to assist lactose maldigesters; still, few people actually need to use these products because their degree of maldigestion is moderate.[17]

Use of yogurt helps people with lactose maldigestion and intolerance meet calcium needs.

Concept | Check

The RDA for carbohydrate is 130 g per day. The typical North American diet provides 180 to 330 g/day. A reasonable goal is to have about half of our energy intake coming from starch and our total carbohydrate intake making up about 60% of our energy intake, with a range of 45 to 65%. This should allow for the recommended intake of 25 to 38 g of fiber/day for men and women, respectively. High-fiber diets must be accompanied by adequate fluid intakes to avoid constipation and phytobezoars and should be followed under a physician's guidance.

North Americans eat about 82 g of sugars added to foods each day. Most of these sugars are added to foods and beverages in processing. To reduce consumption of sugars, one must reduce consumption of items with added sugars, such as some baked goods, sweetened beverages, and presweetened ready-to-eat breakfast cereals. This is one practice that can help reduce the development of dental caries and likely improve diet quality. Lactose maldigestion is a condition that results when cells of the intestine do not make sufficient lactase, the enzyme necessary to digest lactose, resulting in symptoms such as abdominal gas, pain, and diarrhea. Most people with lactose maldigestion can tolerate cheeses and yogurt, as well as moderate amounts of milk.

Case Scenario | Follow-up

In the case scenario, Myeshia suspected she was sensitive to milk because, when she consumed it during one meal, she developed bloating and gas. She tried to reproduce these symptoms by eating yogurt, but was not successful. In this way, she discovered that yogurt in conjunction with milk during the meal did not produce any symptoms. As you just learned, yogurt is tolerated better than milk by people with lactose maldigestion because the bacteria that are present in yogurt digest much of the lactose. Note, however, many people with lactose maldigestion can consume moderate amounts of milk with few or no symptoms from the lactose present.

Rice is a rich source of carbohydrate.

Carbohydrates in Foods: Food Sweeteners

The foods that yield the highest percentage of energy from carbohydrates are table sugar, honey, jam, jelly, fruit, and plain baked potatoes. These foods are rich sources of carbohydrate; carbohydrates deliver much of their food energy. Corn flakes, rice, bread, and noodles all contain at least 75% of energy as carbohydrates. Foods with moderate amounts of carbohydrate energy are peas, broccoli, oatmeal, dry beans and other legumes, cream pies, french fries, and skim milk. In these foods, the carbohydrate content is diluted either by protein, as in the case of skim milk, or by fat, as in the case of a cream pie. Foods with essentially no carbohydrates include beef, eggs, chicken, fish, vegetable oils, butter, and margarine.

In planning a high-carbohydrate diet, you need to emphasize grains, pasta, fruits, and vegetables. On the other hand, you can't create a diet high in carbohydrate energy from chocolate, potato chips, and french fries because these foods contain too much fat. The percentage of energy from carbohydrate is more important than the total amount of carbohydrate in a food when planning a high-carbohydrate diet.

The various substances that impart sweetness to foods fall into two broad classes: nutritive sweeteners, which can be metabolized to yield energy, and alternative sweeteners, which provide no food energy. As was shown in Table 5-4, the alternative sweeteners are much sweeter on a per-gram basis than the nutritive sweeteners.

Food Sources of Carbohydrate

Food Item and Amount	*Carbohydrate (g)*
Baked potato, 1	51
Cola drink, 12 fluid ounces	39
M&M's plain chocolate candies, 1.5 ounces	30
Banana, 1	28
Cooked rice, ½ cup	22
Cooked corn, ½ cup	21
Yogurt with aspartame, 1 cup	19
Kidney beans, ½ cup	19
Spaghetti noodles, ½ cup	19
Orange, 1	16
Seven grain bread, 1 slice	12
Milk, 1 cup	12
Pineapple, ½ cup	10
Cooked carrots, ½ cup	8
Peanuts, 1 oz	6

Nutritive Sweeteners

Both sugars and sugar alcohols provide energy along with sweetness. Sugars are found in many different food products, whereas sugar alcohols have rather limited uses.

Sugars

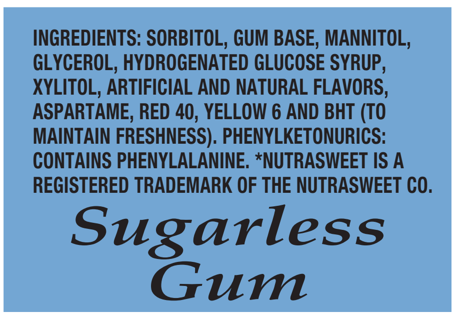
All of the monosaccharides (glucose, fructose, and galactose) and disaccharides (sucrose, lactose, and maltose) that we discussed earlier are designated *nutritive sweeteners* (Table 5-7). The taste and sweetness of sucrose make it the benchmark against which all other sweeteners are measured.

A sweetener used frequently today is high-fructose corn syrup, which is 40 to 90% fructose. High-fructose corn syrup is made by treating cornstarch with acid and enzymes. This treatment breaks down much of the starch into glucose. Then some of the glucose is converted by enzymes into fructose. The final syrup is usually as sweet as sucrose. Its major advantage is that it is cheaper than sucrose. Also, it doesn't form crystals, and it has better freezing properties. High-fructose corn syrups are used in soft drinks, candies, jam, jelly, other fruit products, and desserts (e.g., packaged cookies).

In addition to sucrose and high-fructose corn syrup, brown sugar, turbinado sugar (sold as raw sugar), honey, maple syrup, and other sugars are also added to foods. Turbinado sugar is a partially refined version of raw sucrose; it has a slight molasses flavor. Brown sugar is essentially sucrose containing some molasses; either the molasses is not totally removed from the sucrose during processing or it is added to the sucrose crystals.

Table 5-7 Names of Sugars Used in Foods

Sugar	Invert sugar	Honey	Maple syrup
Sucrose	Glucose	Corn syrup or sweeteners	Dextrin
Brown sugar	Sorbitol	High-fructose corn syrup	Dextrose
Confectioner's sugar (powdered sugar)	Levulose	Molasses	Fructose
Turbinado sugar	Polydextrose	Date sugar	Maltose
	Lactose		Caramel
	Mannitol		Fruit sugar



Sugar alcohols can be found in sugarless gum. Note that the alternate sweetener, aspartame, is also used to sweeten this product.

Maple syrup is made by boiling down and concentrating the sap that runs during the late winter in sugar maple trees. Most pancake syrup sold in supermarkets is not pure maple syrup, which is quite expensive. Instead, it is primarily corn syrup and high-fructose corn syrup with maple flavor added.

Honey is a product of plant nectar that has been altered by bee enzymes. The enzymes break down much of the nectar's sucrose into fructose and glucose. As we noted earlier, honey offers essentially the same nutritional value as other simple sugars—a source of energy and little else. However, honey is not safe to feed to infants because it can contain spores of the bacterium *Clostridium botulinum*. These spores can become the bacteria that cause fatal foodborne illness. Honey does not pose the same threat to adults because the acidic environment of an adult's stomach inhibits the growth of the bacteria. An infant's stomach, however, does not produce much acid, making infants susceptible to the threat that this bacterium poses (see Chapters 17 and 19).

Sugar Alcohols

The sugar alcohols **sorbitol, mannitol,** and **xylitol** are also used as nutritive sweeteners. Although sugar alcohols contribute energy (about 3 kcal/g), they are absorbed and metabolized to glucose more slowly than sugars. In large quantities sugar alcohols can cause diarrhea. In fact, any products whose foreseeable consumption may result in a daily ingestion of 50 g of sorbitol or mannitol must bear this labeling statement: "Excess consumption may have a laxative effect."

Sugar alcohols must be listed on labels, and if only one sugar alcohol is used in a product it must be distinguished; however, if two or more are used in one product they are grouped together under the heading "sugar alcohols." The actual energy value is calculated, taking in account each sugar alcohol, so that, when one reads the total energy content of a product, it includes the sugar alcohols in the overall amount.

Sorbitol and xylitol are used in sugarless gum, breath mints, and candy. These are not readily metabolized by bacteria in the mouth and thus do not promote dental caries nearly so readily as simple sugars such as sucrose. Recall from Chapter 2 that such a health claim can be made on these products.

sorbitol An alcohol derivative of glucose that yields about 3 kcal/g but is slowly absorbed from the small intestine. It is used in some sugarless gums and dietetic foods.

mannitol An alcohol derivative of fructose.

xylitol An alcohol derivative of the five-carbon monosaccharide xylose.

saccharin An alternative sweetener that yields no energy to the body; it is 300 times sweeter than sucrose.

cyclamate An alternative sweetener that yields no energy to the body; it is 30 times sweeter than sucrose.

aspartame An alternative sweetener made from two amino acids and methanol; it is 200 times sweeter than sucrose.

neotame A general-purpose nonnutritive sweetener that is approximately 7000 to 13,000 times sweeter than table sugar. It has a chemical structure similar to aspartame. Neotame is heat stable and can be used as a tabletop sweetener as well as in cooking applications. It is not broken down in the body after consumption to its amino acid components.

Alternative Sweeteners

Often called artificial sweeteners, alternative sweeteners include **saccharin, cyclamate, aspartame, neotame, sucralose,** and **acesulfame-K** (Fig. 5-10).[9] Alternative sweeteners yield little or no energy when consumed in amounts typically used in food products. Five are currently available in the United States: saccharin, aspartame, neotame, acesulfame-K, and sucralose. Cyclamate was banned for use in the United States in 1970, although it has never been conclusively proved to cause health problems when used appropriately. Cyclamate is used in Canada as a sweetener in medicines and as a tabletop sweetener.

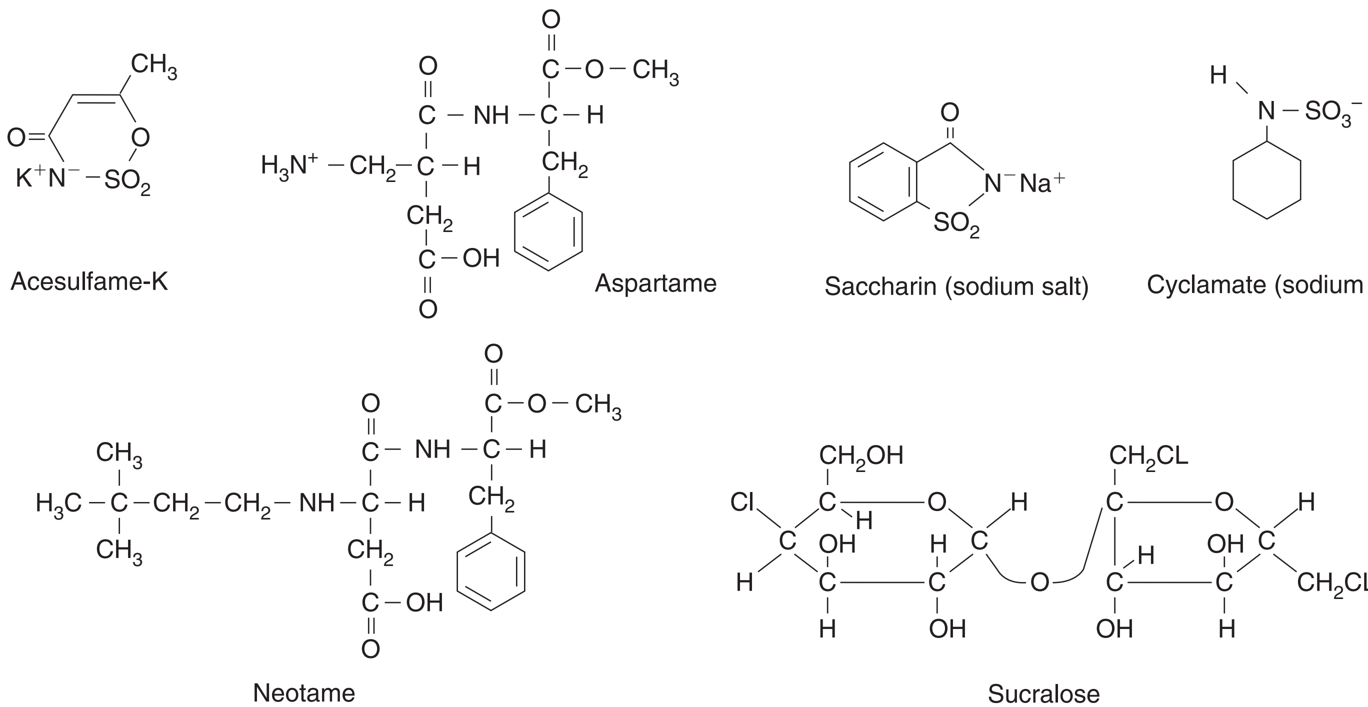


Figure 5-10 Chemical Structures of Alternative Sweeteners*

*Cyclamate is available in Canada, but not in the United States.

Saccharin

The oldest alternative sweetener, saccharin (sodium salt), was first produced in 1879 and is currently approved for use in more than 90 countries. Saccharin was once thought to pose a risk of bladder cancer based on laboratory animal studies, but it is no longer listed as a potential cause of cancer in humans since the earlier research is now considered weak and inconclusive.

Aspartame

In 1981, the alternative sweetener aspartame became available. When the NutraSweet company held the patent on aspartame, it was sold as NutraSweet when added to foods and Equal when sold as a powder. Now, though, other companies manufacture aspartame. Aspartame is in widespread use throughout the world. It has been approved for use by more than 90 countries, and its use has been endorsed by the World Health Organization, the American Medical Association, the American Diabetes Association, and the American Academy of Pediatrics Committee on Nutrition.[9]

The components of aspartame are the amino acids phenylalanine and aspartic acid, along with methanol. Recall that amino acids are the building blocks of proteins, so aspartame is more of a protein than a carbohydrate. Aspartame yields about 4 kcal/g, but it is 180 to 200 times sweeter than sucrose. Thus, only a small amount of aspartame is needed to obtain the desired sweetness, so the amount of energy added is insignificant unless the product is abused. Today aspartame is used in beverages, gelatin desserts, chewing gum, toppings and fillings in precooked bakery goods, and cookies. Aspartame does not cause tooth decay. Like other proteins, however, aspartame is damaged when heated for a long time and thus cannot be widely used in products requiring cooking.

Some complaints have been filed with FDA by people claiming to have had adverse reactions to aspartame: headaches, dizziness, seizures, nausea, and other side effects. It is important for people who are sensitive to aspartame to avoid it, even though the percentage of people being affected is likely to be small. The relatively limited number of complaints about aspartame, considering its wide use in food products, means that most people can use it.

CONTAINS: CARBONATED WATER, ORANGE JUICE, CITRIC ACID, NUTRASWEET* BRAND OF ASPARTAME**, POTASSIUM BENZOATE (A PRESERVATIVE), CITRUS PECTIN, POTASSIUM CITRATE, CAFFEINE, MALTODEXTRIN, GUM ARABIC, NATURAL FLAVORS, BROMINATED VEGETABLE OIL, YELLOW #5 AND ERYTHORBIC ACID (TO PROTECT FLAVOR).
*NUTRASWEET® AND THE NUTRASWEET SYMBOL ARE REGISTERED TRADEMARKS OF THE NUTRASWEET COMPANY.
PHENYLKETONURICS: CONTAINS PHENYLALANINE.

Note the warning above for people with PKU that this diet soft drink with aspartame contains phenylalanine.

Critical | Thinking

John and Mike are identical twins who like the same games, sports, and foods. However, John likes to chew sugar-free gum and Mike doesn't. At their last dental visit, John had no cavities, but Mike had two. Mike wants to know why John, who chews gum after eating, doesn't have cavities and he does. How would you explain this to him?

The acceptable daily intake of aspartame set by FDA is 50 mg/kg of body weight per day. This is equivalent to about 14 cans of diet soft drink for an adult or about 80 packets of Equal. Aspartame appears to be safe for pregnant women and children, but some scientists suggest cautious use by these groups, especially young children, who need ample food energy to grow.

Persons with an uncommon disease called phenylketonuria (PKU), which interferes with the metabolism of phenylalanine, should avoid aspartame because of its high phenylalanine content. (PKU was discussed in Chapter 4.)

Neotame

Neotame was recently approved by FDA for use as a general-purpose sweetener in a wide variety of food products, other than meat and poultry. Neotame is a nonnutritive, high-intensity sweetener that, depending on its food application, is approximately 7000 to 13,000 times sweeter than table sugar. It has a chemical structure similar to aspartame. Neotame is heat stable and can be used as a tabletop sweetener as well as in cooking applications. Examples of uses for which it has been approved include baked goods, nonalcoholic beverages (including soft drinks), chewing gum, confections and frostings, frozen desserts, gelatins and puddings, jams and jellies, processed fruits and fruit juices, toppings and syrups. Neotame is safe for use by the general population, including children, pregnant and lactating women, and people with diabetes. In addition, no special labeling for people with phenylketonuria is needed since after consumption neotame is not broken down in the body to its amino acid components.

acesulfame-K An alternative sweetener that yields no energy to the body; it is 200 times sweeter than sucrose.

sucralose An alternative sweetener that has chlorines in place of some hydroxyl (–OH) groups on sucrose. It is 600 times sweeter than sucrose.

Acesulfame-K

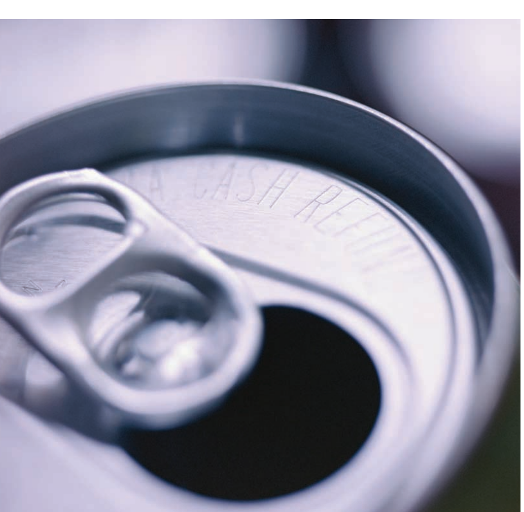
The alternative sweetener acesulfame-K (the K stands for potassium) (Sunette) was approved by FDA in July 1988. It is approved for use in more than 40 countries and has been in use in Europe since 1983. Acesulfame-K is 200 times sweeter than sucrose. It contributes no energy to the diet because it is not digested by the body, and it does not cause dental caries.

Unlike aspartame, acesulfame-K can be used in baking because it does not lose its sweetness when heated. In the United States, it is currently approved for use in chewing gum, powdered drink mixes, gelatins, puddings, baked goods, tabletop sweeteners, candy, throat lozenges, yogurt, and nondairy creamers; additional uses may soon be approved. One recent trend is to combine it with aspartame in soft drinks.

Sucralose

Sucralose (Splenda) is 600 times sweeter than sucrose. It is made by substituting three chlorines (Cl) for three hydroxyl groups (-OH) on sucrose. FDA approved sucralose's use in 1998 as an additive to foods such as soda, gum, baked goods, syrups, gelatins, frozen dairy desserts such as ice cream, jams, and processed fruits and fruit juices and for tabletop use. Sucralose doesn't break down under high heat conditions and can be used in cooking and baking. It is also excreted as such in the feces. The little that is absorbed is excreted in the urine. Canadians had access to sucralose before its U.S. introduction.

Overall, alternative sweeteners enable people with diabetes to enjoy the flavor of sweetness while controlling sugars in their diets; they also provide noncaloric or very-low-calorie sugar substitutes for persons trying to lose (or control) body weight.



Diet soft drinks typically take advantage of the alternative sweeteners such as saccharin, aspartame, and acesulfame-K.

Concept | Check

Foods that are essentially all carbohydrate are sugars, jam, jelly, fruit, and plain baked potatoes. Grains and vegetables are also rich sources of carbohydrate. Five major alternative sweeteners are available in the United States today—saccharin, aspartame, neotame, acesulfame-K, and sucralose. Canadians also have access to cyclamate. These can aid in the goal of reducing sugar intake.

Summary

1. The common monosaccharides are glucose, fructose, and galactose. Once these are absorbed from the small intestine and delivered to the liver, much of the fructose and galactose is converted to glucose.
2. The major disaccharides are sucrose (glucose plus fructose), maltose (glucose plus glucose), and lactose (glucose plus galactose). When digested, these yield their component monosaccharides.
3. One major group of polysaccharides consists of storage forms of glucose: starches in plants and glycogen in humans. In these polymers, the multiple glucose units are linked by alpha bonds, which can be broken by human digestive enzymes, releasing the glucose units. The main plant starches—straight-chain amylose and branched-chain amylopectin—are digested by enzymes in the mouth and small intestine. In humans, glycogen is synthesized in the liver and muscle tissue from glucose. Under the influence of hormones, liver glycogen is readily broken down to glucose, which can enter the bloodstream.
4. Fiber is composed primarily of the polysaccharides cellulose, hemicellulose, pectin, gum, and mucilage, as well as the noncarbohydrate lignins. These substances are not broken down by human digestive enzymes. However, soluble (also called viscous) fiber is fermented by bacteria in the large intestine.
5. Some starch digestion occurs in the mouth. Carbohydrate digestion is completed in the small intestine. Some plant fibers are digested by the bacteria present in the large intestine; undigested plant fibers become part of the feces. Monosaccharides in the intestinal contents mostly follow an active absorption process. They are then transported via the portal vein that leads directly to the liver.
6. Carbohydrates provide energy (on average, 4 kcal/g), protect against wasteful breakdown of food and body protein, and prevent ketosis. The RDA for carbohydrate is 130 g/day to meet the energy needs of the central nervous system. If carbohydrate intake is inadequate to supply the body's needs, protein is metabolized to provide glucose (gluconeogenesis) for energy needs. However, the price is loss of body protein, ketosis, and eventually a general body weakening. For this reason, low-carbohydrate diets are not recommended for extended periods (greater than 4 to 6 weeks).
7. Insoluble (also called poorly fermented) fiber provides mass to the feces, thus easing elimination. In high doses, soluble fiber can help control blood glucose in diabetic people and lower blood cholesterol.
8. Diets high in complex carbohydrates are encouraged as a replacement for high-fat diets. A goal of about half of energy as complex carbohydrates is a good one, with about 60% of total energy coming from carbohydrates in general. Foods to consume are whole-grain cereal products, pasta, legumes, fruits, and vegetables. Many of these foods are rich in fiber.
9. Moderating sugar intake, especially between meals, in turn reduces the risk of dental caries. Other health benefits also occur, such as a reduced glycemic load for a meal or snack. Alternative sweeteners, such as aspartame, aid in reducing intake of sugars.
10. The ability to digest large amounts of lactose often diminishes with age. People in some ethnic groups are especially affected. This condition develops early in childhood and is referred to as *lactose maldigestion*. Undigested lactose travels to the large intestine, resulting in such symptoms as abdominal gas, pain, and diarrhea. Most people with lactose maldigestion can tolerate cheese and yogurt and moderate amounts of milk.

Study Questions

1. Identify the three major disaccharides. Describe how each plays a part in the human diet.
2. How do amylose, amylopectin, and glycogen differ from one another? Why can this be important metabolically and in food processing?
3. What are the possible roles that dietary fiber plays in the diet?
4. Why must we generally limit our fiber intake to no more than 60 g/day? What are the possible effects of a diet too high in fiber (or too low in fluid relative to fiber content)?
5. Briefly describe the chemical structure, sweetness, and food uses of alternative sweeteners.
6. Why do we need carbohydrates in the diet? Briefly describe two reasons.
7. State the RDA for carbohydrate and summarize current carbohydrate intake recommendations.
8. Write a list of suggestions for a patient who has been diagnosed with lactose maldigestion. Design a 1-day sample menu that provides adequate calcium (1000 mg) for this patient.

After reading the Nutrition Perspective, answer the following questions:

9. How does type 1 diabetes differ from type 2 diabetes in cause and treatment?
10. What treatment is recommended for the typical form of hypoglycemia?

Annotated References

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   It is preferable that this fiber be obtained from foods as opposed to fiber supplements. This paper discusses the possible health benefits of fiber, as well as some of the potential negative effects of excessive fiber intake.

2. American Diabetes Association Position Statement: Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications. *Journal of the American Dietetic Association* 102:109, 2002.

   This paper discusses the goals of medical nutrition therapy for both type 1 and type 2 diabetes. Recommendations are given for amount of *carbohydrate, sweeteners, alcohol, fat, cholesterol, protein, and total energy contained in the diabetic diet.*

3. Berg JM and others: *Biochemistry.* New York: W. H. Freeman and Company, 2002.

   This is a college-level biochemistry textbook that serves as an excellent reference for understanding many biochemistry concepts needed in the study of nutrition, such as that regarding carbohydrate biochemistry and metabolism.

4. Diabetes: A growing public health concern. *FDA Consumer,* p. 26, January–February 2002.

   Between 1958 and 1997, the number of people diagnosed with diabetes has increased more than sixfold. Currently, it is estimated that approximately 16 million people in the United States have diabetes.

5. Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *The New England Journal of Medicine* 346:393, 2002.

   A lifestyle intervention program (i.e., at least a 7% weight loss and at least 150 minutes of physical activity per week) was compared to the administration of the oral diabetes medication metformin to determine the ability of each approach to lower the incidence of type 2 diabetes in those individuals who exhibit several risk factors for the disease. The authors stated that the lifestyle approach was more effective in preventing type 2 diabetes.

6. Food and Nutrition Board: *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids.* Washington, DC: The National Academy Press, 2002.

   This report provides the latest guidance for macronutrient intakes. With regard to carbohydrate, the RDA *has been set at 130 g/day. Carbohydrate intake should range from 45 to 60% of energy intake. Sugars added to foods should constitute no more than 25% of energy intake.*

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   Approximately 25% of all adults have the metabolic syndrome, with 42% of those adults aged 60 years or older having the metabolic syndrome. The underlying causes of the metabolic syndrome include a lack of physical activity and inappropriate dietary practices.

8. Fung TT and others: Whole-grain intake and the risk of type 2 diabetes: A prospective study in men. *American Journal of Clinical Nutrition* 76:535, 2002.

   In men, a diet high in whole grains is associated with a reduced risk of type 2 diabetes. This is especially seen with regard to cereal fiber intake.

9. Henkel J: Sugar substitutes: Americans opt for sweetness and lite. *FDA Consumer*, p. 12, November/December 1999.

   FDA stands behind its approval of current sugar substitutes.

10. Howarth N and others: Dietary fiber and weight regulation. *Nutrition Reviews* 59:129, 2001.

    While controversial, some researchers believe that high intakes of fiber can lead to improved weight regulation, through fiber's effects on hunger, satiety, and energy intake. In general, a high-fiber diet usually has a low energy density, slows gastric emptying, and may reduce absorption of fat and protein.

11. Inzucchi S: Oral antihyperglycemic therapy for type 2 diabetes. *Journal of the American Medical Association* 287:360, 2002.

    In the past 6 years, there has been an increase in the number of oral antihyperglycemic agents available for treatment of type 2 diabetes. This article provides summary information concerning the use of these various drug classes.

12. Johnson R, Fray C: Choose beverages and foods to moderate your intake of sugars: The 2000 Dietary Guidelines for Americans—what's all the fuss about? *Journal of Nutrition* 131:2766S, 2001.

    The 2000 Dietary Guidelines for Americans suggest that Americans attempt to moderate their intake of sugars by limiting the amount of high-sugar foods and beverages they consume. According to recent U.S. Food Supply data, Americans' per capita consumption of added sugars increased approximately 23% between 1970 and 1996, with the largest source of these added sugars being regular soft drinks.

13. Liu S: Intake of refined carbohydrates and whole-grain foods in relation to risk of type 2 diabetes mellitus and coronary heart disease. *Journal of the American College of Nutrition* 21:298, 2002.

    This review paper provides a summary of the research concerning intake of refined carbohydrate versus whole-grain carbohydrate in the development of type 2 diabetes and coronary heart disease. Epidemiological studies suggest that a higher consumption of whole-grain foods results in a lower risk of both coronary heart disease and type 2 diabetes.

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    In general, foods can be classified as either high-, moderate-, or low-glycemic index foods. The average glycemic index of the North American diet has increased in recent years, due to increased consumption of refined carbohydrate-containing foods.

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    The authors of this article provide a review of recent research concerning the accuracy and precision of screening methods as well as current research regarding the prevention of colorectal cancer, such as an adequate folate, selenium, and calcium intakes, and regular use of nonsteroidal anti-inflammatory drugs, including aspirin and COX-2 inhibitors.

16. Spanheimer R: Reducing cardiovascular risk in diabetes: Which factors to modify first? *Postgraduate Medicine* 109:26, 2001.

    Diabetes can eventually result in both microvascular and macrovascular complications, and diabetes is considered a major cardiovascular risk factor by the American Heart Association. To prevent cardiovascular disease in diabetes, tight glucose control should be maintained, high blood lipids should be managed, hypertension should be controlled, and a healthy weight should be encouraged.

17. Swagerty D and others: Lactose intolerance. *American Family Physician* 65:1845, 2002.

    Lactose maldigestion and intolerance results from a deficiency in the lactose-digesting enzyme, lactase. This is present in up to 15% of Northern Europeans, 22% of American Whites, 70% of Indians, 80% of Blacks and Hispanics, and 100% of American Indians and Asians. Most individuals with lactose maldigestion and intolerance can consume small amounts of dairy products without experiencing symptoms, and yogurts with live cultures tend to be especially well tolerated.

18. Tuomilehto J and others: Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *New England Journal of Medicine* 344:1343, 2001.

    The onset of type 2 diabetes can be delayed or prevented when high-risk people make lifestyle changes that include weight reduction, increased physical activity, adequate fiber intake, and moderation in total fat and saturated fat intake.

19. van Dam R and others: Dietary patterns and risk for type 2 diabetes mellitus in U.S. men. *Annals of Internal Medicine* 136:201, 2002.

    Using data from the Health Professionals Follow-up Study, researchers were able to classify subject's diets as "prudent," (consisting of generous amounts of fish, fruits, vegetables, poultry, and whole grains) or "western" (consisting of a higher consumption of red meat, processed meats, French fries, refined grains, sweets, and desserts). The "prudent" dietary pattern was associated with a slight decreased risk for developing type 2 diabetes, while the "western" dietary pattern was associated with a greatly increased risk for developing type 2 diabetes.

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    Research from several recent studies indicates that diets with a high glycemic index and/or a high glycemic load are associated with an increased risk of type 2 diabetes. Replacing high glycemic load carbohydrates with low glycemic load carbohydrates may lead to a decreased risk of diabetes, as well as improved blood glucose control in diabetics.

Take | Action 

I. How Does Your Diet Rate for Carbohydrate and Fiber?

Let's reevaluate the nutritional assessment you completed at the end of Chapter 2. Here are your tasks:

1. Look at your analysis and find the total number of grams of carbohydrate you ate.

   TOTAL GRAMS OF CARBOHYDRATE __________

   A. Did you consume at least the RDA of 130 g?
   B. Now calculate the percentage of energy in your diet from carbohydrate. You will need the total grams of carbohydrate from your assessment, as well as the total kcals you ate. Use this formula to calculate it:

   $$\frac{\text{Total grams of carbohydrate} \times 4}{\text{Total kcals consumed}} \times 100 = \%\text{ of energy intake from carbohydrate}$$

   ANSWER: __________

   Was about 60% of your total energy intake from carbohydrate? Yes _______ No _______

   If not, list several ways you could increase your carbohydrate intake.

   ____
   ____
   ____

2. Look again at the list of foods you ate, including the amounts, and determine the total amount of fiber you consumed. If you have a computer analysis of your diet, your fiber intake is listed in the printout. Otherwise, look up the fiber content of each food you ate in the food composition table in Appendix N; then calculate your total intake, taking into account the amount of each food you ate.

   TOTAL AMOUNT OF FIBER CONSUMED _______ g

   A. Did you consume the 25 to 38 g suggested for women and men, respectively, in this chapter?
   B. If not, what could you do to increase your fiber intake? What foods could you substitute for some of the foods you ate?

   ____
   ____
   ____

3. Finally, use Table 5-5 as a guide if you need to reduce your intake of added sugars, especially if you need to watch your total energy intake to maintain an appropriate weight. What three foods might you, in fact, limit in the future?

   ____
   ____
   ____

Take | Action

II. Can You Choose the Sandwich with the Most Fiber?

Assume the sandwiches on the blackboard below are available at your local deli and sandwich shop. All of the sandwiches provide about 350 kcal. The fiber content ranges from about 1 g to about 7.5 g. Rank the sandwiches from highest amount of fiber to lowest amount; then check your answers at the bottom of the page.

Answer Key: 1. Soyburger: 7.5 g, 2. Tuna Salad on Whole Wheat: 7 g, 3. Turkey & Swiss on Rye: 4 g, 4. PB&J: 3 g, 5. Ham & Swiss on Sourdough: 1.5 g, 6. Hot Dog: 1g.

When Blood Glucose Regulation Fails

Improper regulation of blood glucose results in either hyperglycemia (high blood glucose) or hypoglycemia (low blood glucose). High blood glucose is most commonly associated with diabetes (technically, *diabetes mellitus*), a disease that affects about 6% of North Americans.[4] The diagnostic criteria is based on a fasting blood glucose of 126 mg/dl or greater (dl represents 100 ml [deciliter]). Of those affected, it is estimated that about ⅓ of these people do not know that they have the disease. In addition, at least another 6% of our population shows evidence of insulin resistance, but not actual diabetes (indicated by a fasting blood glucose of 110–125 mg/dl). Diabetes leads to about 200,000 deaths each year in North America, and the number of new cases is climbing yearly. New recommendations promote testing fasting blood glucose in adults over age 45 every 3 years to help diagnose these missed cases. In contrast, low blood glucose is a much rarer condition.

Previously, a fasting blood glucose of 140 mg/dl was required to diagnose diabetes. Recently, though, amounts in the 120 mg/dl range have been found to cause tissue damage. For this reason, the diagnostic trigger for diabetes using fasting blood glucose has been decreased to 126 mg/dl. The corresponding cut-off value taken 2 hours after a 75 g glucose load is 200 mg/dl.

Regulation of Blood Glucose

Under normal circumstances, blood glucose usually varies between about 70 and 109 mg/dl of blood in the fasting state, which is normally established a few hours after a meal is eaten. If blood glucose rises above 170 mg/dl, glucose begins to spill over into the urine. This leads to hunger and thirst, and eventually to weight loss. If blood glucose falls below 40 to 50 mg/dl, a person begins to feel nervous, irritable, and hungry and may develop a headache. Having high blood glucose is called **hyperglycemia.** Having low blood glucose is called **hypoglycemia.** It is not too surprising that a headache then results, because the brain is fueled almost entirely by glucose.

hyperglycemia High blood glucose, above 125 mg/dl of blood on a fasting basis.

hypoglycemia Low blood glucose, below 40 to 50 mg/dl of blood.

The liver is the main organ for controlling the amount of glucose that is eventually found in the bloodstream. Since it is the first organ to screen the sugars absorbed from the small intestine, the liver serves as a guard, helping control the amount of glucose that enters the bloodstream after a meal (review Fig. 5-5).

The pancreas is another important site of blood glucose control. Small amounts of insulin are released by the pancreas as soon as a person starts to eat. Once much of the dietary glucose enters the bloodstream, the pancreas releases large amounts of insulin. Insulin affects blood glucose in a variety of ways. It promotes increased glycogen synthesis and thus glucose storage in the liver, as well as increased glucose uptake by muscle cells, adipose cells, and some other cells. Both of these actions of insulin lower blood glucose and help return it to the normal fasting range within a few hours after a person eats. In addition, insulin reduces gluconeogenesis by the liver.[3]

Other hormones counteract the effects of insulin. When a person has not eaten carbohydrates for a few hours, the amount of glucose in the blood is maintained by the hormone glucagon, which is also released from the pancreas. This hormone prompts the breakdown of glycogen in the liver, resulting in the release of glucose to the bloodstream. Glucagon also enhances gluconeogenesis. In these ways, glucagon helps restore blood glucose to normal concentrations (Fig. 5-11).

Regularly checking blood glucose is part of diabetes therapy today.

At the same time, the hormones epinephrine (adrenaline) and norepinephrine are released from the adrenal glands and nearby nerve endings. These hormones trigger the breakdown of glycogen in the liver; the resulting glucose is released into the bloodstream. These hormones are responsible for the "fight or flight" reaction. They are released in large amounts in response to a perceived threat, such as a car approaching head-on. The resulting rapid release of glucose into the bloodstream promotes quick mental and physical reactions. Other hormones, such as cortisol and growth hormone, also help regulate blood glucose (Table 5-8).[3]

In essence, the actions of insulin on blood glucose are balanced by the actions of glucagon, epinephrine, norepinephrine, cortisol, and other hormones. If hormonal balance is not maintained, such as during overproduction or underproduction of insulin or glucagon, major changes in blood glucose concentrations

Figure 5-11 Regulation of blood glucose. Insulin and glucagon are key factors in controlling blood glucose. Other hormones, such as epinephrine, norepinephrine, cortisol, and growth hormone, also contribute to blood glucose regulation (see Table 5-8 for details).
Illustration by William Ober.

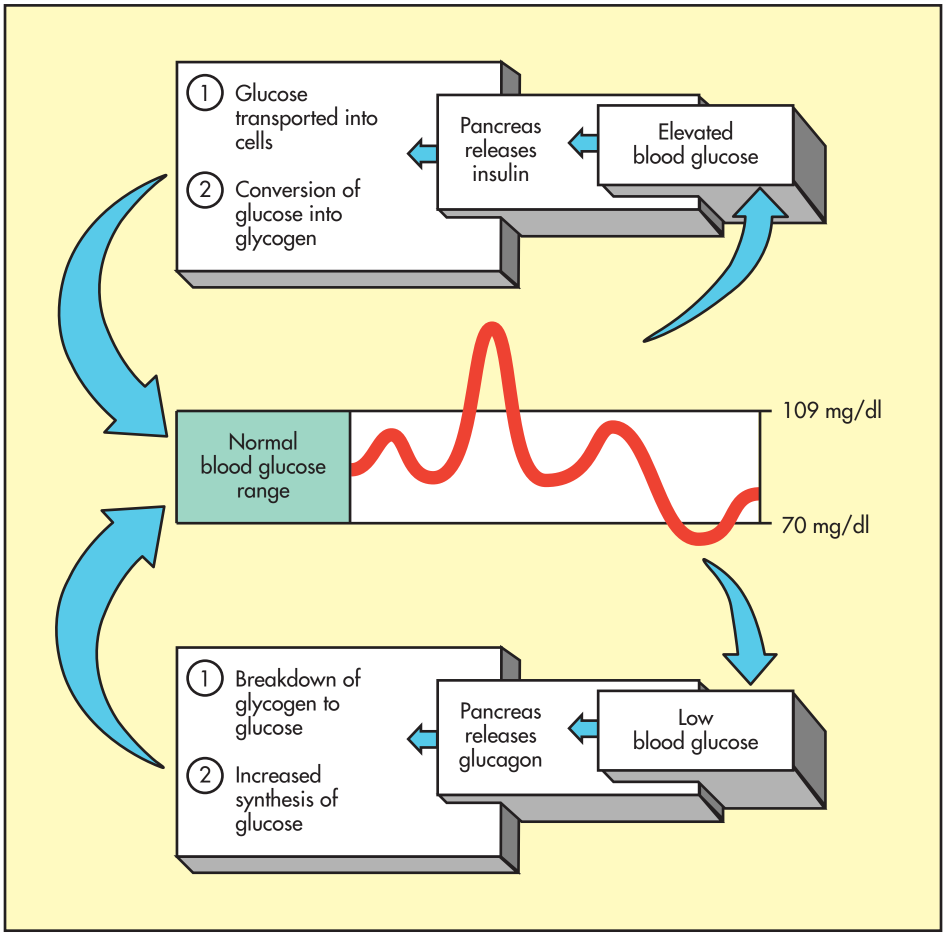


Table 5-8 Role of Various Hormones in the Regulation of Blood Glucose

Hormone	Source	Target Organ or Tissue	Overall Effect on Organ or Tissue	Effect on Blood Glucose
Insulin	Pancreas	Liver, muscle, adipose tissue	Increases glucose uptake by muscles and adipose tissue, increases glycogen synthesis, suppresses gluconeogenesis	Decrease
Glucagon	Pancreas	Liver	Increases glycogen breakdown, with release of glucose by the liver; increases gluconeogenesis	Increase
Epinephrine Norepinephrine	Adrenal glands and nerve endings	Liver, muscle	Increase glycogen breakdown, with release of glucose by the liver; increase gluconeogenesis	Increase
Cortisol	Adrenal glands	Liver, muscle	Increases gluconeogenesis by the liver, decreases glucose use by muscles and other organs	Increase
Growth hormone	Adrenal glands	Liver, muscle, adipose tissue	Decreases glucose uptake by muscles, increases fat mobilization and utilization, increases glucose output by the liver	Increase

Table 5-9 Type 1 vs. Type 2 Diabetes

	Type 1 Diabetes	Type 2 Diabetes
Incidence	5–10% of cases of diabetes	90% of cases of diabetes
Cause	Autoimmune Moderate genetic predisposition	Insulin resistance Strong genetic predisposition
Characteristics	Distinct symptoms (frequent thirst, hunger, and urination) Ketotic	Mild symptoms, especially in early phases of the disease (fatigue and nighttime urination) Generally nonketotic
Treatment	Diet Exercise Insulin	Diet Exercise Oral agents Insulin
Monitor	Blood glucose Urine ketones HbA1c	Blood glucose HbA1c

A common clinical method to determine a person's success in controlling blood glucose is to measure glycated (also termed glycosylated) hemoglobin (hemoglobin A1c). Over time, blood glucose attaches to (glycates) hemoglobin in red blood cells, and more so when blood glucose remains elevated. A hemoglobin A1c value of over 7% indicates poor blood glucose control. An acceptable value is 6% or less. Elevated blood glucose also leads to glycation of various proteins and fats in the body, forming what are called advanced glycation endproducts. These have been shown to be toxic to cells, especially those of immune systems. (Cigarette smoke is also a source.)

occur. This system of checks and balances for blood glucose regulation is typical of how the body maintains blood and other tissue concentrations of its key constituents within fairly narrow ranges.

Diabetes Mellitus

There are two major forms of diabetes: **type 1 diabetes** (formerly called insulin-dependent or juvenile-onset diabetes), and **type 2** (formerly called **non–insulin-dependent** or adult-onset **diabetes**) (Table 5-9).[2] The change in names to type 1 and type 2 diabetes stems from the fact that many "non–insulin-dependent" diabetics eventually have to also rely on insulin injections as a part of their treatment. In addition, many children today have type 2 diabetes. A third form, called gestational diabetes, occurs in pregnant women (see Chapter 16). It is usually treated with an insulin regimen and diet, and resolves after delivery of the baby. However, evidence of this problem suggests that women are at high risk for developing diabetes later in life.

Traditional symptoms of diabetes, known as the three polys, are polyuria (excessive urination), polydipsia (excessive thirst), and polyphagia (excessive hunger). No one symptom is diagnostic of diabetes, and other symptoms—such as unexplained weight loss, exhaustion, blurred vision, tingling in hands and feet, frequent infections, poor wound healing, and impotence—often accompany traditional symptoms.

Type 1 Diabetes

Type 1 diabetes often begins in late childhood, around the age of 8 to 12 years, but can occur at any age. The disease runs in certain families, indicating a clear genetic link. Children usually are admitted to the hospital with abnormally high blood glucose after eating, with ketosis.

The onset of type 1 diabetes is generally associated with decreased release of insulin from the pancreas. As insulin in the blood declines, blood glucose increases, especially after eating. When blood glucose exceeds the kidney's threshold, excess glucose spills over into the urine—hence the term *diabetes mellitus,* which means "flow of much urine" (*diabetes*) that is "sweet" (*mellitus*). Figure 5-12 shows a typical glucose tolerance curve observed in a patient with this form of diabetes, following a test load of 75 g (15 teaspoons) of glucose.

An exciting finding regarding the cause of type 1 diabetes may help physicians treat this disease or even prevent its onset in the future. Most cases of type 1 diabetes begin with an immunological disorder, which causes destruction of the insulin-producing beta cells in the pancreas. Most likely, a virus or protein foreign to the body sets off the **autoimmune** destruction. In response to their destruction, the affected beta cells release other proteins, which stimulate a more furious attack. Eventually, the pancreas loses its ability to synthesize insulin, and the clinical stage of the disease begins. Consequently, early treatment to stop the immune-linked destruction in children may be important. Research on this is continuing.

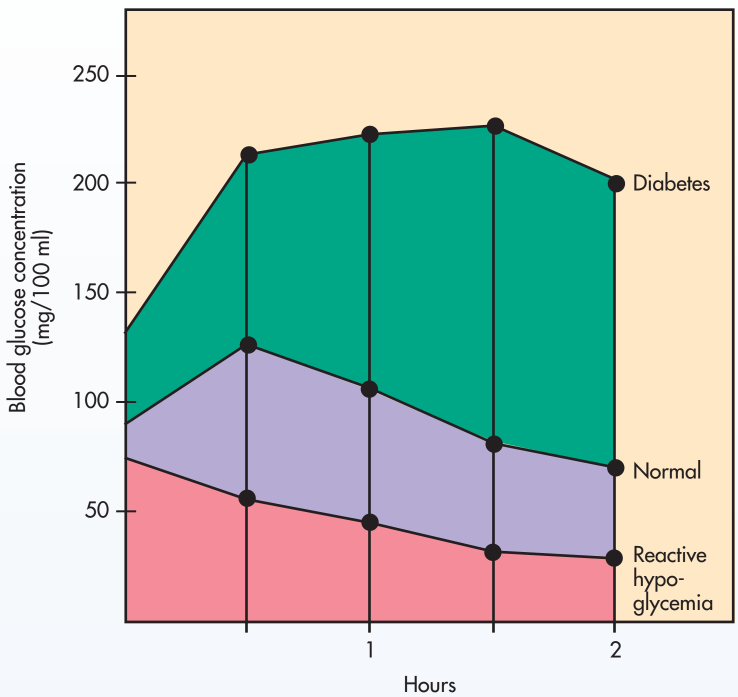
Before 1921, if a person had type 1 diabetes, a high-fat, low-calorie diet was recommended. This approach was found to be the best way to control blood glucose. It was somewhat effective but resulted in

type 1 diabetes A form of diabetes in which the person with the disease is prone to ketosis and requires insulin therapy.

type 2 (non–insulin-dependent) diabetes A form of diabetes in which ketosis is not commonly seen. Insulin therapy can be used but is often not required. This form of the disease is often associated with obesity.

autoimmune Immune reaction against normal body cells; self against self.

Figure 5-12 Glucose tolerance test. These are typical responses seen after consumption of 75 g (19 teaspoons) of glucose by a healthy person and by a person with uncontrolled diabetes or reactive hypoglycemia. Blood glucose concentration is determined during fasting and then at regular intervals after the person consumes the glucose test load. The depiction of reactive hypoglycemia is theoretical; the actual existence of this syndrome is in question. In any case, true hypoglycemia is rare.
Illustration by William Ober.



In both type 1 and type 2 diabetes, control of blood pressure and blood lipids and not smoking are keys to long-term health (see Chapters 6 and 11 for strategies).[16]

carbohydrate counting A diet method that assigns a certain number of food exchanges or carbohydrate grams to each meal and snack. Insulin is matched to carbohydrate intake (i.e., 1 unit of insulin per 10 to 15 g of carbohydrates), and carbohydrate grams can come from several combinations of exchanges.

A recent study showed no benefit when people with diabetes took vitamin E supplements.

poor growth in childhood and was difficult to implement. In the early part of the 1900s, a clinician could walk into a diabetes ward in a hospital and see scores of young, emaciated children. The isolation of insulin by Banting and Best in 1921 and the first use of it soon after in children opened a new door in diabetes care.

Today, type 1 diabetes is treated primarily by insulin therapy, either with injections two to six times a day or with an insulin pump. The pump dispenses insulin at a steady rate into the body, with greater amounts delivered after each meal. Dietary measures include three regular meals and one or more snacks (including one at bedtime), having a regulated carbohydrate:protein:fat ratio to maximize insulin action and minimize swings in blood glucose.[1] If one does not eat often enough, the injected insulin can cause severe hypoglycemia, since it acts on whatever little glucose is available. The diet should be rich in low glycemic load carbohydrates, include ample fiber and polyunsaturated fat, supply an amount of energy in balance with energy needs, and be low in both animal and other solid fats (e.g., stick margarine and shortenings), as well as moderate in high glycemic load carbohydrates.[19]

Type 1 patients often make excellent candidates for **carbohydrate counting,** a method that focuses on the amount of carbohydrates in each food choice. Type 1 patients are often very familiar with the exchange system and are motivated enough to learn how to use it to count carbohydrate intake. This method results in improved blood glucose control with a wider selection of foods.

If a high carbohydrate intake raises triglyceride and cholesterol in the blood beyond desired ranges, carbohydrate intake can be reduced and replaced with unsaturated fat. This change tends to reduce blood triglycerides and cholesterol. Chapter 6 discusses how to implement such a diet. Moderate consumption of sugars with meals is fine, as long as blood glucose regulation is preserved and the sugars replace other carbohydrates in the meal, so that undesirable weight gain does not take place.[2]

Because people with diabetes (type 1 as well as type 2) are at a high risk for cardiovascular disease and related heart attacks, they should take an aspirin each day (generally 80 mg/day to 160 mg/day) if their physicians find no reason not to do so. As discussed in Chapter 6, this practice reduces the risk of heart attack. In fact, the latest evidence suggests that diabetes essentially guarantees development of cardiovascular disease. Vitamin E (200 milligrams [about 400 IU] per day) may be prescribed because of this increased risk of cardiovascular disease. However, there is no convincing evidence that this vitamin E use produces such a benefit with regard to prevention of cardiovascular disease in people with diabetes (see Chapters 6 and 9 for details on vitamin E and cardiovascular disease).

The hormone imbalances that occur in people with untreated type 1 diabetes lead to mobilization of body fat, which is released into liver cells. Ketosis is the result because the fat is mostly converted to ketone bodies. These can rise excessively in the blood, eventually forcing ketone bodies into the urine. These pull sodium and potassium ions with them into the urine. This series of events can contribute to a chain reaction, which eventually leads to dehydration, ion imbalance, coma, and even death, especially in patients with poorly controlled type 1 diabetes. Treatment includes insulin and fluids, as well as sodium, potassium, and chloride.

Other complications of diabetes can be degenerative conditions, such as blindness, cardiovascular disease, and kidney disease; all are caused by poor blood glucose regulation. Nerves can also deteriorate, resulting in many changes that decrease proper nerve stimulation. When this occurs in the intestinal tract, intermittent diarrhea and constipation result. Because of nerve deterioration in the extremities, many people with diabetes lose the sensation of pain associated with injuries or infections. Not having as much pain, they often delay treatment of hand or foot problems. This delay, combined with a rich environment for bacterial growth (bacteria thrive on glucose) sets the stage for complications in the extremities, such as the need for amputation of feet and legs. High blood glucose also contributes to a rapid buildup of fats in blood vessel walls, which eventually limits the blood supply to various organs such as the heart. See Chapter 6 for details.

Current research, such as the Diabetes Control and Complications Trail (DCCT), has shown that the development of blood vessel and nerve complications of diabetes can be slowed with aggressive treatment directed at keeping blood glucose within the normal range. The therapy poses some risks of its own, such as hypoglycemia, so it must be implemented under the close supervision of a physician.[16]

A person with diabetes generally must work closely with a physician and dietitian to make the correct alterations in diet and medications and to perform physical activity safely. Physical activity enhances glucose uptake by muscles independent of insulin action, which in turn can lower blood glucose. This outcome is beneficial, but people with diabetes need to be aware of their own blood glucose response to physical activity and compensate appropriately.[2]

Type 2 Diabetes

Type 2 diabetes typically begins after age 40. This is the most common type of diabetes, accounting for about 90% of the cases diagnosed in North America. Minority populations such as Latino/Hispanic, African Americans, Asian Americans, Native Americans, and Pacific Islanders are at particular risk. The number of people affected with this form of diabetes is especially on the rise, primarily because of widespread inactivity and obesity in our population. In fact, recently there has been a substantial increase in type 2 diabetes in children, due mostly to an increase in overweight in this population (coupled with limited physical activity).[4] This type of diabetes is also genetically linked, but the initial problem is not with the beta cells of the pancreas. Instead, it arises with the insulin receptors on the cell surfaces of certain body tissues, especially muscle tissue. In this case, blood glucose is not readily transferred into cells, so the patient develops hyperglycemia as a result of the glucose's remaining in the bloodstream. The pancreas attempts to increase insulin output to compensate, but there is a limit to its ability to do this. Thus, rather than insufficient insulin production, there is an abundance of insulin, particularly during the onset of the disease. As the disease develops, pancreatic function can fail, leading to reduced insulin output. Because of the genetic link for type 2 diabetes, those who have a family history should be careful to avoid risk factors such as obesity, a diet rich in animal and other solid fats, and high glycemic load foods, and inactivity. Being tested regularly for hyperglycemia is also important.[19]

Regular exercise is a key part of a plan to prevent (and control) type 2 diabetes.

Many cases of type 2 diabetes (about 80%) are associated with obesity (especially fat located in the abdominal region), but the hyperglycemia is not directly caused by the obesity. In fact, some lean people also develop this type of diabetes. Obesity associated with oversized fat cells simply increases the risk for insulin resistance by the body, in turn increasing the risk for type 2 diabetes.

Type 2 diabetes linked to obesity often disappears as weight is lost. Achieving a healthy weight should be a primary goal of treatment, but even limited weight loss can lead to better blood glucose regulation.[5, 18] Oral medications can also help. Some examples are medications that reduce glucose production by the liver (metformin [Glucophage]), increase the ability of the pancreas to release insulin (glipizide [Glucotrol]), and increase the body's response to its own insulin (rosiglitazone [Avandia]). Another class of oral agents used works by delaying carbohydrate digestion and glucose absorption (acarbose [Precose]). A tablet is taken with the first bite of each meal and may be combined with other therapy.[11] (Note that pregnant women cannot use these oral medications because they will affect the blood glucose of the developing fetus.)

Recently people with diabetes have been cautioned not to cook foods at high temperatures for prolonged periods of time. This leads to advanced glycation endpoints forming in food. Use of a lower power setting with a microwave oven, lower oven temperatures, and minimal use of prolonged broiling and prolonged frying is advised. Colas and coffee are also sources of these compounds.

For more information on diabetes, consult the following websites: **www.diabetes.org** and **ndep.nih.gov**

reactive hypoglycemia Low blood glucose that follows a meal high in simple sugars, with corresponding symptoms of irritability, headache, nervousness, sweating, and confusion; also called *postprandial hypoglycemia*.

fasting hypoglycemia Low blood glucose that follows about a day of fasting.

Sometimes it may be necessary to provide insulin injections in type 2 diabetes because nothing else is able to control blood glucose. (This eventually becomes the case in about half of all cases of type 2 diabetes.) Regular physical activity also helps the muscles take up more glucose. And regular meal patterns, with an emphasis on control of energy intake, consumption of low glycemic load foods, with ample fiber, is important therapy. Note that nuts fulfill the last two goals. (An almost daily [$\geq 5\times$/week] intake of nuts was even shown to reduce the risk of developing type 2 diabetes in one recent study.) Some intake of sugars is fine with meals, but again these must be substituted for other carbohydrates, not simply added to the meal plan. Distributing carbohydrates throughout the day is also important, as this helps minimize the high and low swings in blood glucose concentrations.[2] Moderate alcohol use is fine (one serving per day). One recent study showed that this practice substantially reduced heart attack risk in people with type 2 diabetes. Still, the person must be warned that alcohol can lead to hypoglycemia and that the person must test him- or herself regularly for this possibility. Supplemental vitamin E may also be prescribed, as was discussed for type 1 diabetes, but again the benefits of such a practice are in doubt.

People with type 2 diabetes who have high blood triglycerides should moderate their carbohydrate intake and increase their intake of unsaturated fat and fiber, as noted earlier for people with type 1 diabetes.

Although many cases of type 2 diabetes can be relieved by reducing excess fat stores, many people are not able to lose weight. They remain affected with diabetes and may experience the degenerative complications seen in the type 1 form of the disease. Ketosis, however, is not usually seen in type 2 diabetes.

Hypoglycemia

As noted earlier, diabetic people who are taking insulin sometimes have hypoglycemia if they don't eat frequently enough. Hypoglycemia can also develop in nondiabetic individuals. The two common forms of nondiabetic hypoglycemia are termed *reactive* and *fasting*.

Reactive hypoglycemia (also called postprandial hypoglycemia) is described as irritability, nervousness, headache, sweating, and confusion 2 to 4 hours after eating a meal, especially a meal high in simple sugars. The cause of reactive hypoglycemia is unclear, but it may be overproduction of insulin by the pancreas in response to rising blood glucose. Some researchers are unwilling even to acknowledge the existence of reactive hypoglycemia, pointing out that the symptoms are more likely tied to recent, intense exercise, psychological stress, medication use, or excess alcohol consumption. **Fasting hypoglycemia** usually is caused by pancreatic cancer, which may lead to excessive insulin secretion. In this case, blood glucose falls to low concentrations after fasting for about 8 hours to 1 day. This form of hypoglycemia is rare.

The diagnosis of hypoglycemia requires the simultaneous presence of low blood glucose and the typical hypoglycemic symptoms. Blood glucose of 40 to 50 mg/100 ml is suggestive, but just having low blood glucose after eating is not enough evidence to make the diagnosis of hypoglycemia. Although many people think they have hypoglycemia, few actually do.

It is normal for healthy people to have some hypoglycemic symptoms, such as irritability, headache, and shakiness, if they have not eaten for a prolonged period of time. Although not diagnostic of hypoglycemia, if you sometimes have symptoms of hypoglycemia, the standard nutrition therapy is one we all could follow. You need to eat regular meals, make sure you have some protein and fat in each meal, and eat low glycemic load carbohydrates with ample soluble fiber. Avoid meals or snacks that contain little more than sugar. If symptoms continue, try small protein-containing snacks between meals or fruits and juice. Fat, protein, and soluble fiber in the diet tend to moderate swings in blood glucose. Last, moderate caffeine and alcohol intake.