PART TWO
ENERGY NUTRIENTS
AND ENERGY
BALANCE
CHAPTER 4 Carbohydrates

CHAPTER OBJECTIVES  Chapter 4 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. Describe food sources of carbohydrate and list some alternative sweeteners.
3. Explain how carbohydrates are digested and absorbed, including the consequences of lactose maldigestion (and lactose intolerance).
4. List the functions of carbohydrate in the body and the problems that result from not eating enough carbohydrate.
5. Describe the regulation of blood glucose and discuss how other nutrients can be converted to blood glucose.
6. Outline the beneficial effects of fiber on the body.
7. State the RDA for carbohydrate and various guidelines for carbohydrate intake.
8. Identify the consequences of diabetes, and explain appropriate dietary measures that will reduce the adverse effects of this health problem.

CHAPTER OUTLINE

- Chapter Objectives
- Refresh Your Memory
- Carbohydrates—An Introduction
- Simple Carbohydrates
- Complex Carbohydrates
- Fiber
- Carbohydrates in Foods
- Making Carbohydrates Available for Body Use
- Putting Simple Carbohydrates to Work in the Body
- Putting Fiber to Work
- Carbohydrate Needs
- Health Concerns Related to Carbohydrate Intake
- Nutrition and Your Health: Diabetes—When Blood Glucose Regulation Fails
- Case Study: Problems with Milk Intake
- Summary/Study Questions/Check Your Knowledge/Further Readings
- Rate Your Plate

WHAT DID YOU EAT TO OBTAIN THE ENERGY YOU ARE USING RIGHT NOW? Chapters 4, 5, and 6 will examine this question by focusing on the main nutrients the human body uses for fuel. These nutrients are carbohydrates (on average, 4 kcal per gram) and fats and oils (on average, 9 kcal per gram). Although protein (on average, 4 kcal per gram) can be used for energy needs, the body typically reserves this nutrient for other processes. Most people know that potatoes are rich in carbohydrates and steak contains mostly fat and protein, but many people do not know how to use this information.

It is likely that you have recently consumed fruits, vegetables, dairy products, cereal, breads, and pasta. These foods supply carbohydrates. Unfortunately, the benefits of these foods are often underestimated as suggested
The class of carbohydrate that has gained the most attention recently is fiber. Why is this so? Which health problems typically result from a limited intake of fiber? Which foods are good sources of fiber? How much fiber is enough? Too much? Chapter 4 provides some answers.

Refresh Your Memory

As you begin your study of carbohydrates in Chapter 4, you may want to review:

- The concept of energy density and the health claims for various carbohydrates in Chapter 2
- The processes of digestion and absorption in Chapter 3
- The hormones that regulate blood glucose in Chapter 3

CARBOHYDRATES—AN INTRODUCTION

Carbohydrates are a main fuel source for some cells, especially those in the brain, nervous system, and red blood cells. Muscles also rely on a dependable supply of carbohydrate to fuel intense physical activity. Carbohydrates provide on average 4 kcal per gram and are a readily available fuel for all cells, both in the form of blood glucose and glycogen stored in the liver and muscles. The glycogen stored in the liver can be used to maintain blood glucose concentrations in times when you have not eaten for several hours or the diet does not supply enough carbohydrate. Regular intake of carbohydrate is important, because liver glycogen stores are depleted in about 18 hours.
if no carbohydrate is consumed. After that point, the body is forced to produce carbohydrate, largely from breakdown of proteins in the body. This eventually leads to health problems including the loss of muscle tissue.

Humans have sensors on our tongues that recognize the sweetness of carbohydrates. Researchers speculate that this sweetness indicated a safe energy source to early humans, and so it became an important energy source.

Despite their important role as a calorie source, some forms of carbohydrate promote health more than others. As you will see in this chapter, whole-grain breads and cereals have greater health benefits than refined and processed forms of carbohydrate. Choosing the healthiest carbohydrate sources most often, while moderating intake of less healthful sources, contributes to a healthy diet. It is difficult to eat so little carbohydrate that body fuel needs are not met, but it is easy to overconsume the simple carbohydrates that can contribute to health problems. Let’s explore this concept further as we look at carbohydrates in detail.

Green plants create the carbohydrates in our foods. Leaves capture the sun’s solar energy in their cells and transform it to chemical energy. This energy is then stored in the chemical bonds of the carbohydrate glucose as it is produced from carbon dioxide from the air and water from the soil. This complex process is called photosynthesis (Fig. 4-1).

\[
6 \text{ carbon dioxide} + 6 \text{ water (solar energy)} \rightarrow \text{glucose} + 6 \text{ oxygen} \\
(CO_2) + (H_2O) \rightarrow (C_6H_12O_6) + (O_2)
\]

Translated into English, this reads: 6 molecules of carbon dioxide combine with 6 molecules of water to form one molecule of glucose. Converting solar energy into chemical bonds in the sugar is a key part of the process. Six molecules of oxygen are then released into the air.

**SIMPLE CARBOHYDRATES**

As the name suggests, most carbohydrate molecules are composed of carbon, hydrogen, and oxygen atoms. Simple forms of carbohydrates are called sugars. Larger, more complex forms are primarily called either starches or fibers, depending on their digestibility by human GI tract enzymes. Starches are the digestible form.

Monosaccharides and disaccharides are often referred to as simple sugars because they contain only one or two sugar units. Food labels lump all of these sugars under one category, listing them as “sugars.”

**Monosaccharides—Glucose, Fructose, and Galactose**

Monosaccharides are the simple sugar units (mono means one) that serve as the basic unit of all carbohydrate structures. The most common monosaccharides in foods are glucose, fructose, and galactose (Fig. 4-2).
Glucose is the major monosaccharide found in the body. Glucose is also known as dextrose, and glucose in the bloodstream may be called blood sugar. Glucose is an important source of energy for human cells, although foods contain very little carbohydrate as this single sugar. Most glucose comes from the digestion of starches and sucrose (common table sugar) from our food. The latter is made up of the monosaccharides glucose and fructose. For the most part, sugars and other carbohydrates in foods are eventually converted to glucose in the liver. This glucose then goes on to serve as a source of fuel for cells.

**Fructose**, also called fruit sugar, is another common monosaccharide. After it is consumed, fructose is absorbed by the small intestine and then transported to the liver, where it is quickly metabolized. Much is converted to glucose, but the rest goes on to form other compounds, such as fat, if fructose is consumed in very high amounts.

Most of the free fructose in our diets comes from the use of high-fructose corn syrup in soft drinks, candies, jams, jellies, and many other fruit products and desserts (see the later discussion on nutritive sweeteners). Fructose also is found naturally in fruits and forms half of each sucrose molecule, as previously noted.

The sugar galactose has nearly the same structure as glucose. Large quantities of pure galactose do not exist in nature. Instead, galactose is usually found bonded to glucose in lactose, a sugar found in milk and other milk products. After lactose is digested and absorbed, galactose arrives in the liver. There it is either transformed into glucose or further metabolized into glycogen.

**MAKING DECISIONS**

**Nutrient Metabolism**

Now is a good time to begin emphasizing a key concept in nutrition: the difference between intake of a substance and the body’s use of that substance. The body often does not use all nutrients in their original states. Some of these substances are broken down and later reassembled into the same or a different substance when and where they are needed. For example, much of the galactose in the diet is metabolized to glucose. When later required for the production of milk in the mammary gland of a lactating female, galactose is resynthesized from glucose to help form the milk sugar lactose. Knowing this, do you think it is necessary for a lactating woman to drink milk to make milk?

**Disaccharides—Sucrose, Lactose, and Maltose**

Disaccharides are formed when two monosaccharides combine (di means two). The disaccharides in food are sucrose, lactose, and maltose. All contain glucose.

Sucrose forms when the two sugars glucose and fructose bond together (Fig. 4-3). Sucrose is found naturally in sugarcane, sugar beets, honey, and maple sugar. These products are processed to varying degrees to make brown, white, and powdered sugars. Animals do not produce sucrose or much of any carbohydrate except glycogen.
Lactose forms when glucose bonds with galactose during the synthesis of milk. Again, our major food source for lactose is milk products. A later section on lactose malabsorption and lactose intolerance discusses the problems that result when a person can’t readily digest lactose.

Maltose results when starch is broken down to just two glucose molecules bonded together. Maltose plays an important role in the beer and liquor industry. In the production of alcoholic beverages, starches in various cereal grains are first converted to simpler carbohydrates by enzymes present in the grains. The products of this step—maltose, glucose, and other sugars—are then mixed with yeast cells in the absence of oxygen. The yeast cells convert most of the sugars to alcohol (ethanol) and carbon dioxide, a process called fermentation. Little maltose remains in the final product. Few other food products or beverages contain maltose. In fact, most maltose that we ultimately digest in the small intestine is produced during our own digestion of starch.

**COMPLEX CARBOHYDRATES**

In many foods, single-sugar units are bonded together to form a chain, known as a polysaccharide (poly means many). **Polysaccharides**, also called complex carbohydrates or starch, may contain 1000 or more glucose units and are found chiefly in grains, vegetables, and fruits. When food labels list “Other Carbohydrates,” this primarily refers to starch content.

Plants store carbohydrate in two forms of starch digestible by humans: **amylose** and **amylopectin**. Amylose, a long, straight chain of glucose units, comprises about 20% of the digestible starch found in vegetables, beans, breads, pasta, and rice. Amylopectin is a highly branched chain and makes up the remaining 80% of digestible starches in the diet (Fig. 4-4). Cellulose (a fiber) is another complex carbohydrate in plants. Although similar to amylose, it cannot be digested by humans, as discussed in the next section.

The enzymes that break down starches to glucose and other related sugars act only at the end of a glucose chain. Amylopectin, because it is branched, provides many more sites (ends) for enzyme action. Therefore, amylopectin is digested more rapidly and raises blood glucose much more readily than amylose (see the discussion of glycemic load in a later section of Chapter 4, “Carbohydrates in Foods”).

As noted earlier, animals—including humans—store glucose in the form of glycogen. Glycogen consists of a chain of glucose units with many branches, providing even more sites for enzyme action than amylopectin (review Fig. 4-4). Because of its branched structure that can be broken down quickly, glycogen is an ideal storage form of carbohydrate in the body.

The liver and muscles are the major storage sites for glycogen. Because the amount of glucose immediately available in body fluids can provide only about 120 kcal, these glycogen storage sites for carbohydrate energy—amounting to about 1800 kcal—are extremely important. Of this 1800 kcal, liver glycogen (about 400 kcal) can readily contribute to blood glucose. Muscle glycogen stores (about 1400 kcal) cannot raise blood glucose, but instead supply glucose for muscle

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**Figure 4-3** Chemical form of the disaccharide sucrose.
use, especially during high-intensity and endurance exercise (see Chapter 10 for a detailed discussion of carbohydrate use in exercise).

MAKING DECISIONS

Animal Sources of Carbohydrates

If animals store glycogen in their muscles, are meats, fish, and poultry a good source of carbohydrates? No—animal products are not good food sources of this (or any other) carbohydrate because glycogen stores quickly degrade after the animal dies.

FIBER

Fiber as a class is mostly made up of polysaccharides, but they differ from starches insofar as the chemical links that join the individual sugar units cannot be digested by human enzymes in the GI tract. This prevents the small intestine from absorbing the sugars that make up the various fibers. Fiber is not a single substance, but a group of substances with similar characteristics (Table 4-1). The group is comprised of the carbohydrates cellulose, hemicelluloses, pectins, gums, and mucilages, as well as the noncarbohydrate, lignin. In total, these constitute all the nonstarch polysaccharides in foods. Nutrition Facts labels generally do not list these individual forms of fiber, but instead lump them together under the term dietary fiber.

Cellulose, hemicelluloses, and lignin form the structural parts of plants. Bran fiber is rich in hemicelluloses and lignin. (The woody fibers in broccoli are partly lignin.) Bran layers form the outer covering of all grains, so whole grains (i.e., unrefined) are good sources of bran fiber (Fig. 4-5). Because the majority of these fibers neither readily dissolve in water nor are easily metabolized by intestinal bacteria, they are called nonfermentable or insoluble fibers.

Pectins, gums, and mucilages are contained around and inside plant cells. These fibers either dissolve or swell when put into water and are therefore called viscous or soluble fibers. They also are readily fermented by bacteria in the large intestine. These fibers are found in salad dressings, some frozen desserts, jams, and jellies as gum arabic, guar gum, locust bean gum, and various pectin forms. Some forms of hemicelluloses also fall into the soluble category.
Most foods contain mixtures of soluble and insoluble fibers. Food labels do not generally distinguish between the two types, but, manufacturers have the option to do so. Often, if food is listed as a good source of one type of fiber, it usually contains some of the other type of fiber as well. The definition of fiber has recently been expanded to include both the dietary fiber found naturally in foods and additional fiber that is added to foods. This second category is called functional fiber; a fiber of this type 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. 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.

A newly studied category of functional fiber are the prebiotics. Prebiotics include a group of short-chain carbohydrates or oligosaccharides, resistant to digestion, but fermented by the gut bacteria. These fibers can enhance the body’s ability to absorb short-chain fatty acids from the gut, lower blood cholesterol, and prevent constipation.

<table>
<thead>
<tr>
<th>TABLE 4-1 Classification of Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Nonfermentable or Insoluble</td>
</tr>
<tr>
<td>Noncarbohydrate form</td>
</tr>
<tr>
<td>Carbohydrate form</td>
</tr>
<tr>
<td>Viscous or Soluble</td>
</tr>
<tr>
<td>Carbohydrate form</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

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

**total fiber** Combination of dietary fiber and functional fiber in a food. Also just called fiber.

**FIGURE 4-5** Viscous and nonfermentable fiber. (a) The skin of an apple consists of the nonfermentable fiber cellulose, which provides structure for the fruit. The viscous fiber pectin “glues” the fruit cells together. (b) The outside layer of a wheat kernel is made of layers of bran—primarily hemicellulose, a nonfermentable fiber—making this whole grain a good source of fiber. Overall, fruits, vegetables, whole-grain breads and cereals, and beans are rich in fiber.
bacteria in the colon. They are thought to stimulate the growth or activity of beneficial bacteria in the large intestine and therefore promote the host’s health.

**CONCEPT CHECK**

Important monosaccharides in nutrition are glucose, fructose, and galactose. Glucose is a primary energy source for body cells. Disaccharides form when two monosaccharides bond together. Important disaccharides in nutrition are sucrose (glucose + fructose), maltose (glucose + glucose), and lactose (glucose + galactose). Once digested into monosaccharides and absorbed, most carbohydrates are transformed into glucose by the liver.

Amylose, amylopectin, and glycogen are all polysaccharides, which function as storage forms of glucose. Amylose and amylopectin are the major digestible plant polysaccharides and contain multiple glucose units bonded together. Glycogen is a storage form of glucose in our liver and muscle cells.

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

**CARBOHYDRATES IN FOODS**

The food components that yield the highest percentage of calories from carbohydrates are table sugar, honey, jam, jelly, fruit, and plain baked potatoes (Fig. 4-6). Corn flakes, rice, bread, and noodles all contain at least 75% of calories as carbohydrates.

### Food Sources of Carbohydrate

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Carbohydrate (grams)</th>
<th>% RDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDA</td>
<td>130</td>
<td>100%</td>
</tr>
<tr>
<td>Baked potato, 1 each</td>
<td>51</td>
<td>39%</td>
</tr>
<tr>
<td>Cola drink, 12 fluid oz</td>
<td>39</td>
<td>30%</td>
</tr>
<tr>
<td>Plain M&amp;Ms, 1/2 oz</td>
<td>30</td>
<td>23%</td>
</tr>
<tr>
<td>Banana, 1 each</td>
<td>28</td>
<td>22%</td>
</tr>
<tr>
<td>Cooked rice, 1/2 cup</td>
<td>22</td>
<td>17%</td>
</tr>
<tr>
<td>Cooked corn, 1/2 cup</td>
<td>21</td>
<td>16%</td>
</tr>
<tr>
<td>Light yogurt, 1 cup</td>
<td>19</td>
<td>15%</td>
</tr>
<tr>
<td>Kidney beans, 1/2 cup</td>
<td>19</td>
<td>15%</td>
</tr>
<tr>
<td>Spaghetti noodles, 1/2 cup</td>
<td>19</td>
<td>15%</td>
</tr>
<tr>
<td>Orange, 1 each</td>
<td>16</td>
<td>12%</td>
</tr>
<tr>
<td>Seven grain bread, 1 slice</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Fat-free milk, 1 cup</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Pineapple chunks, 1/2 cup</td>
<td>10</td>
<td>8%</td>
</tr>
<tr>
<td>Cooked carrots, 1/2 cup</td>
<td>8</td>
<td>6%</td>
</tr>
<tr>
<td>Peanuts, 1 ounce</td>
<td>6</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Key:**
- **Grains**
- **Vegetables**
- **Fruits**
- **Oils**
- **Milk**
- **Meat & Beans**
- **Discretionary calories**
Foods with moderate amounts of carbohydrate calories are peas, broccoli, oatmeal, dry beans and other legumes, cream pies, French fries, and fat-free milk. In these foods, the carbohydrate content is diluted either by protein, as in the case of fat-free 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.

The percentage of calories from carbohydrate is more important than the total amount of carbohydrate in a food when planning a healthy high-carbohydrate diet. Figure 4-7 shows that the grain, vegetable, fruit, and milk groups contain the most nutrient-dense sources of carbohydrate. 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 calories from chocolate, potato chips, and French fries because these foods contain too much fat. Currently, 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 North Americans (teenagers included) should take a closer look at their main carbohydrate sources and strive to improve them from a nutritional standpoint by including more whole grains, fruits, and vegetables.

**A Closer Look at Sweeteners**

The various substances that impart sweetness to foods fall into two broad classes: nutritive sweeteners, which can provide calories for the body; and alternative sweeteners, which for the most part provide no calories. As shown in Table 4-2, the alternative sweeteners are much sweeter on a per-gram basis than the

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**MyPyramid: Sources of Carbohydrates**

![MyPyramid: Sources of Carbohydrates](image)

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Grains</th>
<th>Vegetables</th>
<th>Fruits</th>
<th>Oils</th>
<th>Milk</th>
<th>Meat &amp; Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources of Carbohydrate</td>
<td>All varieties</td>
<td>All varieties</td>
<td>All varieties</td>
<td>None</td>
<td>Milk</td>
<td>Beans</td>
</tr>
<tr>
<td>Grams per Serving</td>
<td>15</td>
<td>5</td>
<td>18</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

**FIGURE 4-7** Sources of carbohydrates from MyPyramid. The height of the background color (none, 1/3, 2/3, or completely covered) within each group in the pyramid indicates the average nutrient density for carbohydrate in that group. Overall, the grain group, vegetable group, fruit group, and milk group contain many foods that are nutrient-dense sources of carbohydrate. With regard to physical activity, carbohydrates are a key fuel in most endeavors.
The taste and sweetness of sucrose make it the benchmark against which all other sweeteners are measured. Sucrose is obtained from sugar cane and sugar beet plants.

**Nutritive Sweeteners**

Both sugars and sugar alcohols provide calories 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) discussed earlier are designated *nutritive sweeteners* (Table 4-3). Many forms of sugar are used in food products and result in an intake of about 82 grams or 16 teaspoons of sugar per day.

High-fructose corn syrup, generally 55% fructose, is used extensively in the food industry. High-fructose corn syrup is made by treating cornstarch with acid and en-
zymes. 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. 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. Turbinado sugar, a partially refined version of raw sucrose, has a slight molasses flavor.

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 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. 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.

### SUGAR ALCOHOLS

Food manufacturers and consumers have numerous options for obtaining sweetness while consuming less sugar and calories. Overall, sugar alcohols and 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.

Sugar alcohols such as sorbitol and xylitol are used as nutritive sweeteners. Sugar alcohols contribute fewer calories (about 2.6 kcal per gram) than sugars. They also are absorbed and metabolized to glucose more slowly than are simple sugars. Because of this, they remain in the intestinal tract for a longer time and in large quantities can cause diarrhea. In fact, any products that may be consumed in amounts that may result in a daily ingestion of 50 grams of sugar alcohols, must bear this labeling statement: “Excess consumption may have a laxative effect.”

Sugar alcohols are used in sugarless gum, breath mints, and candy. Unlike sucrose, sugar alcohols are not readily metabolized by bacteria to acids in the mouth and thus do not promote tooth decay (see the later section on problems linked to carbohydrate intake).
Sugar alcohols must be listed on labels. If only one sugar alcohol is used in a product, its name must be listed. However, if two or more are used in one product, they are grouped together under the heading "sugar alcohols." The caloric value of each sugar alcohol used in a food product is calculated so that when one reads the total amount of calories a product provides, it includes the sugar alcohols in the overall amount.

**ALTERNATIVE SWEETENERS**

Often called artificial sweeteners, alternative sweeteners include saccharin, cyclamate, aspartame, sucralose, neotame, and acesulfame-K. Unlike sugar alcohols, alternative sweeteners yield little or no calories when consumed in amounts typically used in food products. Six are currently available in the United States: saccharin, aspartame, sucralose, neotame, acesulfame-K, and tagatose. Cyclamate was banned for use in the United States in 1970, although it has never been conclusively proven to cause health problems when used appropriately. Cyclamate is used in Canada as a sweetener in medicines and as a tabletop sweetener.

**Saccharin**

The oldest alternative sweetener, saccharin, was first produced in 1879 and is currently approved for use in more than 90 countries. It represents about half of the alternative sweetener market in North America (typically packaged in pink packets, including Sweet 'N Low®). Based on laboratory animal studies, saccharin was once thought to increase the risk of bladder cancer but it is no longer listed as a potential cause of cancer.

**Aspartame**

Aspartame is in widespread use throughout the world (typically packaged in blue packets, including Equal®). 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 other groups.

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 per gram, but it is about 200 times sweeter than sucrose. Thus, only a small amount of aspartame is needed to obtain the desired sweetness, and the amount of calories added is insignificant unless the product is consumed in unusually high amounts. 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 would lose its sweetness if 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, but the percentage of sensitive people is likely to be extremely small.

The acceptable daily intake of aspartame set by FDA is 50 milligrams per kilogram of body weight. This is equivalent to the aspartame in 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 calories to grow.

**Sucralose**

Sucralose (Splenda®) is 600 times sweeter than sucrose. It is made by adding three chlorines to sucrose. Sucralose is approved for use as an additive to foods such as soft drinks, gum, baked goods, syrups, gelatins, frozen dairy desserts such as ice cream, and many other food products. Sucralose was first produced in 1976. The FDA approved it for use in the United States in 1996. 

Persons with an uncommon disease called phenylketonuria (PKU), which interferes with the metabolism of phenylalanine, should avoid aspartame because of its high phenylalanine content. A warning label is required on products containing aspartame, alerting people with PKU that a product with aspartame contains phenylalanine.

Sugarless Gum

Sugar alcohols and the alternative sweetener aspartame are used to sweeten this product. Note the warning for people with PKU that this product with aspartame contains phenylalanine.
jams, 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 small amount absorbed is excreted in the urine.

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 because neotame is not broken down in the body to its amino acid components.

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 calories 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.

Tagatose

Tagatose is a slightly altered form of the simple sugar fructose. It is approved for use in ready-to-eat breakfast cereals, diet soft drinks, meal replacement bars, frozen desserts, candy, frosting, and chewing gum. Tagatose is poorly absorbed, so it yields only 1.5 kcal per gram to the body. Use also does not raise the risk for dental caries, nor does it increase blood glucose. Eventual fermentation in the large intestine may even lead to a beneficial effect on that organ (i.e., a prebiotic effect, covered in Chapter 3).

CONCEPT CHECK

Table sugar, honey, jam, fruit, and plain baked potatoes contain the highest percentage of calories from carbohydrates. Foods such as cream pies, potato chips, whole milk, and oatmeal contain moderate amounts of carbohydrate. Common nutritive sweeteners added to foods include sucrose, maple sugar, honey, brown sugar, and high-fructose corn syrup. For people who want to limit calories from sugar intake, other sweeteners are available and include the sugar alcohols, saccharin, aspartame, sucralose, neotame, acesulfame-K, and tagatose. Of these, aspartame is the most common alternative sweetener in use.

Stevia comes from a South American shrub; it is 100 to 300 times sweeter than sucrose and provides zero calories. It 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 natural- and health-food stores as a dietary supplement.

Diet soft drinks are now sweetened with a variety of alternative sweeteners.
MAKING CARBOHYDRATES AVAILABLE FOR BODY USE

As discussed in Chapter 3, simply eating a food does not supply nutrients to body cells. Digestion and absorption must occur first.

**Digestion**

Food preparation can be viewed as the start of carbohydrate digestion because cooking softens tough connective structures in the fibrous parts 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 of these effects of cooking generally make carbohydrate-containing foods easier to chew, swallow, and break down during 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, primarily disaccharides, such as maltose (Fig. 4-8). You can taste 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 disaccharides, 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 inactivates salivary amylase.

When the carbohydrates reach the small intestine, the more alkaline environment of the intestine is better suited for further carbohydrate digestion. The pancreas releases enzymes, such as pancreatic amylase, to aid the last stage of starch digestion. After amylase action, the original carbohydrates in a food are now present in the small intestine as the monosaccharides glucose and fructose, originally present as such in food, and disaccharides (maltose from starch breakdown, lactose mainly from dairy products, and sucrose from food and that added at the table).

The disaccharides are digested to their monosaccharide units once they reach the wall of the small intestine, where the specialized enzymes on the absorptive cells digest each disaccharide into monosaccharides. 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.

**Lactose Maldigestion and Lactose Intolerance.** Lactose maldigestion is a normal pattern of physiology that often begins to develop after early childhood, at about ages 3 to 5 years. 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. (When significant symptoms develop after lactose intake it is then called lactose intolerance.) Another form of the problem, secondary lactose maldigestion, is a temporary condition in which lactase production is decreased in response to another condition, such as intestinal diarrhea. The symptoms of lactose intolerance include gas, abdominal bloating, cramps, and diarrhea. The bloating and gas 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.

In North America, approximately 25% of adults show signs of decreased lactose digestion in the small intestine. Many lactose maldigesters are Asian Americans, African Americans, and Latino/Hispanic Americans, and the occurrence increases as people age. 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.

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. Thus, it is unnecessary for these people to greatly restrict their intake of lactose-containing foods, such as milk and milk products. 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 in a diet.

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 fermentation of lactose by bacteria in the large intestine. 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 their lactase. In addition, an array of products, such as low-lactose milk and lactase pills, are available to assist lactose maldigesters when needed.

**Absorption**

Monosaccharides found naturally in foods and those formed as by-products of starch and disaccharide digestion in the mouth and small intestine generally follow an active absorption process. Recall from Chapter 3 that this is a process that requires a specific
carrier and energy input 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 pumped into the absorptive cells along with sodium.

Fructose 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 thus slower than that seen with glucose or galactose. So, large doses of fructose are not readily absorbed and can contribute to diarrhea as the monosaccharide remains in the small intestine and attracts water.

Once glucose, galactose, and fructose enter the absorptive cells, some fructose is metabolized into glucose. The single sugars in the absorptive cells are then transferred to the portal vein that goes directly to the liver. The liver then metabolizes those sugars by transforming the monosaccharides galactose and fructose into glucose and:

- Releasing it directly into the bloodstream for transport to organs such as the brain, muscles, kidneys, and adipose tissues
- Producing glycogen for storage of carbohydrate
- Producing fat (minor amount, if any)

Of these three options, producing fat is the least likely, except when carbohydrates are consumed in high amounts and overall calorie needs are exceeded.

Unless an individual has a disease that causes malabsorption, or an intolerance to a carbohydrate such as lactose (or fructose), only a minor amount of some sugars (about 10%) escapes digestion. Any undigested carbohydrate travels to the large intestine and is fermented there by bacteria. The acids and gases produced by bacterial metabolism of the undigested carbohydrate are absorbed into the bloodstream. Scientists suspect that some of these products of bacterial metabolism promote the health of the large intestine by providing it with a source of calories.

### MAKING DECISIONS

**Fermentable Fiber**

Bacteria in the large intestine ferment soluble fibers into such products as acids and gases. The acids, once absorbed, also provide calories for the body. In this way, soluble fibers provide about 1.5 to 2.5 kcal per gram. Although the intestinal gas (flatuscence) produced by this bacterial fermentation is not harmful, it can be painful and sometimes embarrassing. Over time, however, the body tends to adapt to a high-fiber intake, eventually producing less gas.

Name some potentially gas-forming foods. Are these foods good sources of soluble fiber?

---

**CONCEPT CHECK**

Carbohydrate digestion is the process of breaking down larger carbohydrates into smaller units, and eventually to monosaccharide forms. The enzymatic digestion of starches in the body 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. 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. When significant symptoms develop after lactose intake, it is called lactose intolerance. Following primarily an active absorption process, glucose and galactose, (resulting from the digestive process or present in the meal), are taken up by absorptive cells in the intestine. Fructose undergoes facilitated absorption. All of the monosaccharides then enter the portal vein that goes directly to the liver. The liver finally exercises its metabolic options, producing glucose, glycogen, and even fat if carbohydrates are consumed in great excess and overall calorie needs are exceeded.
PUTTING SIMPLE CARBOHYDRATES 
TO WORK IN THE BODY

As just discussed, all of the digestible carbohydrate that we eat is eventually converted to glucose. Glucose then is the form of carbohydrate that goes on to function in body metabolism. The other sugars can generally be converted to glucose and the starches are broken down to yield glucose, so the functions described here apply to most carbohydrates. The functions of glucose in the body start with supplying calories to fuel the body.

Yielding Energy

The main function of glucose is to supply calories for use by the body. Certain tissues in the body, such as red blood cells, can use only glucose and other simple carbohydrate forms for fuel. Most parts of the brain and central nervous system also derive energy only from glucose, unless the diet contains almost none. In that case, much of the brain can use partial breakdown products of fat—called ketone bodies—for energy needs. Other body cells, including muscle cells, can use simple carbohydrates as fuel but many of these cells can also use fat or protein for energy needs.

Sparing Protein from Use as an Energy Source 
and Preventing Ketosis

A diet that supplies enough digestible carbohydrates to prevent breakdown of proteins for energy needs is considered protein sparing. Under normal circumstances, digestible carbohydrates in the diet mostly end up as blood glucose, and protein is reserved for functions such as building and maintaining muscles and vital organs. However, if you don’t eat enough carbohydrates, your body is forced to make glucose from body proteins, draining the pool of amino acids available in cells for other critical functions. During long-term starvation, the continuous withdrawal of proteins from the muscles, heart, liver, kidneys, and other vital organs can result in weakness, poor function, and even failure of body systems.

In addition to the loss of protein, when you don’t eat enough carbohydrates, the metabolism of fats is inefficient. In the absence of adequate carbohydrate, fats don’t break down completely in metabolism and instead form ketone bodies. This condition, known as ketosis, should be avoided because it disturbs the body’s normal acid-base balance and leads to other health problems. This is a good reason to question the long-term safety of the low-carbohydrate diets that have been popular.

MAKING DECISIONS

Carbohydrates and Protein Sparing

The wasting of protein that occurs during long-term fasting can be life threatening. This has prompted companies that make formulas for rapid weight loss to include sufficient carbohydrate in the products to decrease protein breakdown and thereby protect vital tissues and organs, including the heart. Most of these very low-calorie products are powders that can be mixed with different types of fluids and are consumed five or six times per day. When considering any weight-loss products, be sure that your total diet provides at least the RDA for carbohydrate.

Regulating Glucose

Under normal circumstances, a person’s blood glucose concentration is regulated within a narrow range. Recall from Chapter 3 that when carbohydrates are digested and taken up by the absorptive cells of the small intestine, the resulting monosaccharides are
transported directly to the liver. One of the liver’s roles, then, is to guard against excess glucose entering the bloodstream after a meal. The liver works in concert with the pancreas to regulate blood glucose.

When the concentration of glucose in the blood is high, such as during and immediately after a meal, the pancreas releases the hormone \textit{insulin} into the bloodstream. Insulin delivers two different messages to various body cells to cause the level of glucose in the blood to fall. First, insulin directs the liver to store the glucose as glycogen. Second, insulin directs muscle, adipose, and other cells to remove glucose from the bloodstream by taking it into those cells. By triggering both glycolysis synthesis in the liver and glucose movement out of the bloodstream into certain cells, insulin keeps the concentration of glucose from rising too high in the blood (Fig. 4-9).

On the other hand, when a person has not eaten for a few hours and blood glucose begins to fall, the pancreas releases the hormone \textit{glucagon}. This hormone has the opposite effect of insulin. It prompts the breakdown of liver glycogen into glucose, which is then released into the bloodstream. In this way, glucagon keeps blood glucose from falling too low.

A different mechanism increases blood glucose during times of stress. \textit{Epinephrine} (adrenaline) is the hormone responsible for the “flight or fight” reaction. Epinephrine and a related compound are released in large amounts from the adrenal glands (located on each kidney) and various nerve endings in response to a perceived threat, such as a car approaching head-on. These hormones cause glycogen in the liver to be quickly broken down into glucose. The resulting rapid flood of glucose from the liver into the bloodstream helps promote quick mental and physical reactions.

In essence, the actions of insulin on blood glucose are balanced by the actions of glucagon, epinephrine, and other hormones. If hormonal balance is not maintained, such as during over- or underproduction of insulin or glucagon, major changes in blood glucose concentrations occur. The disease, type 1 diabetes, is an example of the under-production of insulin. To maintain blood glucose within an acceptable range, the body relies on a complex regulatory system. This provides a safeguard against extremely high blood glucose (hyperglycemia) or low blood glucose (hypoglycemia). The failure of blood glucose regulation will be discussed in the “Nutrition and Your Health” section at the end of this chapter.

**FIGURE 4-9** Regulation of blood glucose. Insulin and glucagon are key hormones in controlling blood glucose concentration within the normal range of 70 to 99 milligrams per deciliter (mg/dL). Other hormones, such as epinephrine, also contribute to blood glucose regulation. When we eat a meal, insulin is released to promote glucose uptake by cells, thus reversing the increase in blood glucose that results from absorption of various sugars after a meal and in turn restoring the balance. When fasting, blood glucose falls. Glucagon is released to promote glucose release from glycogen stores in the liver. This raises blood glucose, again restoring the balance.
The Glycemic Index and Glycemic Load of Carbohydrate Sources

Our bodies react uniquely to different sources of carbohydrates, such that a serving of a high-fiber food, such as baked beans, results in lower blood glucose levels compared to the same size serving of mashed potatoes. Why are we concerned with the effects of various foods on blood glucose? Foods that result in a high blood glucose elicit a large release of insulin from the pancreas. Chronically high insulin output leads to many deleterious effects on the body: high blood triglycerides, increased fat deposition in the 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 macronutrients in the blood as it stimulates their storage, signaling hunger). Over time, this increase in insulin output may cause the muscles to become resistant to the action of insulin, and eventually lead to type 2 diabetes in some people. Two food measurements have been developed that are useful in predicting the blood sugar response to various foods and for planning a diet to avoid hyperglycemia (high blood glucose).

The first of these tools is glycemic index (GI). Glycemic index is a ratio of the blood glucose response to a given food compared to a standard (typically, glucose or white bread) (Table 4-4). Glycemic index is influenced by starch structure, fiber content, food processing, physical structure, and other macronutrients in the meal, such as fat. Foods with particularly high glycemic index values are potatoes, especially baking potatoes (due to higher amylopectin content compared to red potatoes), mashed potatoes (due to greater surface area exposed), short grain white rice, honey, and jelly beans. A major shortcoming of glycemic index is that the measurement is based on a serving of food that would provide 50 grams of carbohydrate. As you can imagine, this amount of food may not reflect the amount typically consumed.

Another way of describing how different foods affect blood glucose (and insulin) levels is glycemic load (GL). The glycemic load is more useful because it takes into account the glycemic index and the amount of carbohydrate consumed. Glycemic load, therefore, better reflects a food's effect on one's blood glucose than either number alone. To calculate the glycemic load of a food, the amount (in grams) of carbohydrate in a serving of the food is multiplied by the glycemic index of that food, and then divided by 100 (because glycemic index is a percentage). For example, vanilla wafers have a glycemic index of 77, and a small serving contains 15 grams of carbohydrate:

\[
\text{Glycemic Load} = \frac{\text{Glycemic Index} \times \text{Grams of Carbohydrate}}{100} = \frac{77 \times 15}{100} = 11.5
\]

Even though the glycemic index of vanilla wafers (77) is considered high, the glycemic load calculation shows that the impact of this food on blood glucose levels is fairly low (review Table 4-4).

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. At least once per meal, consider substituting a food that has a low glycemic load for one with a higher value, such as long grain rice or spaghetti for a baked potato. 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.

Substituting low glycemic load carbohydrates for high glycemic load foods can help in the treatment of diabetes; Chapter 10 discusses the use of foods with different glycemic load values in planning diets for athletes.
You might wonder why the glycemic index and glycemic load of white bread and whole wheat are similar. This is because whole-wheat flour is typically so finely ground that it is quickly digested. Thus the effect of fiber in slowing digestion and related absorption of glucose is no longer present. Some experts suggest we focus more on minimally processed (e.g., coarsely ground, steel cut, or rolled) grains, such as with whole-wheat flour and oatmeal, to get the full benefits of these fiber sources.

The glycemic load of breads is due mostly to portion size, not carbohydrate content.

<table>
<thead>
<tr>
<th>Pastas/Grains</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White, long grain</td>
<td>1 cup</td>
<td>56</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>White, short grain</td>
<td>1 cup</td>
<td>72</td>
<td>53</td>
<td>38</td>
</tr>
<tr>
<td>Spaghetti</td>
<td>1 cup</td>
<td>41</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots, boiled</td>
<td>1 cup</td>
<td>49</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>1 cup</td>
<td>55</td>
<td>39</td>
<td>21</td>
</tr>
<tr>
<td>Potato, baked</td>
<td>1 cup</td>
<td>85</td>
<td>57</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dairy Foods</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, skim</td>
<td>1 cup</td>
<td>32</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Yogurt, low-fat</td>
<td>1 cup</td>
<td>33</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>Ice cream</td>
<td>1 cup</td>
<td>61</td>
<td>31</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Legumes</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baked beans</td>
<td>1 cup</td>
<td>48</td>
<td>54</td>
<td>26</td>
</tr>
<tr>
<td>Kidney beans</td>
<td>1 cup</td>
<td>27</td>
<td>38</td>
<td>10</td>
</tr>
<tr>
<td>Navy beans</td>
<td>1 cup</td>
<td>38</td>
<td>54</td>
<td>21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sugars</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honey</td>
<td>1 tsp</td>
<td>73</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Sucrose</td>
<td>1 tsp</td>
<td>65</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Fructose</td>
<td>1 tsp</td>
<td>23</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breads and Muffins</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagel</td>
<td>1 small</td>
<td>72</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Whole-wheat bread</td>
<td>1 slice</td>
<td>69</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>White bread</td>
<td>1 slice</td>
<td>70</td>
<td>10</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>1 medium</td>
<td>38</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium</td>
<td>55</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>Orange</td>
<td>1 medium</td>
<td>44</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beverages</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange juice</td>
<td>1 cup</td>
<td>46</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Gatorade</td>
<td>1 cup</td>
<td>78</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>1 cup</td>
<td>63</td>
<td>26</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Snack Foods</th>
<th>Serving Size (grams)</th>
<th>Glycemic Index (GI)</th>
<th>Carbohydrate (grams)</th>
<th>Glycemic Load (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato chips</td>
<td>1 oz</td>
<td>54</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Vanilla wafers</td>
<td>5 cookies</td>
<td>77</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Jelly beans</td>
<td>1 oz</td>
<td>80</td>
<td>26</td>
<td>21</td>
</tr>
</tbody>
</table>

CONCEPT CHECK

Carbohydrates provide glucose for the energy needs of red blood cells and parts of the brain and nervous system. Eating too little carbohydrates forces the body to make glucose using primarily amino acids from proteins found in muscles and other vital organs. A low glucose supply in cells also inhibits efficient metabolism of fats. Ketosis can then result.

Blood glucose concentration is maintained within a narrow range. When blood glucose rises after a meal, the hormone insulin is released in great amounts from the pancreas. Insulin acts to lower blood glucose by increasing glucose storage in the liver and glucose uptake by other body cells. If blood glucose falls during fasting, glucagon and other hormones increase the liver’s release of glucose into the bloodstream to restore normal blood glucose concentrations. In a similar way, the hormone epinephrine can make more glucose available in response to stress. This balance in hormone activity helps maintain blood glucose within a healthy range.

PUTTING FIBER TO WORK

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 to contract, which aids elimination. Consequently, less pressure is necessary to expel the stool.

When too little fiber is eaten, the opposite can occur: very little water is present in the feces, making it small and hard. Constipation may result, which forces 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 many small pouches called diverticula (Fig. 4-10). Hemorrhoids may also result from excessive straining during defecation (review 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 and painful, a condition known as diverticulitis. Surprisingly, 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.

Aside from its role in maintaining bowel regularity, the consumption of fiber has many additional health benefits. A diet high in fiber likely controls weight and reduces the risk of developing obesity. The bulky nature of high-fiber foods requires more time to chew and fills us up without yielding many calories. Increasing intake of foods rich in fiber is one strategy for feeling satisfied or full after a meal (review the discussion of energy density in Chapter 2). This is still another reason to question the low-carbohydrate diets—where is the whole-grain fiber going to come from?

Over the past 30 years, many population studies have shown a link between increased fiber intake and a decrease in colon cancer development. Most of the research on diet and colon cancer is focusing on the potential preventive effects of fruits, vegetables, whole-grain breads and cereals, and beans (rather than just fiber). Smoking, obesity in men, excessive alcohol use, starch- and sugar-rich foods, and processed meat intake are under study as potential causes of colon cancer. Overall, the health benefits to the colon that stem from a high-fiber diet are partially due to the nutrients that are commonly present in most high-fiber foods, such as vitamins, minerals, phytochemicals, 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.

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.”
Consuming large amounts of viscous fibers, such as oat fiber, slow glucose absorption from the small intestine, and so contribute to better blood glucose regulation. 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.

Recall that good sources of viscous fiber are apples, bananas, oranges, carrots, barley, oats, and kidney beans. A high intake of viscous fiber also inhibits absorption of cholesterol and cholesterol-rich bile acids from the small intestine, thereby reducing blood cholesterol and possibly reducing the risk of cardiovascular disease and gallstones. The beneficial bacteria in the large intestine degrade soluble fiber and produce certain fatty acids that probably also reduce cholesterol synthesis in the liver. In addition, the slower glucose absorption that occurs with diets high in viscous fiber is linked to a decrease in insulin release. One of the effects of insulin is to stimulate cholesterol synthesis in the liver, so this reduction in insulin may contribute to the ability of viscous fiber to lower blood cholesterol. Overall, a fiber-rich diet containing fruits, vegetables, beans, and whole-grain breads and cereals (including whole-grain breakfast cereals) is advocated as part of a strategy to reduce cardiovascular disease (coronary heart disease and stroke) risk. And again, this is something that a low-carbohydrate diet can’t promise.

**CONCEPT CHECK**

Fiber forms a vital part of the diet by adding mass to the stool, which eases elimination. Fiber-rich foods also help in weight control and reduce the risk of developing obesity and cardiovascular disease, and possibly colon cancer. Soluble fiber can also be useful for controlling blood glucose in patients with diabetes and in lowering blood cholesterol. Whole-grain breads and cereals, vegetables, beans, and fruits are excellent sources of fiber.

**CARBOHYDRATE NEEDS**

Currently, recommendations for carbohydrate intake vary widely in the scientific literature and popular press. The RDA for carbohydrates is 130 grams per day for adults. This is based on the amount needed to supply adequate glucose for the brain and nervous system, without having to rely on ketone bodies from incomplete fat breakdown as a calorie source. Somewhat exceeding this amount is fine; the Food and Nutrition Board recommends that carbohydrate intake should range from 45% to 65% of total calorie intake. The Nutrition Facts panel on food labels uses 60% of calorie intake as the standard for recommended carbohydrate intake. This would be 300 grams of carbohydrate when consuming a 2000-calorie diet.

North American adults consume about 180 to 330 grams of carbohydrates per day, which supply about 50% of calorie intake. Worldwide, however, carbohydrates account for about 70% of all calories consumed, and in some countries, up to 80% of the calories consumed. One recommendation on which almost all experts agree is that one’s carbohydrate intake should be based primarily on fruits, vegetables, whole-grain breads and cereals, and beans, rather than on refined grains, potatoes, and sugar.

The 2005 Dietary Guidelines for Americans recommend that we choose fiber-rich fruits, vegetables, and whole grains often. More specifically, three or more ounces of grains, roughly one-half of one’s grains, should be whole. Remember that the 2005 Dietary Guidelines define whole grain as the entire grain seed or kernel made of three components: bran, germ, and endosperm.
How Much Fiber Do We Need?

An Adequate Intake for fiber has been set based on the ability of fiber to reduce risk of cardiovascular disease (and likely many cases of diabetes). The Adequate Intake for fiber for adults is 25 grams per day for women and 38 grams per day for men. The goal is to provide at least 14 grams per 1000 kcal in a diet. After age 50, the Adequate Intake falls to 21 grams per day and 30 grams per day, respectively. The Daily Value used for fiber on food and supplement labels is 25 grams for a 2000 kcal diet. In North America, fiber intake averages 13 grams per day for women and 17 grams per day for men and the average whole-grain intake is less than one serving per day. This low intake is attributed to the lack of knowledge on the benefits of whole grains, and the inability 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 (at least 3 grams of fiber per serving) for breakfast is one easy way to increase fiber intake (Fig. 4-11).

The “Rate Your Plate” exercise shows a diet containing 25 or 38 grams of fiber within moderate calorie intakes. Diets to meet the fiber recommendations are possible and enjoyable if you incorporate plenty of whole-wheat bread, fruits, vegetables, and beans. Use the “Rate Your Plate” exercise to estimate the fiber content of your diet. What is your fiber score?

MAKING DECISIONS

Whole Grains

When buying bread, if you see the name “wheat bread” on the label, do you think you are buying a whole-wheat product? Most people do. The flour is from the wheat plant, so manufacturers correctly list enriched white (refined) flour as wheat flour on food labels. However, 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 the term whole grains on the food label to ensure that you are getting a good source of natural fiber.

In the final analysis, keep in mind that any nutrient can lead to health problems when consumed in excess. High carbohydrate, high fiber, and low fat does not mean zero calories. Carbohydrates help moderate calorie intake in comparison with fats, but high-carbohydrate foods also contribute to total calorie intake.

HEALTH CONCERNS RELATED TO CARBOHYDRATE INTAKE

Aside from the health risks related to ketosis, both excessive fiber and sugar intakes can pose health problems. Too much lactose in the diet is also a problem for some people.

Problems with High-Fiber Diets

Very high intakes of fiber—for example, 60 grams per day—can pose some health risks and therefore should be followed only under the guidance of a physician. Increased fluid intake is extremely important with a high-fiber diet. Inadequate fluid intake can leave the stool very hard and painful to eliminate. In more severe cases, the combination of excess fiber and insufficient fluid may contribute to blockages in the intestine, which may require surgery.

Aside from problems with the passage of materials through the GI tract, a high-fiber diet may also decrease the availability of nutrients. Certain components of fiber...
FIGURE 4-11 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. Did 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. 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**

<table>
<thead>
<tr>
<th>Serving Size</th>
<th>1 cup (65g/2.0 oz.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount Per Serving</td>
<td>Cereal</td>
</tr>
<tr>
<td>Calories</td>
<td>170</td>
</tr>
<tr>
<td>Calories from Fat</td>
<td>10</td>
</tr>
<tr>
<td>Total Fat</td>
<td>1.5g</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>0g</td>
</tr>
<tr>
<td>Trans Fat</td>
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</tr>
<tr>
<td>Cholesterol</td>
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</tr>
<tr>
<td>Sodium</td>
<td>300mg</td>
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<tr>
<td>Potassium</td>
<td>340mg</td>
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<tr>
<td>Total Carbohydrate</td>
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</tr>
<tr>
<td>Dietary Fiber</td>
<td>7g</td>
</tr>
<tr>
<td>Sugars</td>
<td>14g</td>
</tr>
<tr>
<td>Other Carbohydrate</td>
<td>25g</td>
</tr>
<tr>
<td>Protein</td>
<td>1g</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>15%</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>20%</td>
</tr>
<tr>
<td>Calcium</td>
<td>2%</td>
</tr>
<tr>
<td>Iron</td>
<td>65%</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>10%</td>
</tr>
<tr>
<td>Thiamin</td>
<td>25%</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>25%</td>
</tr>
<tr>
<td>Niacin</td>
<td>25%</td>
</tr>
<tr>
<td>Vitamin B6</td>
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</tr>
<tr>
<td>Folic acid</td>
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</tr>
<tr>
<td>Vitamin B12</td>
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</tr>
<tr>
<td>Phosphorus</td>
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</tr>
<tr>
<td>Magnesium</td>
<td>20%</td>
</tr>
<tr>
<td>Zinc</td>
<td>25%</td>
</tr>
<tr>
<td>Copper</td>
<td>10%</td>
</tr>
</tbody>
</table>

*Amount in cereal. One half cup skim milk contributes an additional 40 calories, 0g total fat, 0g total carbohydrate, and 4g protein.

**Daily Value**

<table>
<thead>
<tr>
<th>Serving Size:</th>
<th>1/4 Cup (30g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount Per Serving</td>
<td>Cereal</td>
</tr>
<tr>
<td>Calories</td>
<td>170</td>
</tr>
<tr>
<td>Calories from Fat</td>
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<tr>
<td>Saturated Fat</td>
<td>0g</td>
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<tr>
<td>Trans Fat</td>
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<tr>
<td>Cholesterol</td>
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<td>Potassium</td>
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<tr>
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<tr>
<td>Dietary Fiber</td>
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</tr>
<tr>
<td>Sugars</td>
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<tr>
<td>Other Carbohydrate</td>
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<tr>
<td>Protein</td>
<td>3g</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>25%</td>
</tr>
<tr>
<td>Vitamin C</td>
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</tr>
<tr>
<td>Calcium</td>
<td>0%</td>
</tr>
<tr>
<td>Iron</td>
<td>10%</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>10%</td>
</tr>
<tr>
<td>Thiamin</td>
<td>25%</td>
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<tr>
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<tr>
<td>Niacin</td>
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<td>Vitamin B6</td>
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</tr>
<tr>
<td>Folic acid</td>
<td>25%</td>
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</tr>
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<td>Phosphorus</td>
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</tr>
<tr>
<td>Magnesium</td>
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</tr>
<tr>
<td>Zinc</td>
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</tr>
<tr>
<td>Copper</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Amount in Cereal. One half cup skim milk contributes an additional 40 calories, 0g total fat, 0g total carbohydrate, and 4g protein.

**Ingredients:** Wheat bran with other parts of wheat, raisins, sugar, corn syrup, salt, malt flavoring, glycerin, iron, niacinamide, zinc oxide, pyridoxine hydrochloride (vitamin B6), riboflavin (vitamin B2), vitamin A palmitate, thiamin hydrochloride (vitamin B1), folic acid, vitamin B12, and vitamin D.

**Whole-grain foods, such as granola, are excellent sources of fiber.**
may bind to essential minerals, keeping them from being absorbed. For example, when fiber is consumed in large amounts, zinc and iron absorption may be hindered. In children, a very high fiber intake may reduce overall calorie intake, because fiber can quickly fill a child’s small stomach before food intake meets energy needs.

**Problems with High-Sugar Diets**

The main problems with consuming an excess amount of sugar are that it provides empty calories and increases the risk for dental decay.

**Diet Quality Declines When Sugar Intake Is Excessive.** 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 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. This exchange of soft drinks for milk can compromise bone health because milk contains calcium and vitamin D, both essential for bone health.

Supersizing sugar-rich beverages is also a growing problem; for example, in the 1950s a typical serving size of a soft drink was a 6½ ounce bottle, and now a 20 ounce plastic bottle is a typical serving. This one change in serving size contributes 170 extra kcal of sugars to the diet. Most convenience stores now offer cups that will hold 64 ounces 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 ounce serving a day is generally fine. Switching to diet soft drinks would spare the simple sugar calories, but still lacks nutritional value, except for the fluid.

The sugar found in cakes, cookies, and ice cream also supplies many extra calories that promote weight gain, unless an individual is physically active. Today’s low-fat and fat-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 equal to or greater in calorie content than the high-fat food product it was designed to replace.

With regard to sugar intake, an upper limit of 25% of total calorie intake from “added sugars” has been set by the Food and Nutrition Board (sugars added to foods during processing and preparation). Diets that go beyond this upper limit are likely to be deficient in vitamins and minerals. The World Health Organization suggests that added sugars provide no more than 10% of total daily calorie intake.

A moderate intake of about 10% of calorie intake corresponds to a maximum of approximately 50 grams (or 12 tsp) of sugars per day, based on a 2000 kcal diet. Most of the sugars we eat come from foods and beverages to which sugar has been added during processing and/or manufacture. On average, North Americans eat about 82 grams of added sugars daily, amounting to about 16% of calorie intake. Major sources of added sugars include soft drinks; cakes; cookies; fruit punch; and dairy desserts, such as ice cream. Following the recommendation of having no more than 10% of added calories from sugars is easier if sweet desserts such as cakes, cookies, and ice cream (full and reduced fat) are consumed sparingly (Table 4-5).

**MAKING DECISIONS**

Sugar and Hyperactivity

There is a widespread notion that high sugar intake by children causes hyperactivity, typically part of the syndrome called **attention deficit hyperactivity disorder (ADHD)**. However, most researchers find that sucrose may have the opposite effect. 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. 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.
Sugars in the diet (and starches readily fermented in the mouth, such as crackers and white bread) also increase the risk of developing **dental caries**. Recall that caries, also known as cavities, are formed when sugars and other carbohydrates are metabolized into acids by bacteria that live in the mouth (Fig. 4-12). These acids dissolve the tooth enamel and underlying structure. Bacteria also use the sugars to make plaque, a sticky substance that both adheres acid-producing bacteria to teeth and diminishes the acid-neutralizing effect of saliva.

The worst offenders in terms of promoting 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. Frequent consumption of liquid sugar sources (e.g., fruit juices) can also cause 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 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 promote acid production by bacteria in the mouth. As mentioned, if starch-containing foods (e.g., crackers and bread) are held in the mouth for a long time, the starch will be broken down to sugars by enzymes in the mouth; bacteria can then produce acid from these sugars. Overall, the sugar and starch content of a food and its ability to remain in the mouth largely determine its potential to cause caries.

**Fluoridated water and toothpaste have contributed to fewer dental caries in North American children over the past 20 years due to fluoride’s tooth-strengthening effect** (see Chapter 9). Research has also indicated that certain foods—such as cheese, peanuts, and sugar-free chewing gum—can 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.
TABLE 4-5 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 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.
- For snacks, buy reduced-fat microwave popcorn to replace candy.

**In the Kitchen**

- Reduce the sugar in foods prepared at home. Try new low-sugar recipes or adjust your own. Start by reducing the sugar gradually until you’ve decreased it by one-third or more. Consider using Splenda to substitute for some sugar.
- 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 higher in sugar.

**At the Table**

- Use less of all sugars. This includes white and brown sugars, honey, molasses, syrups, jams, and jellies.
- Choose fewer foods high in sugar, such as prepared baked goods, candies, and sweet desserts.
- Reach for fresh fruit instead of cookies or candy 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.


**CONCEPT CHECK**

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

North Americans eat about 82 grams 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 and various aspects of health.
Improper regulation of blood glucose results in either hyperglycemia (high blood glucose) or hypoglycemia (low blood glucose) as noted in this chapter. High blood glucose is most commonly associated with diabetes (technically, diabetes mellitus), a disease that affects 6.5% of the North American population. Of these, it is estimated one-third to one-half of these people do not know that they have the disease. Diabetes leads to about 200,000 deaths each year in North America. Diabetes is currently increasing in epidemic proportions in North America. New recommendations promote testing fasting blood glucose in adults over age 45 every 3 years to help diagnose the problem. Diabetes is diagnosed when one’s fasting blood glucose is 126 milligrams per 100 milliliters of blood or greater. In contrast, low blood glucose is a much rarer condition.

**DIABETES**

There are two major forms of diabetes: type 1 (formerly called insulin-dependent or juvenile-onset diabetes), and type 2 diabetes (formerly called non–insulin-dependent or adult-onset diabetes) (Table 4-6). The change in names to type 1 and type 2 diabetes stems from the fact that many type 2 diabetics eventually must 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 some pregnant women (see Chapter 14). It is usually treated with an insulin regimen and diet and resolves after delivery of the baby. However, women who have gestational diabetes during pregnancy are at high risk for developing type 2 diabetes later in life.

<table>
<thead>
<tr>
<th>TABLE 4-6 Comparing and Contrasting Type 1 and Type 2 Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occurrence</strong></td>
</tr>
<tr>
<td>Cause</td>
</tr>
<tr>
<td>Risk Factors</td>
</tr>
<tr>
<td></td>
</tr>
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<td>Characteristics</td>
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<td>Complications*</td>
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<tr>
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</tr>
</tbody>
</table>

*In both cases maintaining a healthy blood lipid profile and normal blood pressure is vital to avoid these complications (see Chapters 5 and 9 for strategies).
Traditional symptoms of diabetes are excessive urination, excessive thirst, and 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, as well as evidence of 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. Figure 4-13 shows a typical glucose tolerance curve observed in a patient with this form of diabetes after consuming about 75 grams of glucose. When blood glucose levels are high, the kidneys let excess glucose spill into the urine, resulting in frequent urination of urine high in sugar.

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. Maintaining near-normal hemoglobin A1c levels greatly reduces the risk of death and developing other diseases in people with diabetes. Elevated blood glucose also leads to glycation of other proteins and fats in the body, forming what are called advanced glycation endproducts (AGEs). These have been shown to be toxic to cells, especially those of the immune system and kidneys.

Most cases of type 1 diabetes begin with an immune system disorder, which causes destruction of the insulin-producing cells in the pancreas. Most likely, a virus or protein foreign to the body sets off the destruction. In response to their damage, the affected pancreatic 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 into this area is ongoing.

Type 1 diabetes is treated primarily by insulin therapy, either with injections two to six times per day or with an insulin pump. The pump dispenses insulin at a steady rate into the body, with greater amounts delivered after each meal. Inhaled forms of insulin also are available. Dietary therapy includes three regular meals and one or more snacks (including one at bedtime) and having a regulated ratio of carbohydrate: protein:fat to maximize insulin action and control the blood glucose levels.

**Symptoms of Diabetes**

The symptoms of diabetes may occur suddenly, and include one or more of the following:

- Extreme thirst
- Frequent urination
- Drowsiness, lethargy
- Sudden vision changes
- Increased appetite
- Sudden weight loss
- Sugar in urine
- Fruity, sweet, or winelike odor on breath
- Heavy, labored breathing
- Stupor, unconsciousness

**FIGURE 4-13** Glucose tolerance test. A comparison of blood glucose concentrations in untreated diabetic and healthy (normal) persons after consuming a load of glucose (about 75 grams).
minimize swings in blood glucose. If one does not eat often enough, the injected insulin can cause a severe drop in blood glucose or hypoglycemia, because it acts on whatever glucose is available. The diet should be moderate in simple carbohydrates, include ample fiber and polyunsaturated fat, but be low in both animal and trans fats, supply an amount of calories in balance with needs, and include fish twice a week. Meeting magnesium needs is also helpful, as well as a moderate intake of coffee.

If a high carbohydrate intake raises triglycerides and cholesterol in the blood beyond desired ranges, carbohydrate intake can be reduced and replaced with unsaturated fat. Surprisingly, this change tends to reduce blood triglycerides and cholesterol. Chapter 5 discusses how to implement such a diet (as well as when certain related medications may be beneficial). Some 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.

The latest evidence suggests that diabetics essentially guarantees development of cardiovascular disease. 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 to 160 milligrams per day) if their physicians find no reason not to do so. Blood cholesterol lowering medications also may be prescribed. As discussed in Chapter 5, these practices reduce the risk of heart attack.

The hormone imbalances that occur in people with untreated type 1 diabetes—chiefly, not enough insulin—lead to mobilization of body fat, taken up by liver cells. Ketosis is the result because the fat is partially broken down to ketone bodies. Ketone bodies can rise excessively in the blood, eventually forcing ketone bodies into the urine. These pull sodium and potassium ions and water with them into the urine. This series of events also causes frequent urination and can contribute to a chain reaction that eventually leads to dehydration; ion imbalance; coma; and even death, especially in patients with poorly controlled type 1 diabetes. Treatment includes provision of insulin, fluids, and minerals such as sodium and potassium.

In addition to cardiovascular disease, other degenerative complications that result from poor blood glucose regulation, specifically long-term hyperglycemia, include blindness, kidney disease, and deterioration of nerves. The high blood sugar concentration physically deteriorates small blood vessels (capillaries) and nerves. When improper nerve stimulation 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. They do not have as much pain, so 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 damage and death of tissues in the extremities, sometimes leading to the need for amputation of feet and legs. Current research 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.

A person with diabetes generally must work closely with a physician and registered 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 type 1 diabetes need to be aware of their blood glucose response to physical activity and compensate appropriately.

### TYPE 2 DIABETES

Type 2 diabetes usually 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 Americans, African Americans, Asian Americans, Native Americans, and those from Pacific Islands are at particular risk. As noted in the introduction, the overall number of people affected also is on the rise, primar-
ily because of widespread inactivity and obesity in our population. 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). Type 2 diabetes is also genetically linked, so family history is an important risk factor. However, the initial problem is not with the insulin-secreting cells of the pancreas. Instead, type 2 diabetes arises when the insulin receptors on the cell surfaces of certain body tissues, especially muscle tissue, become insulin resistant. In this case, blood glucose is not readily transferred into cells, so the person develops high blood glucose as a result of the glucose 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 schedule regular blood glucose tests and be careful to avoid risk factors such as obesity, inactivity, a diet rich in animal and trans fats, and simple carbohydrates.

Many cases of type 2 diabetes (about 80%) are associated with obesity (especially with fat located in the abdominal region), but high blood glucose is not directly caused by the obesity. In fact, some lean people also develop this type of diabetes. Obesity associated with oversized adipose cells increases the risk for insulin resistance by the body as more fat is added to these cells during weight gain.

Type 2 diabetes linked to obesity often disappears if the obesity is corrected. Achieving a healthy weight therefore should be a primary goal of treatment, but even limited weight loss can lead to better blood glucose regulation. Although many cases of type 2 diabetes can be relieved by reducing excess adipose tissue 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. Certain oral medications can also help control blood glucose. Adequate chromium intake is also important for blood glucose regulation (see Chapter 9). Patients with type 2 diabetes may experience decreased effectiveness of their treatments over time resulting in spikes in blood glucose after meals and weight gain. New classes of drugs that mimic gut hormones are helping diabetic patients overcome the chronic problems that conventional treatments alone have been unable to control.

Sometimes it may be necessary to provide insulin injections in type 2 diabetes because nothing else is able to control the disease. (This eventually becomes true 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 calorie intake and consumption of mostly fiber-rich carbohydrates, as well as regular fish intake, is important therapy. Nuts help fulfill the goal of increased fiber consumption. And regular meal patterns, with an emphasis on control of calorie intake and consumption of mostly fiber-rich carbohydrates, as well as regular fish intake, is important therapy. Nuts help fulfill the goal of increased fiber consumption. (An almost daily intake of nuts was even shown to reduce the risk of developing type 2 diabetes in one study.) Some sugar consumption 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. Moderate alcohol use is acceptable (1 serving per day) and has been shown
to substantially reduce heart attack risk in people with type 2 diabetes. Still, the person must be warned that alcohol can lead to hypoglycemia and that regular testing for this possibility is necessary. And, as mentioned before, meeting magnesium needs and moderate coffee intake are also helpful.

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.

### HYPOGLYCEMIA

As noted earlier, people with diabetes 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** occurs 2 to 4 hours after eating a meal, especially a meal high in simple sugars. It results in irritability, nervousness, headache, sweating, and confusion. The cause of reactive hypoglycemia is unclear, but it may be overproduction of insulin by the pancreas in response to rising blood glucose. In **fasting hypoglycemia**, blood glucose falls to low concentrations after fasting for about 8 hours to 1 day. It usually is caused by pancreatic cancer, which may lead to excessive insulin secretion. 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 milligrams per 100 milliliters 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. If you sometimes have symptoms of hypoglycemia, you need to eat regular meals, make sure you have some protein and fat in each meal, and eat complex carbohydrates with ample soluble fiber. Avoid meals or snacks that contain little more than simple carbohydrates. This standard nutrition therapy is one we all could follow. If symptoms continue, try small protein-containing snacks or fruits and juice between meals. Fat, protein, and viscous fiber in the diet tend to moderate swings in blood glucose. Last, moderate caffeine and alcohol intake.

### METABOLIC SYNDROME

**Metabolic syndrome**, also known as Syndrome X, is characterized by the occurrence of several risk factors for diabetes and cardiovascular disease. The precise definition and criteria for diagnosis have recently been debated by health scholars. A person with metabolic syndrome has several or all of the following conditions: abdominal obesity (accumulation of fat around and within the midsection), high blood triglycerides, low HDL or “good” cholesterol, hypertension, high fasting blood glucose, increased blood clotting, and increased inflammation (Fig. 4-14).

Each aspect of metabolic syndrome is a unique health problem with its own treatment. In metabolic syndrome, however, these risk factors are clustered together, making a person twice as likely to develop cardiovascular disease and five times more likely to develop diabetes.

It is generally accepted that one key element unifies all the aspects of metabolic syndrome: **insulin resistance**. As you learned in this chapter, insulin is a hormone that directs tissues to pull glucose out of the blood and into cells for storage or fuel. With insulin resistance, the pancreas produces plenty of insulin, but the cells of the body do not respond to it effectively. Instead, excess glucose stays in the bloodstream. For a while the pancreas may be able to compensate for the resistance of cells to insulin by overproducing insulin. Over time, however, the pancreas is unable to keep up the accelerated insulin production and blood glucose levels remain elevated. With metabolic syndrome, blood glucose is not high enough to be classified as diabetes (≥126 milligrams per deciliter), but without intervention, it is likely to get worse and eventually lead to diabetes.

Genetics and aging contribute to the development of insulin resistance and the
ars and refined starches and low in fiber, coupled with little physical activity. Nutrition and lifestyle changes are key strategies in addressing all of the unhealthy conditions of metabolic syndrome as a whole. Suggested interventions include:

• Decrease body weight. Even small improvements (e.g., 5% weight loss) for overweight and obese individuals can lessen disease risk. The most successful weight loss and weight maintenance programs include moderate dietary restriction combined with physical activity.

• Increase physical activity. To alleviate risks for chronic diseases, the Dietary Guidelines for Americans include a recommendation for at least 30 minutes of moderate-intensity physical activity on most days of the week.

• Choose healthy fats. Limiting intakes of total fat, saturated fat, and trans fat are generally recommended for improving blood lipids. Including omega-3 fats, such as those found in fish and nuts, is another way to combat chronic disease.

• For those with particularly high risk for cardiovascular disease, medications may be warranted.

**FIGURE 4-14** For a patient to be diagnosed with metabolic syndrome, he or she must have three of the five risk factors listed above.
1. The common monosaccharides in food 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 + fructose), maltose (glucose + glucose), and lactose (glucose + 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. These can be broken down by human digestive enzymes, releasing the glucose units. The main plant starches—straight-chain amylose and branched-chain amylpectin—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. Table sugar, honey, jelly, fruit, and plain baked potatoes are some of the most concentrated sources of carbohydrates. Other high-carbohydrate foods, such as pie and fat-free milk, are diluted by either fat or protein. Nutritive sweeteners in food include sucrose, high-fructose corn syrup, brown sugar, and maple syrup. Several alternative sweeteners are approved for use by FDA: saccharin, aspartame, sucralose, neotame, acesulfame-K, and tagatose.

6. 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.

7. The ability to digest large amounts of lactose often diminishes with age. People in some ethnic groups are especially affected. This condition often develops early in childhood and is referred to as lactose malabsorption. 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, yogurt, and moderate amounts of milk.

8. Carbohydrates provide calories (on average, 4 kcal per gram), protect against wasteful breakdown of food and body protein, and prevent ketosis. The RDA for carbohydrate is 130 grams per day. If carbohydrate intake is inadequate for the body’s needs, protein is metabolized to provide glucose 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.

9. Insoluble (also called nonfermentable) 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.

10. Diets high in complex carbohydrates are encouraged as a replacement for high-fat diets. A goal of about half of calories as complex carbohydrates is a good one, with about 45% to 65% of total calories com-
ing 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.

11. Moderating sugar intake, especially between meals, reduces the risk of dental caries. Alternative sweeteners, such as aspartame, aid in reducing intake of sugars.

12. Diabetes is characterized by a persistent high blood glucose concentration. A healthy diet and regular physical activity are helpful in treating both type 1 and type 2 diabetes. Insulin is the main medication employed—it is required in type 1 diabetes and may be used in type 2 diabetes.

STUDY QUESTIONS

1. Outline the basic steps in blood glucose regulation, including the roles of insulin and glucagon.

2. What are the three major monosaccharides and the three major disaccharides? Describe how each plays a part in the human diet.

3. Why are some foods that are high in carbohydrates, such as cookies and fat-free milk, not considered to be concentrated sources of carbohydrates?

4. Describe the digestion of the various types of carbohydrates in the body.

5. Describe the reason why some people are unable to tolerate high intakes of milk.

6. What are the important roles that fiber plays in the diet?

7. What, if any, are the proven ill effects of sugar in the diet?

8. Why do we need carbohydrates in the diet?

9. Summarize current carbohydrate intake recommendations.

10. List three alternatives to simple sugars for adding sweetness to the diet.

CHECK YOUR KNOWLEDGE

Answers to the following multiple choice questions are in Appendix A.

1. Dietary fiber
   a. raises blood cholesterol levels.
   b. speeds up transit time for food through the digestive tract.
   c. causes diverticulosis.
   d. causes constipation.

2. When the pancreas detects excess glucose, it releases the
   a. enzyme amylase.
   b. monosaccharide glucose.
   c. hormone insulin.
   d. hormone glucagon.

3. Cellulose is a(n)
   a. indigestible fiber.
   b. simple carbohydrate.
   c. energy-yielding nutrient.
   d. animal polysaccharide.

4. Digested white sugar is broken into __________ and __________.

5. Starch is a
   a. complex carbohydrate.
   b. fiber.
   c. simple carbohydrate.
   d. gluten.

6. Fiber content of the diet can be increased by adding
   a. fresh fruits.
   b. fish and poultry.
   c. eggs.
   d. whole grains and cereals.
   e. Both a and d.

7. Which form of diabetes is most common?
   a. type 1
   b. type 2
   c. type 3
   d. gestational

8. The recommended daily intake for fiber is approximately __________ grams.
   a. 5
   b. 30
   c. 100
   d. 450

9. Glucose, galactose, and fructose are
   a. disaccharides.
   b. sugar alcohols.
   c. monosaccharides.
   d. polysaccharides.

10. One of the components of metabolic syndrome is
    a. obesity.
    b. diabetes.
    c. low blood sugar.
    d. low blood pressure.

FURTHER READINGS

1. ADA Reports: Position of the American Dietetic Association: Use of nutritive and non-nutritive sweeteners. Journal of the American Dietetic Association 104:225, 2004. When currently recommended diet practices are met, such as the Dietary Guidelines for Americans, use of some nutritive and non-nutritive sweeteners is acceptable. The text of the article explores in detail both classes of sweeteners, in turn supporting this overall conclusion.


3. Artificial Sweeteners: No calories…Sweet! FDA Consumer 40(4):406, 2006. This article is an update on the artificial sweeteners approved by the FDA. To date, five...
artificial sweeteners are approved by the FDA: aspartame, saccharin, acesulfame-K, neotame, and sucralose. The typical amount of each of these sweeteners used by U.S. consumers is well within designated levels that can be consumed safely every day over a lifetime. The article provides a detailed look at each of the sweeteners.


The understanding of diabetes has increased greatly over the past 10 years. Along with this better understanding have come new products and treatment options. These new products include new insulin analogues, inhaled insulin, and new therapies that mimic other factors that work alongside insulin (glucagon-like peptide 1 and amylin). These therapies are welcome because they provide great promise for increasing numbers of people with diabetes.


The results of this study of the National Health And Nutrition Examination Survey (NHANES) suggest that 73 million Americans have diabetes or are at risk based on higher-than-normal blood glucose levels. The prevalence of diagnosed diabetes increased significantly over the last decade, and minority groups remain disproportionately affected. The overall prevalence of total diabetes in 1999–2002 was 9.3% (13.9 million), consisting of 6.5% diagnosed and 2.8% undiagnosed. The prevalence of diagnosed diabetes rose from 5.1% in 1988–1994 to 6.5% in 1999–2002. The prevalence of total diabetes was much greater (21.6%) in older individuals and 26.5% years. Diagnosed diabetes was twice as prevalent in non-Hispanic blacks and Mexican-Americans compared with non-Hispanic whites.


Missing one’s fiber needs is very important for preventing diverticular disease. To do so, eat plenty of fruits, vegetables, and whole grain products. Regular physical activity also helps prevent the problem.


The consumption of sugar-sweetened drinks by children has increased dramatically over the past 20 years right along with the rise in childhood obesity. A new intervention aimed at limiting consumption of sugary drinks had a beneficial effect on weight loss in teens. The intervention was the home delivery of noncaloric beverages (water and artificially sweetened drinks) to displace sugar-sweetened beverages. The teens were also instructed on how to choose noncaloric drinks outside the home. The intervention decreased consumption of sugary drinks by 82%. The heavier the teen, the greater was the effect on body weight. The authors calculate that a single 12-ounce sugar-sweetened beverage per day results in about 1 pound of weight gain over 3 to 4 weeks.


This report provides the latest guidance for macronutrient intakes. With regard to carbohydrate, the RDA has been set at 130 grams per day. Carbohydrate intake should range from 45% to 65% of calorie intake. Sugars added to foods should constitute no more than 25% of calorie intake.


The metabolic syndrome concept has led to the development of clinical guidelines by the World Health Organization and the National Cholesterol Education Program. These guidelines have been well accepted by medical professionals. This article reviews the new diagnosis of metabolic syndrome and discusses why organizations including the American Diabetes Association and many diabetes specialists have not embraced the clustering of its risk factors.


In this study of 128 overweight or obese young adults, both high-protein and low-glycemic index diets increased body fat loss. Cardiovascular disease risk was decreased best with a high-glycemic index index diet.


In this large analysis of pooled data from 13 prospective studies, dietary fiber was inversely associated with risk of colorectal cancer when data were adjusted for age. However, when other dietary risk factors (red meat, total milk, and alcohol intake) were accounted for, high-dietary fiber intake was not associated with a decreased risk of colorectal cancer. The authors conclude that a diet high in dietary fiber from whole plant foods can still be advised because this has been related to lower risks of other chronic conditions, including heart disease and diabetes.


Metabolic syndrome, especially its link to obesity, has become better understood in recent years. This article reviews the role of obesity, the dilemmas of diagnosis, new diet and activity guidelines, and the need for a combination of therapeutic approaches for metabolic syndrome.


Patients with diabetes, especially type 2 diabetes, experience spikes in blood glucose after meals, weight gain, and decreased effectiveness of their treatments over time. New classes of diabetes drugs that mimic gut hormones are helping diabetic patients overcome the chronic problems that conventional treatments alone have been unable to control. Some new drugs are already available and others are under development.


An analysis of the results of 21 studies of lactose intolerance revealed that lactose is not a major cause of symptoms for lactose malabsorbers after a moderate intake of dairy foods equaling about 1 cup.


The 2005 Dietary Guidelines recommend 3 or more ounces of whole-grain products per day. This equals about one-half of one’s intake from the grain group. Recent surveys, however, have found that only 5% of American adults eat one-half of their grains as whole grains. This article discusses the need to better educate consumers about whole grain including better definitions and ways of measuring these foods.


Limiting simple sugars in a diet is important to lessen the risk of developing obesity, diabetes, and dental caries, as well as increasing diet quality. Moderate use of the alternative sweeteners listed in the article helps one meet that goal.


Regular whole-grain consumption may help prevent cardiovascular disease, unnecessary weight gain, and the metabolic syndrome. This is easier to do today because many whole-grain products are available.


Obesity and excess upper body fat stores are both risk factors for developing type 2 diabetes. Avoiding both conditions is important, especially excess upper body fat distribution.


Polyols (i.e., sugar alcohols) yield from 0.2–3.0 kcal per gram, so still need to be considered when calculating the calorie content of a diet. A major attribute of these products is that they do not increase the risk for dental caries.

Check out the Contemporary Nutrition ARIS site www.mhhe.com/wardlawcont7 for quizzes, flash cards, other activities, and weblinks designed to further help you learn about what you eat and why.
I. Estimate Your Fiber Intake

Review the sample menus shown in Table 4-7. The first menu contains 1600 kcal and 25 grams of fiber (AI for women); the second menu contains 2100 kcal and 38 grams of fiber (AI for men).

**TABLE 4-7 Sample of Menus Containing 1600 kcal and 25 grams of Fiber, and 2000 kcal and 38 grams of Fiber**

<table>
<thead>
<tr>
<th></th>
<th>25 grams Fiber</th>
<th>38 grams Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Serving Size</td>
<td>Carbohydrate Content (grams)</td>
</tr>
<tr>
<td><strong>Breakfast</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange juice (with pulp)</td>
<td>1 cup</td>
<td>28</td>
</tr>
<tr>
<td>Wheaties</td>
<td>¾ cup</td>
<td>17</td>
</tr>
<tr>
<td>2% milk</td>
<td>½ cup</td>
<td>6</td>
</tr>
<tr>
<td>Whole-wheat toast</td>
<td>1 slice</td>
<td>13</td>
</tr>
<tr>
<td>Margarine</td>
<td>1 tsp</td>
<td>—</td>
</tr>
<tr>
<td>Coffee</td>
<td>1 cup</td>
<td>1</td>
</tr>
<tr>
<td><strong>Lunch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean ham</td>
<td>2 oz</td>
<td>—</td>
</tr>
<tr>
<td>Whole-wheat bread</td>
<td>2 slices</td>
<td>26</td>
</tr>
<tr>
<td>Mayonnaise</td>
<td>2 tsp</td>
<td>2</td>
</tr>
<tr>
<td>Lettuce</td>
<td>¼ cup</td>
<td>—</td>
</tr>
<tr>
<td>Cooked white beans</td>
<td>¹/³ cup</td>
<td>15</td>
</tr>
<tr>
<td>Pear (with skin)</td>
<td>½</td>
<td>12</td>
</tr>
<tr>
<td>1% milk</td>
<td>½ cup</td>
<td>6</td>
</tr>
<tr>
<td><strong>Snack</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot (as carrot sticks)</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td><strong>Dinner</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broiled chicken (no skin)</td>
<td>3 oz</td>
<td>—</td>
</tr>
<tr>
<td>Baked potato (large, with skin)</td>
<td>½</td>
<td>15</td>
</tr>
<tr>
<td>Margarine</td>
<td>1½ tsp</td>
<td>—</td>
</tr>
<tr>
<td>Cooked green beans</td>
<td>1 cup</td>
<td>10</td>
</tr>
<tr>
<td>Margarine</td>
<td>½ tsp</td>
<td>—</td>
</tr>
<tr>
<td>1% milk</td>
<td>1 cup</td>
<td>12</td>
</tr>
<tr>
<td>Apple (with peel)</td>
<td>½</td>
<td>16</td>
</tr>
<tr>
<td><strong>Snack</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raisin bagel</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>226 grams</td>
<td>25 grams</td>
</tr>
</tbody>
</table>

*The overall diet pattern is based on MyPyramid. Breakdown of approximate calorie content: carbohydrate, 55%; protein, 20%; fat, 25%.
To roughly estimate your daily fiber consumption, determine the number of servings that you ate yesterday from each food category listed here. If you are not meeting your needs, how could you do so? Multiply the serving amount by the value listed and then add up the total amount of fiber.

<table>
<thead>
<tr>
<th>Food</th>
<th>Servings</th>
<th>Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1 cup raw leafy greens or 1/2 cup other vegetables)</td>
<td>_______ × 2</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Fruits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1 whole fruit; 1/2 grapefruit; 1/2 cup berries or cubed fruit; 1/4 cup dried fruit)</td>
<td>_______ × 2.5</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Beans, lentils, split peas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1/2 cup cooked)</td>
<td>_______ × 7</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Nuts, seeds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1/4 cup; 2 tbsp peanut butter)</td>
<td>_______ × 2.5</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Whole grains</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1 slice whole-wheat bread; 1/2 cup whole-wheat pasta, brown rice, or other whole grain; 1/2 each bran or whole-grain muffin)</td>
<td>_______ × 2.5</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Refined grains</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: 1 slice bread, 1/2 cup pasta, rice, or other processed grains; and 1/2 each refined bagels or muffins)</td>
<td>_______ × 1</td>
<td>_______</td>
</tr>
<tr>
<td><strong>Breakfast cereals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serving size: check package for serving size and amount of fiber per serving)</td>
<td>_______ × grams of _______ fiber per serving</td>
<td></td>
</tr>
</tbody>
</table>

Total Grams 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? If you are not meeting your needs, how could you do so?
II. Can You Choose the Sandwich with the Most Fiber?

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

Deli

Turkey & Swiss on Rye
Served with tomato slices, sliced cucumbers, romaine lettuce, and mustard

Ham & Swiss on Sourdough
Extra-thick ham served with mayonnaise

Tuna Salad on Whole Wheat
Our tuna salad contains tuna, grated carrots, onions, and mayonnaise, and is served with alfalfa sprouts, romaine lettuce, and cucumber slices

Specials

Hot Dog
Served on a white bun with relish, mustard, and ketchup

Soyburger
Served on a whole-wheat English muffin with tomato and pickle slices, romaine lettuce, and mayonnaise

PB & J
Soft white bread with strawberry jelly and smooth peanut butter

Answer Key:

1. Tuna Salad on Whole Wheat
2. Soyburger
3. PB & J
4. Ham & Swiss on Sourdough
5. Turkey & Swiss on Rye
6. Hot Dog

† 6. Hot Dog: 1.5 grams
† 5. Ham & Swiss on Sourdough: 1.5 grams
† 4. PB & J: 3 grams
† 3. Soyburger: 2 grams
† 2. Tuna Salad on Whole Wheat: 7 grams
† 1. Turkey & Swiss on Rye: 4 grams