For Colorado black bears, fall is a time of nonstop foraging; they consume about 65 pounds of apples and berries each day. Why the continuous buffet? Bears need this food to accumulate body fat that they use for energy during their long winter slumber.

Fat is an important source of energy for humans as well. Of course, our metabolism is vastly different from that of bears. If we were to eat as many calories as they do during the fall months, the equivalent of 10 double cheeseburgers everyday, sleeping through the winter would be the least of our concerns. But the fat in our diet and in our bodies is important. Excess body fat is usually detrimental, but in some situations, having a bit more stored fat and eating more fat can be advantageous. An increase in body fat can protect against the depletion of lipids: fats, phospholipids, and sterols.
intramuscular fat during extended periods of exertion. And a diet high in fat may help prepare one for arduous, sustained exercise such as ultramarathons or survival in extreme environments.

The universality of a taste for fat among many animals indicates its importance to survival. It plays a tremendous role in the resilience of mammals—including a pair of interesting omnivores: the slumbering bear and the more wakeful humans.
Fats in Our Food

LEARNING OBJECTIVES

1. Describe the qualities that fat adds to foods.
2. Identify sources of hidden fat in the diet.
3. Discuss how fat intake in the United States has changed since the 1970s.

The fats in our foods contribute to their texture, flavor, and aroma. It is the fat that gives ice cream its smooth texture and rich taste. Olive oil imparts a unique flavor to salads and many traditional Italian and Greek dishes. Sesame oil gives egg rolls and other Chinese foods their distinctive aroma. But while the fats in our foods contribute to their appeal, they also add more calories than other nutrients (9 Calories/gram) so consuming too much can contribute to weight gain. The types of fats we eat also can affect our health; too much of the wrong types can increase the risk of heart disease and cancer.

Sources of Fat in Our Food

Sometimes the fat in our food is obvious. You can see the stripes of fat in a slice of bacon sizzling in a frying pan, for example, or the layer of fat around the outside of your steak. Other visible sources of fat in our diets are the fats we add to foods at the table—the pat of butter melting on your steaming baked potato and the dressing you pour over your salad. When you choose these items you know you are eating a high-fat food.

Not all sources of dietary fat are obvious. Cheese, ice cream, and whole milk are high in fat, and foods that we think of as sources of carbohydrate, such as crackers, doughnuts, cookies, and muffins, may also be quite high in fat (Figure 5.1). We also add invisible fat when we fry foods: French fries start as potatoes, which are low in fat, but when they are immersed in hot oil for frying, they soak up fat, increasing their calorie content.

America’s Changing Fat Intake

Eating patterns in the United States have changed significantly over the past 40 years, even though total fat intake hasn’t changed much. Beginning in the 1950s, Americans were told that too much fat made them fat, increased their risk of heart disease, and maybe even increased their risk of cancer. In response to these messages, many Americans switched from whole milk to low-fat, chose chicken in place of beef, consumed fewer eggs, and used less butter and high-fat salad dressing. But in addition to these changes, they consumed more hidden fats from foods such as pizza, pasta dishes, snack foods, and fried potatoes. Thus, even though the sources of fat in the U.S. diet have changed since 1970, the types of fat and the number of grams of fat Americans consume daily have changed little.

What has changed in the past 40 years is our energy intake: It has increased. While the number of calories we eat has increased, the number of grams of fat we eat has remained constant, causing the percentage of calories from fat to drop from about 37% to 34% (Figure 5.2).

Efforts to reduce chronic disease risk by cutting fat from our diets have failed not just because we haven’t really cut our fat intake but because fat does not deserve its bad reputation. Changing the kinds of foods we choose without paying attention to calories hasn’t promoted weight loss. Limiting visible fats without considering hidden fats, the types of fats, and our intake of other dietary components, such as whole grains, fruits, and vegetables, hasn’t reduced the incidence of heart disease or cancer. A healthy diet requires eating the right kinds of fats and making healthy choices from all the food groups.

Visible and hidden fats • Figure 5.1

The amount of fat in a food is not always obvious. The two strips of bacon in this breakfast provide a total of 8 grams of fat, and the muffin provides 16 grams.

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a. In the 1970s, a typical dinner included high-fat meat, bread with butter, and mashed potatoes with lots of gravy, and it was usually served with a glass of whole milk.

b. Today we drink low-fat milk and eat leaner meats, but we eat more fat from takeout Chinese and Mexican foods and fast-food pizza, French fries, hamburgers, and cheeseburgers than we did in the 1970s.1

c. In 1971, U.S. men consumed an average of 2450 Calories/day and women 1540 Calories/day.2 Today, men consume over 2500 Calories/day and women over 1750 Calories/day.3 Because of this increase in energy intake, the percentage of calories from fat has decreased, but we don’t consume any less total fat today than we did in the 1970s.

Interpreting Data

If the number of grams of fat in the U.S. diet has not changed, why has the percentage of fat in the diet gone down?

CONCEPT CHECK

1. How does adding fat affect the calorie content of a food?
2. What are some invisible sources of fat in the diet?
3. How have the sources of fat in the U.S. diet changed since the 1970s?

Types of Lipids

LEARNING OBJECTIVES

1. Explain the relationship between triglycerides and fatty acids.
2. Compare the structures of saturated, monounsaturated, polyunsaturated, omega-6, omega-3, and trans fatty acids.
3. Describe how phospholipids and cholesterol are used in the body.
4. Name foods that are sources of saturated, monounsaturated, polyunsaturated, omega-6, omega-3, and trans fatty acids.

lipids are substances that do not dissolve in water. We tend to use the term fat to refer to lipids, but we are usually referring to types of lipids called triglycerides. Triglycerides make up most of the lipids in our food and in our bodies. The structure of triglycerides includes lipid molecules called fatty acids. Two other types of

triglyceride The major type of lipid in food and the body, consisting of three fatty acids attached to a glycerol molecule.

fatty acid A molecule made up of a chain of carbons linked to hydrogens, with an acid group at one end of the chain.
lipids that are important in nutrition but are present in the body in smaller amounts are phospholipids and sterols.

**Triglycerides and Fatty Acids**

A triglyceride consists of the three-carbon molecule glycerol with three fatty acids attached to it (Figure 5.3). A fatty acid is a chain of carbon atoms with an acid group at one end of the chain. Fatty acids vary in the length of their carbon chains and the types and locations of carbon–carbon bonds within the chain. Fatty acids are what we are really talking about when we refer to trans fat or saturated fat—these terms really mean trans fatty acids and saturated fatty acids. Triglycerides may contain any combination of fatty acids.

**Saturated Fatty Acids:**
Saturated fatty acids contain no carbon–carbon double bonds. Red meat, butter, cheese, and whole milk are high in saturated fatty acids, such as palmitic acid.

**Unsaturated Fatty Acids:**
Unsaturated fatty acids include monounsaturated and polyunsaturated fatty acids.

**Monounsaturated Fatty Acids:**
Monounsaturated fatty acids contain one carbon–carbon double bond. Canola, olive, and peanut oils, as well as nuts and avocados, are high in monounsaturated fatty acids, such as oleic acid.

**Polyunsaturated Fatty Acids:**
Polyunsaturated fatty acids contain two or more carbon–carbon double bonds. Fatty fish, such as salmon and trout, are high in polyunsaturated fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

**Triacylglycerol (Triglyceride) Structure:**
A triglyceride contains glycerol and three fatty acids. The carbon chains of the fatty acids vary in length from short-chain fatty acids (4 to 7 carbons) to medium-chain (8 to 12 carbons) and long-chain fatty acids (more than 12 carbons). The whole chains of these fatty acids pack tightly together.

**Unsaturated Fatty Acids:**
If the carbon chain of a fatty acid has adjacent carbons with only one hydrogen atom attached, a double bond forms between them. These unsaturated fatty acids may have one or more carbon–carbon double bonds.

**Saturated Fatty Acids:**
At the omega or methyl (CH₃) end of the carbon chain, three hydrogen atoms are attached to the carbon. At the other end of the chain, an acid group (COOH) is attached to the carbon. Each of the carbon atoms in between is attached to two carbon atoms and up to two hydrogen atoms.

**Phospholipids:**
A type of lipid whose structure includes a phosphorus atom.

**Saturated Fatty Acid:**
A fatty acid in which the carbon atoms are bonded to as many hydrogen atoms as possible; it therefore contains no carbon–carbon double bonds.

**Trans Fatty Acid:**
Fatty acids with a structure composed of multiple chemical rings.

**Sterol:**
A type of lipid that is important in nutrition but are present in the body in smaller amounts are phospholipids and sterols.

**Phospholipid:**
A type of lipid whose structure includes a phosphorus atom.

**Unsaturated Fatty Acid:**
A fatty acid in which the carbon atoms are bonded to as many hydrogen atoms as possible; it therefore contains no carbon–carbon double bonds.

**Trans Fatty Acid:**
Fatty acids with a structure composed of multiple chemical rings.

**Sterol:**
A type of lipid that is important in nutrition but are present in the body in smaller amounts are phospholipids and sterols.
The fatty acids in triglycerides determine its function in the body and the properties it gives to food.

**Saturated and unsaturated fatty acids** Fatty acids are classified as saturated fatty acids or unsaturated fatty acids, depending on whether they contain carbon–carbon double bonds (Figure 5.4a and b). The number and location of these double bonds affect the characteristics that fatty acids give to food and the health effects they have in the body. Saturated fatty acids have straight carbon chains that pack tightly together. Therefore, triglycerides that are high in saturated fatty acids, such as those found in beef, butter, and lard, tend to be solid at room temperature. Diets high in saturated fatty acids have been shown to increase the risk of heart disease. Unsaturated fatty acids have bent chains. This makes triglycerides that are higher in unsaturated fatty acids, such as those found in corn, safflower, and sunflower oils, liquid at room temperature. Diets high in unsaturated fatty acids are associated with a lower risk of heart disease.

The body is capable of synthesizing most of the fatty acids it needs from glucose or other sources of carbon, hydrogen, and oxygen, but the body cannot make some of the fatty acids it needs. These must be consumed in the diet and are referred to as essential fatty acids.

Saturated fatty acids are more plentiful in animal foods, such as meat and dairy products, than in plant foods. Plant oils are generally low in saturated fatty acids (Figure 5.4c). Exceptions include

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**Polyunsaturated Fatty Acids:**

Polyunsaturated fatty acids contain more than one carbon–carbon double bond.

**Omega-6 Polyunsaturated Fatty Acids:** When the first double bond occurs between the sixth and seventh carbon atoms (from the omega end), the fatty acid is called an omega-6 fatty acid. Corn oil, safflower oil, soybean oil, and nuts are sources of the omega-6 polyunsaturated fatty acid linoleic acid.

**Omega-3 Polyunsaturated Fatty Acids:** If the first double bond occurs between the third and fourth carbon atoms (from the omega end), the fatty acid is an omega-3 fatty acid. Flaxseed, canola oil, and nuts are sources of the omega-3 polyunsaturated fatty acid alpha-linolenic acid, and fish oils are high in longer-chain omega-3 fatty acids.

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**Ask Yourself**

Based on the table above:
1. Which two foods are highest in omega-3 fatty acids?
2. Which two foods are highest in saturated fatty acids?
palm oil, palm kernel oil, and coconut oil, which are saturated plant oils. These are often called **tropical oils** because they are found in plants that are common in tropical climates. Saturated plant oils are useful in food processing because they are less susceptible to spoilage than are more unsaturated oils. Spoilage of fats and oils, referred to as **rancidity**, occurs when the unsaturated bonds in fatty acids are damaged by oxygen. When fats go rancid, they give food an “off” flavor.

**Trans fatty acids** Food manufacturers can increase the shelf life of oils by using a process called **hydrogenation**, which makes unsaturated oils more saturated. This improves the storage properties of the oils and makes them more solid at room temperature. Products such as hard margarine and shortening can be made using hydrogenation. A disadvantage of this process is that in addition to converting some double bonds into saturated bonds, it transforms some double bonds from the **cis** to the **trans** configuration (Figure 5.5). As discussed later, consumption of **trans** fats increases the risk of developing heart disease.

**Cis and trans fatty acids • Figure 5.5**

a. The orientation of hydrogen atoms around the carbon–carbon double bond distinguishes **cis** fatty acids from **trans** fatty acids. Most unsaturated fatty acids found in nature have double bonds in the **cis** configuration.

In **trans** fatty acids the hydrogens are on opposite sides of the double bond, making the carbon chain straighter, similar to the shape of a saturated fatty acid.

In **cis** fatty acids, the hydrogens are on the same side of the double bond and cause a bend in the carbon chain.

b. Small amounts of **trans** fatty acids occur naturally, and larger amounts are generated by hydrogenation. Many manufacturers have reformulated their products to reduce the amounts of **trans** fatty acids.

<table>
<thead>
<tr>
<th>Food</th>
<th>Trans Fat (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crackers (5)</td>
<td>1.5</td>
</tr>
<tr>
<td>Chocolate chip cookies (3)</td>
<td>1.5</td>
</tr>
<tr>
<td>Biscuit (1 medium)</td>
<td>1</td>
</tr>
<tr>
<td>Shortening (1 Tbsp)</td>
<td>1</td>
</tr>
<tr>
<td>Margarine (1 Tbsp)</td>
<td>1</td>
</tr>
<tr>
<td>Whole milk (1 cup)</td>
<td>1</td>
</tr>
<tr>
<td>Ground beef (3 oz)</td>
<td>1</td>
</tr>
<tr>
<td>Milk chocolate (1 oz)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Ask Yourself**

Which of the foods shown here contain only natural sources of **trans** fatty acids?
a. Like a triglyceride, a phospholipid, such as the lecithin molecule shown here, has a backbone of glycerol, but it contains two fatty acids rather than three. Instead of the third fatty acid, a phospholipid has a chemical group containing phosphorus, called a **phosphate group**. The fatty acids (the tails) at one end of a phospholipid molecule are soluble in fat, while the phosphate-containing region at the other end (the head) is soluble in water.

b. Phospholipids act as emulsifiers because they can surround droplets of oil, allowing them to remain suspended in a watery environment. The salad dressing shown here does not contain an emulsifier, so it separates into layers of oil and vinegar and must be shaken before it is poured on your salad. Many salad dressings are emulsified so that they do not separate when left standing.

**Think Critically** How does the structure of a phospholipid facilitate its function as an emulsifier?

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### Phospholipids

Phospholipids, though present in small amounts, are important in food and in the body because they allow water and fat to mix. They can do this because one side of the molecule dissolves in water, and the other side dissolves in fat (**Figure 5.6a**). In foods, substances that allow fat and water to mix are referred to as **emulsifiers**. For example, the phospholipids in egg yolks allow the oil and water in cake batter to mix; phospholipids in salad dressings prevent the oil and vinegar in the dressing from separating.

One of the best-known phospholipids is **lecithin** (shown in **Figure 5.6a**). Eggs and soybeans are natural sources of lecithin. The food industry uses lecithin as an emulsifier in margarine, salad dressings, chocolate, frozen desserts, and baked goods to prevent oil from separating from the other ingredients (**Figure 5.6b**). In the body, lecithin is a major constituent of cell membranes (**Figure 5.6c**). It is also used to synthesize the neurotransmitter acetylcholine, which activates muscles and plays an important role in memory.
CHAPTER 5 Lipids: Fats, Phospholipids, and Sterols

Plants do contain other sterols, however, and these plant sterols have a role similar to that of cholesterol in animals: They help form plant cell membranes. Plant sterols are found in small quantities in most plant foods; when consumed in the diet, they can help reduce cholesterol levels in the body.

Sterols

The best-known sterol is cholesterol (Figure 5.7). It is needed in the body, but because the liver manufactures it, it is not essential in the diet. More than 90% of the cholesterol in the body is found in cell membranes (see Figure 5.6c). It is also part of myelin, the insulating coating on many nerve cells. Cholesterol is needed to synthesize other sterols, including vitamin D; bile acids, which are emulsifiers in bile; cortisol, which is a hormone that regulates our physiological response to stress; and testosterone and estrogen, which are hormones necessary for reproduction.

In the diet, cholesterol is found only in foods from animal sources. Plant foods do not contain cholesterol unless it has been added in the course of cooking or processing. Plants do contain other sterols, however, and these plant sterols have a role similar to that of cholesterol in animals: They help form plant cell membranes. Plant sterols are found in small quantities in most plant foods; when consumed in the diet, they can help reduce cholesterol levels in the body.

CONCEPT CHECK

1. How are triglycerides and fatty acids related?
2. What is the structural difference between saturated and unsaturated fatty acids?
3. Why are phospholipids good emulsifiers?
4. Which food groups contain the most saturated fat?
Absorbing and Transporting Lipids

LEARNING OBJECTIVES
1. Discuss the steps involved in the digestion and absorption of lipids.
2. Describe how lipids are transported in the blood and delivered to cells.
3. Compare the functions of LDLs and HDLs.

The fact that oil and water do not mix poses a problem for the digestion and absorption of lipids in the watery environment of the small intestine and their transport in the blood, which is mostly water. Therefore, the body has special mechanisms that allow it to digest, absorb, and transport lipids.

Digestion and Absorption of Lipids
In healthy adults, most fat digestion and absorption occurs in the small intestine (Figure 5.8). Here, bile acts as an emulsifier, breaking down large lipid droplets into small globules. The triglycerides in the globules can then be digested by enzymes from the pancreas. The resulting

Lipid digestion and absorption • Figure 5.8

1. A small amount of lipid digestion occurs in the stomach due to lipases produced in the mouth and stomach. These particular lipases work best on the triglycerides present in milk and so are particularly important in infants whose diet consists entirely of milk.

2. The liver produces bile, which is stored in the gallbladder and released into the small intestine to aid in the digestion and absorption of fat.

3. The pancreas produces the enzyme pancreatic lipase, which is released into the small intestine to break down triglycerides into monoglycerides, fatty acids, and glycerol.

4. In the small intestine, the products of fat digestion and bile form micelles, which move close enough to the microvilli to allow lipids to diffuse into the mucosal cells.

5. Inside the mucosal cells, fatty acids and monoglycerides are reassembled into triglycerides and incorporated into lipid transport particles, which enter the lymph.

6. Since fat absorption in the small intestine is efficient, very little fat is normally lost in the feces.

Ask Yourself
1. Where are micelles formed?
2. Which of the following is not part of a micelle?
   a. Fatty acids
   b. Monoglycerides
   c. Bile
   d. Triglycerides

The bulk of our dietary lipids are triglycerides, which need to be digested before they can be absorbed. The diet also contains smaller amounts of phospholipids, which are partially digested, and cholesterol and fat-soluble vitamins, which are absorbed without digestion.
and must be packaged for transport. They are covered with a water-soluble envelope of protein, phospholipids, and cholesterol to form particles called lipoproteins (Figure 5.9). Different types of lipoproteins transport dietary lipids from the small intestine to body cells, from the liver to body cells, and from body cells back to the liver for disposal.

**Transport from the small intestine** After long-chain fatty acids (from the digestion of triglycerides) have been absorbed into the mucosal cells, they are reassembled into triglycerides. These triglycerides, along with cholesterol and fat-soluble vitamins, are packaged with phospholipids, and protein to form lipoproteins called chylomicrons. Chylomicrons are too large to enter the capillaries in the small intestine, so they pass from the intestinal mucosa into the lymph, which then delivers them to the blood (Figure 5.10). They circulate in the blood, delivering triglycerides to body cells. To enter the cells, the triglycerides must first be broken down into fatty acids and glycerol, which can diffuse across the cell membrane. Once inside the cells, fatty acids can either be used to provide energy or reassembled into triglycerides for storage.

**Transporting Lipids in the Blood**

Lipids that are consumed in the diet are absorbed into the intestinal mucosal cells. From here, small fatty acids, which are soluble in water, are absorbed into the blood and travel to the liver for further processing. Long-chain fatty acids, cholesterol, and fat-soluble vitamins, which are not soluble in water, are not absorbed directly into the blood and must be packaged for transport. They are covered with a water-soluble envelope of protein, phospholipids, and cholesterol to form particles called lipoproteins (Figure 5.9). Different types of lipoproteins transport dietary lipids from the small intestine to body cells, from the liver to body cells, and from body cells back to the liver for disposal.

**Lipoprotein structure • Figure 5.9**

A lipoprotein consists of a core of triglycerides and cholesterol surrounded by a shell of protein, phospholipids, and cholesterol. Phospholipids orient with their fat-soluble “tails” toward the interior and their water-soluble “heads” toward the outside. This allows the fat-soluble substances in the interior to travel through the aqueous blood.

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**monoglyceride** A glycerol molecule with one fatty acid attached.

**micelle** A particle that is formed in the small intestine when the products of fat digestion are surrounded by bile. It facilitates the absorption of lipids.

**lipoprotein** A particle that transports lipids in the blood.

**chylomicron** A lipoprotein that transports lipids from the mucosal cells of the small intestine and delivers triglycerides to other body cells.
Chylomicrons and very-low-density lipoproteins transport triglycerides and deliver them to body cells. Low-density lipoproteins transport and deliver cholesterol, and high-density lipoproteins help return cholesterol to the liver for reuse or elimination.

1. Chylomicrons formed in the mucosal cells pass first into the lymph, which drains into the blood. They circulate in the blood, delivering triglycerides to body cells.

2. The enzyme lipoprotein lipase, which is present on the surface of cells lining the blood vessels, breaks down the triglycerides in chylomicrons into fatty acids and glycerol. These can then enter the surrounding cells.

3. What remains of the chylomicrons consists mostly of cholesterol and protein. These particles travel to the liver to be disassembled.

4. VLDLs are made in the liver and transport lipids away from the liver. They function similarly to chylomicrons because both particles deliver triglycerides to body cells with the help of the enzyme lipoprotein lipase.

5. What remains of the VLDL particles after the triglycerides are removed is either returned to the liver or transformed in the blood into LDL particles.

6. To deliver cholesterol, LDL particles bind to a protein on the cell membrane called an LDL receptor. This binding allows the whole LDL particle to be removed from circulation and enter the cell, where the cholesterol and other components can be used.

7. HDLs pick up cholesterol from other lipoproteins and body cells and return it to the liver. Some of this cholesterol is broken down and some is transferred to organs with high requirements for cholesterol, such as those that synthesize steroid hormones.

Ask Yourself
1. Which lipoprotein contains the highest proportion of cholesterol?
2. Which lipoprotein has the highest proportion of triglyceride?
**Transport from the liver** The liver can synthesize lipids. Lipids are transported from the liver in very-low-density lipoproteins (VLDLs). Like chylomicrons, VLDLs are lipoproteins that circulate in the blood, delivering triglycerides to body cells. When the triglycerides have been removed from the VLDLs, a denser, smaller particle remains. About two-thirds of these particles are returned to the liver, and the rest are transformed in the blood into low-density lipoproteins (LDLs). LDLs are the primary cholesterol delivery system for cells. They contain a higher proportion of cholesterol than do chylomicrons or VLDLs (see Figure 5.10). High levels of LDLs in the blood have been associated with an increased risk for heart disease. For this reason, they are sometimes referred to as “bad cholesterol.”

**Eliminating cholesterol** Because most body cells have no system for breaking down cholesterol, cholesterol must be returned to the liver to be eliminated from the body. This reverse cholesterol transport is accomplished by high-density lipoproteins (HDLs) (see Figure 5.10). HDL cholesterol is often called “good cholesterol” because high levels of HDL in the blood are associated with a reduction in the risk of heart disease.

**CONCEPT CHECK**

1. **How** does bile help in the digestion and absorption of lipids?
2. **Why** are lipoproteins needed to transport lipids?
3. **What** is the primary function of LDLs?

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**Lipid Functions**

**LEARNING OBJECTIVES**

1. **List** the functions of lipids in the body.
2. **Explain** why we need the right balance of omega-3 and omega-6 fatty acids.
3. **Summarize** how fatty acids are used to provide energy.
4. **Describe** how fat is stored and how it is retrieved from storage.

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**Adipose tissue • Figure 5.11**

**a.** The amount and location of adipose tissue affect our body size and shape. When people have liposuction to slim their hips, the surgeon is actually vacuuming out fat cells from the adipose tissue in the region.

**b.** Adipose tissue cells contain large droplets of triglyceride that push the other cell components to the perimeter of the cell. As weight is gained, the triglyceride droplets enlarge.
Lipid Functions

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Essential Fatty Acids

Humans are not able to synthesize fatty acids that have double bonds in the omega-6 and omega-3 positions (see Figure 5.4b). Therefore, the fatty acids linoleic acid (omega-6) and alpha-linolenic acid (alpha-linolenic acid) (omega-3) are considered essential fatty acids. They must be consumed in the diet because they cannot be made in the body. If the diet is low in linoleic acid and/or alpha-linolenic acid, other fatty acids that the body would normally synthesize from them become dietary essentials as well (Figure 5.12).

Omega-6 and omega-3 fatty acids are important for health. They are needed for the formation of the phospholipids that give cell membranes their structure and functional properties. Therefore, they are essential for growth, development, fertility, and maintaining the structure of red blood cells and cells in the skin and nervous system. The omega-3 fatty acid DHA is particularly important in the retina of the eye. Both DHA and the omega-6 fatty acid arachidonic acid are needed to synthesize cell membranes in the central nervous system and are therefore important for normal brain development in infants and young children.

If adequate amounts of linoleic and alpha-linolenic acid are not consumed, an essential fatty acid deficiency will result. Symptoms include scaly, dry skin, liver abnormalities, poor healing of wounds, impaired vision and hearing, and growth failure in infants. Because the requirement for essential fatty acids is well below the typical intake in the United States, essential fatty acid deficiencies are rare in this country. However, deficiencies have occurred in infants and young children consuming low-fat diets and in individuals who are unable to absorb lipids.

Getting enough essential fatty acids in your diet will prevent deficiency, but the ratio of dietary omega-6 to omega-3 fatty acids also affects your health. This is because the omega-6 and omega-3 polyunsaturated fatty acids made from them are used to make hormone-like molecules called eicosanoids. Eicosanoids help regulate blood clotting, blood pressure, immune function, and other body processes.

The effect of an eicosanoid on these functions depends on the fatty acid from which it is made. For example, when the omega-6 fatty acid arachidonic acid is the starting material, the eicosanoid synthesized increases blood clotting; when the omega-3 fatty acid EPA is the starting material, the eicosanoid made decreases blood clotting. The ratio of dietary omega-6 to omega-3 fatty acids affects the balance of the omega-6 and omega-3 fatty acids in the body and, therefore, the balance of the omega-6 and omega-3 eicosanoids produced.

The U.S. diet contains a higher ratio of omega-6 to omega-3 fatty acids than is optimal for health. Increasing consumption of foods that are rich in omega-3 fatty acids increases the proportion of omega-3 eicosanoids (see Figure 5.4c). This reduces the risk of heart disease.
Fat as a Source of Energy

Fat is an important source of energy in the body (Figure 5.13). Triglycerides that are consumed in the diet can be either used immediately to fuel the body or stored in adipose tissue. Depositing fat in adipose tissue is an efficient way to store energy because each gram of fat provides 9 Calories, compared with only 4 Calories per gram from carbohydrate or protein. This allows a large amount of energy to be stored in the body without a great increase in body size or weight. For example, even a lean man stores over 50,000 Calories of energy in his adipose tissue.

Throughout the day, as we eat and then go for hours without eating, triglycerides are stored and then retrieved from storage, depending on the body’s immediate energy needs. For example, after we have feasted on a meal, some...
triglycerides will be stored; then, in the small fasts between meals, some of the stored triglycerides will be broken down to provide energy. When the energy consumed in the diet equals the body’s energy requirements, the net amount of body fat does not change.

**Feasting** When we consume more calories than we need, the excess is stored primarily as fat. Excess fat from our diet is packaged in chylomicrons and transported directly from the intestines to the adipose tissue. Because the fatty acids in our body fat come from the fatty acids we eat, what we eat affects the fatty acid composition of our adipose tissue; therefore, if you eat more saturated fat, there will be more saturated fat in your adipose tissue. Excess calories that are consumed as carbohydrate or protein must first go to the liver, where they can be used to synthesize fatty acids, which are then assembled into triglycerides, packaged in VLDLs, and transported in the blood to adipose tissue (Figure 5.14).

The ability of the body to store excess triglycerides is theoretically limitless. Cells in your adipose tissue can increase in weight by about 50 times, and new fat cells can be made when existing cells reach their maximum size.

**Fasting** When you eat fewer calories than you need, your body takes energy from its fat stores. In this situation, an enzyme inside the fat cells receives a signal to break down stored triglycerides. The fatty acids and glycerol that result are released directly into the blood and circulate throughout the body. They are taken up by cells and used to produce ATP (see Figures 5.13 and 5.14).

To be used for energy, fatty acids are broken into two-carbon units that form acetyl-CoA. When oxygen and carbohydrate are available, acetyl-CoA can be used to generate ATP. If there is not enough carbohydrate available in cells to allow the acetyl-CoA to enter the citric acid cycle, it will be used to make ketones (see Chapter 4). Many tissues in the body can use ketones as an energy source. During prolonged fasting, even the brain can adapt itself to use ketones to meet about half of its energy needs. For the other half, the brain continues to require glucose. Fatty acids cannot be used to make glucose, and only a small amount of glucose can be made from the glycerol released from triglyceride breakdown.

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**Feasting and Fasting • Figure 5.14**

When we eat too much, excess energy is stored as triglycerides. When we don’t eat enough, triglycerides in adipose tissue are broken down, releasing fatty acids, which can be used to provide energy.

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**CONCEPT CHECK**

1. **Why** does a deficiency of essential fatty acids cause health problems?
2. **How** does eating fish regularly affect the types of eicosanoids produced?
3. **How** are fatty acids used to produce ATP?
4. **What** happens to excess dietary fat after it has been absorbed?
Lipids in Health and Disease

LEARNING OBJECTIVES

1. Describe the events that lead to the development of atherosclerosis.
2. Evaluate your risk of heart disease.
3. Discuss the roles of dietary fat in cancer and obesity.

The amount and types of fat you eat can affect your health. A diet that is too low in fat can reduce the absorption of fat-soluble vitamins, slow growth, and impair the functioning of the skin, eyes, liver, and other body organs. Eating the wrong types of fat can contribute to chronic diseases such as heart disease and cancer. Consuming too much fat can increase calorie intake and contribute to extra body fat storage and therefore weight gain. Excess body fat, in turn, is associated with an increased risk of diabetes, cardiovascular disease, and high blood pressure.

Heart Disease

More than 80 million people in the United States suffer from some form of cardiovascular disease, which is any

Think Critically

How is blood LDL cholesterol related to the formation of atherosclerotic plaque?

Development of atherosclerosis • Figure 5.15

1 Normal Artery

The wall of a normal, healthy artery is lined with a layer of epithelial cells that are surrounded by smooth muscle.

2 Damage to the Artery Wall

Damage to the lining of an artery causes inflammation and begins the process of plaque formation. The injury attracts white blood cells, which mature into macrophages, and makes the lining more permeable to LDL particles. Inside the artery wall, LDL is oxidized to form oxidized LDL cholesterol.

3 Plaque Formation

Inside the artery wall, macrophages fill up with oxidized LDL cholesterol and are transformed into foam cells. These cells get so full that they burst, depositing cholesterol. The accumulation of cholesterol and proteins forms a plaque.
Atherosclerosis is a type of cardiovascular disease that involves the buildup of fatty material in the artery walls. It is the number-one cause of death for both men and women in the United States. Atherosclerosis is a type of cardiovascular disease in which cholesterol is deposited in the artery walls, reducing their elasticity and eventually blocking the flow of blood. The development of atherosclerosis has been linked to diets that are high in cholesterol, saturated fat, and trans fat.

How atherosclerosis develops

**Inflammation**, the process whereby the body responds to injury, drives the formation of atherosclerotic plaque. For example, cutting yourself triggers an inflammatory response. White blood cells, which are part of the immune system, rush to the injured area, blood clots form, and soon new tissue grows to heal the wound. Similar inflammatory responses occur when an artery is injured, but instead of resulting in healing, they lead to the development of atherosclerotic plaque (Figure 5.15). Therefore, the atherosclerotic process begins with an injury, and the response to this injury causes changes in the lining of the artery wall.

The exact cause of the injuries that initiate the development of atherosclerosis is not known but may be related to elevated blood levels of LDL cholesterol, glucose, or the amino acid homocysteine or to high blood pressure, smoking, diabetes, genetic alterations, or infection. The specific cause may be different in different people.

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**Lipids in Health and Disease**

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Risk factors for heart disease  Diabetes, high blood pressure, obesity, and high blood cholesterol levels are considered primary risk factors for heart disease because they directly increase risk. Other factors that affect risk include age, gender, genetics, and lifestyle factors such as smoking, exercise, and diet (Table 5.1).

Diet and heart disease risk  The risk of heart disease is affected by individual nutrients and particular whole foods. For example, diets high in sodium and saturated fat increase heart disease risk. Diets high in fiber and certain vitamins can reduce heart disease risk. Consuming fish, nuts, and whole grains may decrease risk, while diets that are high in red meat may increase risk. More important than any individual dietary factor, though, are overall dietary and lifestyle patterns. For example, diets that are plentiful in fruits, vegetables, and whole grains and low in high-fat meats and dairy products reduce the risk of heart disease. The importance of dietary patterns is exemplified by the fact that the incidence of heart disease is lower in Asian and Mediterranean countries than in the United States (Figure 5.16). The heart-protective effect that these traditional diets seem to have has prompted nutrition experts to promote a Mediterranean dietary pattern to reduce the risk of heart disease in the United States.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>How it affects risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obesity</td>
<td>Obesity increases blood pressure, blood cholesterol levels, and the risk of developing diabetes. It also increases the amount of work the heart must do to pump blood throughout the body.</td>
</tr>
<tr>
<td>Diabetes</td>
<td>High blood glucose damages blood vessel walls, initiating atherosclerosis.</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>High blood pressure can damage blood vessel walls, initiating atherosclerosis. It forces the heart to work harder, causing it to enlarge and weaken over time.</td>
</tr>
<tr>
<td>Gender</td>
<td>Men and women are both at risk for heart disease, but men are generally affected a decade earlier than women. This difference is due in part to the protective effect of the hormone estrogen in women. As women age, the effects of menopause—including a decline in estrogen level and a gain in weight—increase heart disease risk.</td>
</tr>
<tr>
<td>Age</td>
<td>The risk of heart disease is increased in men age 45 and older and in women age 55 and older.</td>
</tr>
<tr>
<td>Family history</td>
<td>Individuals with a male family member who exhibited heart disease before age 55 or a female family member who exhibited heart disease before age 65 are considered to be at increased risk. African Americans have a higher risk of heart disease than the general population, in part due to the high incidence of high blood pressure among African Americans.</td>
</tr>
<tr>
<td>Lifestyle</td>
<td>Smoking increases risk. Regular exercise decreases risk by reducing blood pressure, increasing healthy HDL cholesterol levels, reducing the risk of diabetes, and promoting a healthy weight. Diet, including the types of lipids and the amounts of fiber, as well as other dietary components, can affect the risk of heart disease.</td>
</tr>
<tr>
<td>Blood lipid level</td>
<td>Blood levels of total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides all affect risk.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blood lipid level</th>
<th>Low risk/optimal</th>
<th>Near optimal</th>
<th>Borderline high</th>
<th>High risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol (mg/100 ml)</td>
<td>&lt; 200</td>
<td></td>
<td>200–239</td>
<td>≥ 240</td>
</tr>
<tr>
<td>LDL cholesterol (mg/100 ml)</td>
<td>&lt; 100</td>
<td>100–129</td>
<td>130–159</td>
<td>≥ 160</td>
</tr>
<tr>
<td>HDL cholesterol (mg/100 ml)</td>
<td>≥ 60</td>
<td></td>
<td></td>
<td>&lt; 40</td>
</tr>
<tr>
<td>Triglycerides (mg/100 ml)</td>
<td>&lt; 150</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
a. In the Mediterranean region, the main source of dietary fat is olive oil, and the typical diet is high in nuts, vegetables, and fruits. Fish is consumed routinely and red meat rarely. Despite a fat intake that is similar to that of the U.S. diet, the incidence of heart disease is much lower. This diet pyramid is based on the dietary patterns of Crete, Greece, and southern Italy around 1960, when the rates of chronic disease in this region were among the lowest in the world.

b. In Asian countries, plant foods that are rich in fiber and antioxidants form the base of the diet, and animal products are more peripheral. Traditional Asian diets include more fish and seafood than red meat. Combined with small amounts of vegetable oil, this pattern produces a balance of omega-6 to omega-3 fatty acids that helps prevent heart disease. Routine consumption of green tea, which is high in antioxidants, may also contribute to the low rate of chronic disease in the region. This diet pyramid was inspired by the traditional cuisines of southern and eastern Asia.

c. Traditional Asian and Mediterranean diets often protect against heart disease, but as younger generations abandon these long-established dietary patterns for more modern ones, the incidence of high blood pressure, elevated blood lipids, diabetes, and obesity is likely to rise.
Much of the impact that a dietary pattern has on heart disease risk depends on the abundance of nutrients and other dietary components that affect blood cholesterol levels. For example, saturated fatty acids and cholesterol from high-fat meats and dairy products can cause an increase in blood levels of total and LDL cholesterol. High intakes of trans fat from products that contain hydrogenated vegetable oils increase blood levels of LDL cholesterol and the risk of heart attack. Replacing foods that are high in cholesterol-raising fats with foods that provide omega-3 fatty acids, monounsaturated fat, soluble fiber, and plant sterols, which have been shown to lower total and LDL cholesterol, can reduce the risk of heart disease (Figure 5.17) (see Debate: Good Egg, Bad Egg?).

Nutrients and other dietary components can also affect heart disease risk through mechanisms unrelated to blood cholesterol level. For example, adequate intakes of vitamin B₆, vitamin B₁₂, and folate help protect against heart disease through mechanisms unrelated to blood cholesterol level. For example, adequate intakes of vitamin B₆, vitamin B₁₂, and folate help protect against heart disease through mechanisms unrelated to blood cholesterol level. For example, adequate intakes of vitamin B₆, vitamin B₁₂, and folate help protect against heart disease through mechanisms unrelated to blood cholesterol level. For example, adequate intakes of vitamin B₆, vitamin B₁₂, and folate help protect against heart disease through mechanisms unrelated to blood cholesterol level.

Eating to reduce the risk of heart disease • Figure 5.17

a. Fish, flaxseed, and vegetable oils are high in omega-3 fatty acids, which reduce the risk of heart disease and decrease mortality due to heart attacks. In addition to lowering LDL cholesterol and triglyceride levels, omega-3 fatty acids protect against heart disease by decreasing blood clotting, lowering blood pressure, improving the function of the cells lining blood vessels, reducing inflammation, and modulating heartbeats.

b. Nuts, olives, and avocados are all good sources of monounsaturated fat, which lowers LDL cholesterol and makes it less susceptible to oxidation. Nuts are also high in omega-3 fatty acids, fiber, vegetable protein, antioxidants, and plant sterols. Diets containing nuts may lower heart disease risk by decreasing total and LDL cholesterol, increasing HDL cholesterol, and improving the functioning of cells lining the artery wall.

c. Oatmeal, legumes, and brown rice are good sources of soluble fiber, which has been shown to reduce blood cholesterol levels. In addition to fiber, whole grains provide omega-3 fatty acids, B vitamins, and antioxidants, as well as other phytochemicals that may protect against heart disease.

d. Moderate alcohol consumption—that is, one drink a day for women and two a day for men (one drink is equivalent to 5 ounces wine, 12 ounces beer, or 1.5 ounces distilled spirits)—reduces blood clotting and increases HDL cholesterol but also raises blood triglyceride levels. Higher alcohol intake increases the risk of heart disease and causes other health and social problems.

e. Modest consumption of dark chocolate is associated with reduced risk of heart disease. This is attributed to the phytochemicals in dark chocolate. In addition, most of the fat in chocolate is from stearic acid, which is a saturated fatty acid that does not cause an increase in blood levels of LDL cholesterol.

f. Consuming plant sterols reduces cholesterol absorption in the small intestine, lowering total and LDL cholesterol levels. Small quantities of plant sterols are found in vegetable oils, nuts, seeds, cereals, legumes, and many fruits and vegetables. Larger amounts have been added to products such as margarines, salad dressings, and orange juice.
Debate Good Egg, Bad Egg?

The Issue: Does eating eggs increase your risk of cardiovascular disease?

Dietary recommendations in the United States have been telling us to limit egg consumption since the 1960s. What could be bad about this high-protein, easy-to-prepare food? The problem is that one egg has over 200 mg of cholesterol. An ounce of lean meat has only about 30 mg. The Dietary Guidelines and the American Heart Association recommend limiting cholesterol to less than 300 mg per day. So, is it okay to eat eggs for breakfast?

The cholesterol in our bodies comes from what we eat as well as cholesterol synthesized by our livers. Even if you don’t eat any cholesterol, your liver will make all you need. For many people, when they eat cholesterol, their liver production slows, so blood levels don’t rise; others are missing this regulation. For them, an increase in dietary cholesterol results in an increase in blood cholesterol. However, the increase is typically due to increases in “good” HDL cholesterol as well as “bad” LDL cholesterol, so the risk of atherosclerosis does not change.10 Furthermore, the LDL particles that form when dietary cholesterol increases are large. These larger LDL particles are thought to be less of a cardiovascular risk than smaller ones.10

Currently, the vast majority of epidemiological studies do not find a relationship between dietary cholesterol or egg consumption and cardiovascular disease.10,11 For example, an evaluation of more than 20,000 male physicians participating in the Physicians’ Health Study found that eating up to six eggs per week did not affect the risk or incidence of cardiovascular disease.12 However, eating seven or more eggs per week caused an increased risk of death from cardiovascular disease, and eating any eggs was found to increase the risk of cardiovascular disease in people with type 2 diabetes.12,13

Nutrition professionals recognize that it is the overall dietary pattern, not the avoidance of particular foods, that is most important for health and wellness. Eggs are part of the Asian and Mediterranean dietary patterns, and both of these patterns are associated with good cardiovascular health. One large egg contains 6 grams of high-quality protein, and unlike many other sources of cholesterol, eggs are low in cholesterol-raising saturated fat (see table). Eggs are also a good source of zinc, B vitamins, vitamin A, and iron. The yolk is rich in lutein and zeaxanthin, two phytochemicals that help protect against age-related eye disorders. Eggs may also help you maintain your weight. A recent study found that people who eat an egg-based breakfast ate fewer overall calories during the day than people who have a bagel-based breakfast.14

The 2010 Dietary Guidelines has concluded that eating one egg per day is not harmful and does not result in increased risk of cardiovascular disease in healthy individuals. Despite this, they continue to recommend limiting dietary cholesterol to less than 300 mg per day, with further reductions to less than 200 mg per day for persons with or at high risk for cardiovascular disease.15 If you eat an egg every day, is your diet likely to exceed 300 mg of cholesterol per day?

Think critically: What food or foods in this table other than eggs are high in cholesterol but low in saturated fat? How might they impact the risk of cardiovascular disease?

<table>
<thead>
<tr>
<th>Cholesterol and saturated fat content of foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>Egg, one</td>
</tr>
<tr>
<td>Shrimp, 3 oz, raw</td>
</tr>
<tr>
<td>Salmon, 3 oz, cooked</td>
</tr>
<tr>
<td>Hamburger patty, 3 oz, broiled</td>
</tr>
<tr>
<td>Chicken breast, 3 oz, roasted, no skin</td>
</tr>
<tr>
<td>Bacon, 3 oz, pan fried</td>
</tr>
<tr>
<td>Pork sausage, 3 oz, cooked</td>
</tr>
<tr>
<td>Butter, 2 Tbsp</td>
</tr>
<tr>
<td>Milk, whole, 8 fluid oz</td>
</tr>
<tr>
<td>Cheese, cheddar, 1 oz</td>
</tr>
<tr>
<td>Ice cream, vanilla, ½ cup</td>
</tr>
</tbody>
</table>

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Meeting Lipid Needs

LEARNING OBJECTIVES

1. Discuss the recommendations for fat and cholesterol intake.
2. Choose heart-healthy foods from each section of MyPlate.
3. Use food labels to choose foods containing healthy fats.

The amount of fat the body requires from the diet is small, but a diet that provides only the minimum amount would be very high in carbohydrate, would not be very palatable, and would not necessarily be any healthier than diets with more fat. Therefore, the recommendations for fat intake focus on getting enough to meet the need for essential fatty acids and choosing the amounts and types of fat that will promote health and prevent disease.
Rafael is a financial advisor who spends much of his day sitting at his computer. When he is home with his family, he enjoys watching his children play soccer and basketball but rarely finds time to exercise himself. Rafael’s doctor recently told him that his blood cholesterol levels are elevated. His blood lipids and other information from his medical history are given below:

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>35</td>
</tr>
<tr>
<td>Family history</td>
<td>Mother had heart attack at age 60</td>
</tr>
<tr>
<td>Height/weight</td>
<td>68 inches/160 lb</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>145/80 (optimal is &lt; 120/80)</td>
</tr>
<tr>
<td>Smoker</td>
<td>Yes</td>
</tr>
<tr>
<td>Activity level</td>
<td>Sedentary</td>
</tr>
</tbody>
</table>

Blood values:
- Total cholesterol: 210 mg/100 ml
- LDL cholesterol: 160 mg/100 ml
- HDL cholesterol: 34 mg/100 ml
- Triglycerides: 120 mg/100 ml

Which of the factors listed here increase Rafael’s risk of developing cardiovascular disease?

Your answer:

Rafael meets with a dietitian. A diet recall reveals that his breakfast typically consists of a bagel with cream cheese and coffee with cream and sugar. For lunch, he goes out with his colleagues for a fast-food hamburger, fries, and a soda. Dinner at home with his family consists of beef or chicken, a green or orange vegetable, and rice or potatoes.

An analysis of his diet indicates that his total fat intake is within the recommended range of 20 to 35% of calories, but he consumes more saturated fat than is recommended. In addition, he does not consume enough omega-3 fatty acids relative to the amounts of omega-6 fatty acids, and he eats few foods that are high in heart-healthy monounsaturated fatty acids.

Fat and Cholesterol Recommendations

The DRIs recommend a total fat intake of 20 to 35% of calories for adults. Of this, a small proportion needs to come from the essential fatty acids. The AI for linoleic acid is 12 grams/day for women and 17 grams/day for men. You can meet your requirement by consuming a half-cup of almonds or 2 tablespoons of corn oil. For α-linolenic acid, the AI is 1.1 grams/day for women and 1.6 grams/day for men. Your requirement can be met by eating a quarter-cup of walnuts or 1 tablespoon of ground flaxseed. Consuming these amounts provides the recommended ratio of linoleic to α-linolenic acid of between 5:1 and 10:1.

To reduce Rafael’s intake of saturated fat, the dietitian suggests that he switch to cereal with low-fat milk for breakfast and make better fast-food choices at lunchtime.

What substitutions could Rafael make in his fast-food meal to reduce his intake of saturated fat?

Your answer:

At home, to increase intake of omega-3 and monounsaturated fatty acids, the family switches to canola oil and olive oil for cooking and has fish or shellfish twice a week. Because his modified diet has fewer calories and Rafael does not need to lose weight, he starts bringing granola bars to work for a snack.

Look at the labels from these two granola bars. Based on the amounts of saturated fat, trans fat, fiber, and calories in each, explain which one you would recommend.

(Work through Problem J.1.2.)

**Granola Bar A**

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serving Size: 1 bar (35g)</td>
</tr>
<tr>
<td>Amount Per Serving</td>
</tr>
<tr>
<td>Calories: 140</td>
</tr>
<tr>
<td>Calories from Fat: 30</td>
</tr>
<tr>
<td>% Daily Value*</td>
</tr>
<tr>
<td>Total Fat: 3.5g</td>
</tr>
<tr>
<td>Saturated Fat: 2g</td>
</tr>
<tr>
<td>Trans Fat: 0g</td>
</tr>
<tr>
<td>Cholesterol: 0mg</td>
</tr>
<tr>
<td>Sodium: 130mg</td>
</tr>
<tr>
<td>Total Carbohydrate: 26g</td>
</tr>
<tr>
<td>Dietary Fiber: 1g</td>
</tr>
<tr>
<td>Sugars: 13g</td>
</tr>
<tr>
<td>Protein: 2g</td>
</tr>
</tbody>
</table>

**Granola Bar B**

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serving Size: 1 bar (68g)</td>
</tr>
<tr>
<td>Amount Per Container</td>
</tr>
<tr>
<td>Calories: 230</td>
</tr>
<tr>
<td>Calories from Fat: 30</td>
</tr>
<tr>
<td>% Daily Value*</td>
</tr>
<tr>
<td>Total Fat: 3g</td>
</tr>
<tr>
<td>Saturated Fat: 0.5g</td>
</tr>
<tr>
<td>Trans Fat: 0g</td>
</tr>
<tr>
<td>Cholesterol: 0mg</td>
</tr>
<tr>
<td>Sodium: 125mg</td>
</tr>
<tr>
<td>Total Carbohydrate: 45g</td>
</tr>
<tr>
<td>Dietary Fiber: 5g</td>
</tr>
<tr>
<td>Sugars: 21g</td>
</tr>
<tr>
<td>Protein: 19g</td>
</tr>
</tbody>
</table>

Your answer:
Choosing Fats Wisely

The typical U.S. diet falls within the recommended 20 to 35% of calories from fat. Our trans fat intake is declining because food manufacturers have reduced the trans fat content of fats and oils used in processing. However, our intake of cholesterol and saturated fat often exceeds recommendations, and most people don’t get enough omega-3 polyunsaturated fatty acids.3, 15

Shifting the sources of dietary fat can improve the proportion of healthy fats in your diet. Limiting fatty cuts of meat, full-fat dairy products, and high-fat processed meats, and trimming the fat from meat and removing the skin from poultry will reduce your intake of saturated fat and cholesterol (see What a Scientist Sees). Avoiding foods such

To reduce the risk of heart disease the 2010 Dietary Guidelines recommend limiting saturated fat intake to less than 10% of total calories by replacing foods high in saturated fat with sources of mono or polyunsaturated fat. Reducing saturated fat intake to 7% of calories and keeping trans fat intake as low as possible can lower risk even more. The guidelines recommend limiting cholesterol to less than 300 mg per day for the general population and suggest that those at high risk for heart disease reduce their cholesterol intake to less than 200 mg/day. Limiting sources of solid fats in the diet will help to reduce saturated fat, trans fat, and cholesterol.15

Children need more fat than adults to allow for growth and development so their acceptable ranges of fat intake are higher: 30% to 40% of calories for ages 1 to 3 and 25% to 35% of calories for ages 3 to 18. Like adults, adolescents and children over age 2 should consume a diet that is low in saturated fat, cholesterol, and trans fat.15

Choosing Fats Wisely

The typical U.S. diet falls within the recommended 20 to 35% of calories from fat. Our trans fat intake is declining because food manufacturers have reduced the trans fat content of fats and oils used in processing. However, our intake of cholesterol and saturated fat often exceeds recommendations, and most people don’t get enough omega-3 polyunsaturated fatty acids.3, 15

Shifting the sources of dietary fat can improve the proportion of healthy fats in your diet. Limiting fatty cuts of meat, full-fat dairy products, and high-fat processed meats, and trimming the fat from meat and removing the skin from poultry will reduce your intake of saturated fat and cholesterol (see What a Scientist Sees). Avoiding foods such
Oils, butter, margarine, fatty sauces, and salad dressings used in cooking or added at the table are the most concentrated sources of fat in the diet. Limiting these can reduce your total fat and calorie intake, and choosing liquid oils, which are high in mono- and polyunsaturated fats, will limit your intake of solid fats, which includes fats that are high in saturated or trans fat, and choosing liquid oils, which are high in mono- and polyunsaturated fats.

Making wise MyPlate choices Your choices from each food group can have a significant impact on the amounts and types of fats in your diet (Figure 5.18). Generally, grains, fruits, and vegetables are low in total fat and saturated fat, and they contain no cholesterol. However, choices from these groups need to be made with care to avoid fats that are added in processing or preparation. Smart choices from the protein group and the dairy group can reduce your intake of unhealthy fats.
Lipids on food labels • Figure 5.19

a. Understanding how to use food labels can help you make more informed choices about the foods you include in your diet. By noting the grams of fat and the total number of Calories, you can determine the percentage of calories from fat in a product as follows:

1. Multiply the grams of fat by 9 Calories/gram. For example, this product provides 8 grams of fat:
   
   \[8 \text{ grams} \times 9 \text{ Calories/gram} = 72 \text{ Calories from fat}\]

2. Divide Calories from fat by total Calories and multiply by 100 to obtain the percentage. For example, this food contains 160 Calories/serving and 72 Calories from fat:
   
   \[\frac{72 \text{ Calories}}{160 \text{ Calories}} \times 100 = 45\% \text{ of Calories from fat}\]

b. Food labeling regulations have developed standard definitions for descriptors such as "low fat" and "low cholesterol," and such terms can be used only in ways that will not confuse the consumer. For example, because saturated fat in the diet raises blood cholesterol, to be labeled "low cholesterol," a food must contain ≤ 20 mg cholesterol per serving and ≤ 2 g saturated fat per serving. So crackers containing coconut oil, which are low in cholesterol but are high in saturated fat, cannot be labeled "low cholesterol."

The Nutrition Facts panel lists Calories from fat; grams of total fat, saturated fat, and trans fat; and milligrams of cholesterol in a serving. The amount of monounsaturated and polyunsaturated fat is voluntarily included on the labels of some products.

The Daily Values recommend consuming less than 30% of calories as fat, no more than 300 mg of cholesterol per day, and no more than 10% of calories as saturated fat. It is recommended that trans fat intake be limited to the amounts present naturally in meats and dairy products (≤0.5% of calories).

The sources of fat in a product are listed in the ingredient list with the other ingredients, in order of prominence by weight.

**Ask Yourself**

If you eat two servings of these cookies, a.12% what percentage of your recommended saturated fat intake will it provide? b.13% (Assume that you eat 2000 Calories per day.) c. 24% d. 30%

Chocolate Chip Cookies

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serving Size</strong></td>
</tr>
<tr>
<td><strong>Servings Per Container</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amount Per Serving</th>
<th>Calories 160</th>
<th>Calories from Fat 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fat</td>
<td>8g</td>
<td>12%</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>3g</td>
<td>15%</td>
</tr>
<tr>
<td>Trans Fat</td>
<td>0g</td>
<td>0%</td>
</tr>
<tr>
<td>Polyunsat Fat</td>
<td>2.5g</td>
<td>15%</td>
</tr>
<tr>
<td>Monounsat Fat</td>
<td>2g</td>
<td>15%</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0mg</td>
<td>0%</td>
</tr>
<tr>
<td>Sodium</td>
<td>110mg</td>
<td>5%</td>
</tr>
<tr>
<td>Potassium</td>
<td>45mg</td>
<td>1%</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>22g</td>
<td>7%</td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>Less than 1g</td>
<td>3%</td>
</tr>
<tr>
<td>Sugars</td>
<td>11g</td>
<td>3%</td>
</tr>
<tr>
<td>Protein</td>
<td>2g</td>
<td>2%</td>
</tr>
</tbody>
</table>

A % Daily Value is listed for total fat, saturated fat, and cholesterol. This allows consumers to tell how a food fits the recommendations. Generally, ≤5% of the Daily Value is low, and ≥20% is high. There are no Daily Values for trans, polyunsaturated, and monounsaturated fats.

The Nutrition Facts panel contains percentages to allow consumers to tell how a food fits the recommendations. Generally, ≤5% of the Daily Value is low, and ≥20% is high. There are no Daily Values for trans, polyunsaturated, and monounsaturated fats.

The Daily Values recommend consuming less than 30% of calories as fat, no more than 300 mg of cholesterol per day, and no more than 10% of calories as saturated fat. It is recommended that trans fat intake be limited to the amounts present naturally in meats and dairy products (≤0.5% of calories).

The sources of fat in a product are listed in the ingredient list with the other ingredients, in order of prominence by weight.

**Ask Yourself**

If you eat two servings of these cookies, a.12% what percentage of your recommended saturated fat intake will it provide? b.13% (Assume that you eat 2000 Calories per day.) c. 24% d. 30%

The Nutrition Facts panel lists Calories from fat; grams of total fat, saturated fat, and trans fat; and milligrams of cholesterol in a serving. The amount of monounsaturated and polyunsaturated fat is voluntarily included on the labels of some products.

The Daily Values recommend consuming less than 30% of calories as fat, no more than 300 mg of cholesterol per day, and no more than 10% of calories as saturated fat. It is recommended that trans fat intake be limited to the amounts present naturally in meats and dairy products (≤0.5% of calories).

The sources of fat in a product are listed in the ingredient list with the other ingredients, in order of prominence by weight.

**Ask Yourself**

If you eat two servings of these cookies, a.12% what percentage of your recommended saturated fat intake will it provide? b.13% (Assume that you eat 2000 Calories per day.) c. 24% d. 30%

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Meeting Lipid Needs

Looking at food labels  Food labels are an accessible source of information about the fat content of packaged foods. The Nutrition Facts panel shows the amounts of total fat, saturated fat, cholesterol, and trans fat, and the ingredient list indicates the source of the fat—for example, whether a food contains corn oil, soybean oil, coconut oil, or partially hydrogenated vegetable oil. Nutrient content claims such as “low fat,” “fat free,” and “low cholesterol” on food labels can also be used to identify foods that help you meet the recommendations for fat intake. Health claims can help you choose foods that will meet your nutritional goals. For example, foods that are low in saturated fat and cholesterol may state that they help reduce the risk of heart disease (Figure 5.19 and Appendix F).

The Role of Fat Replacers  People often choose low-fat and reduced-fat products in order to reduce the total amount of fat in their diets. Some of these foods, such as low-fat and nonfat milk and yogurt, are made by simply removing the fat, but in other products, the fat is replaced with ingredients that mimic the taste and texture of the fat. Some reduced-fat foods contain added sugars to improve the taste and texture. Some contain soluble fiber or modified proteins that simulate fat, and others contain fats that have been altered to reduce or prevent absorption (Figure 5.20).34 A problem with nonabsorbable fats is that they reduce the absorption of the fat-soluble substances in the diet, including the fat-soluble vitamins, A, D, E, and K. To avoid depleting these vitamins, products made with the nonabsorbable fat substitute Olestra have been fortified with them. However, these products are not fortified with β-carotene and other fat-soluble substances that may be important for health. Another potential problem with Olestra is that it can cause abdominal cramping and loose stools in some individuals because it passes into the colon without being digested.

Will using low-fat and reduced-fat products improve your diet? Some low-fat foods make an important contribution to a healthy diet. Low-fat dairy products are recommended because they provide all the essential nutrients contained in the full-fat versions but have fewer calories than their original counterparts. The sugar sucrose is usually added to low-fat and nonfat baked goods to improve flavor and add volume. Sucrose adds 4 Calories per gram. Protein-based fat replacers are made from milk and egg proteins processed to form millions of microscopic balls that slide over each other, mimicking the creamy texture of fat.34 They are used in frozen desserts, cheese foods, and other products but cannot be used for frying because they break down at high temperatures.

Fat replacers • Figure 5.20

Carbohydrates and proteins added to replace fat add calories to foods. In some cases, so much is added that the low-fat food is not much lower in calories than the original product. Some fat replacers are made from fats that have been modified to reduce how well they can be digested and absorbed. The calories they provide depend on how much is absorbed.

The artificial fat Olestra (sucrose polyester) is made from sucrose with fatty acids attached. Olestra cannot be digested by either human enzymes or bacterial enzymes in the gastrointestinal tract. Therefore, it is excreted in the feces without being absorbed.

Polysaccharides such as pectins and gums are often used in baked goods, as well as salad dressings, sauces, and ice cream, to mimic the texture that fat provides. They reduce the amount of fat in a product and at the same time add soluble fiber.

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WHAT SHOULD I EAT?
Fats and Cholesterol

Limit your intake of cholesterol, trans fat, and saturated fat
• Choose low-fat milk and yogurt.
• Trim the fat from your meat and serve chicken and fish but don’t eat the skin.
• Cut in half your usual amount of butter and use soft rather than stick margarine.
• Watch your fast food choices—choose chicken over burgers and skip the special sauce.

Increase the proportion of polyunsaturated and monounsaturated fats
• Snack on nuts and seeds.
• Add olives and avocados to your salads.
• Use olive, peanut, or canola oil for cooking and salad dressing.
• Use corn, sunflower, or safflower oil for baking.

and less saturated fat and cholesterol. Using these products increases the nutrient density of the diet as a whole. However, not all reduced-fat foods are nutrient dense. Low-fat baked goods often have more sugar than the full-fat versions because extra sugar is needed to add volume and make up for the flavor that is lost when the fat is removed. Some are just lower-fat versions of nutrient-poor choices, such as baked goods and chips. If these reduced-fat desserts and snack foods replace whole grains, fruits, and vegetables, the resulting diet could be low in fat but also low in fiber, vitamins, minerals, and phytochemicals (see What Should I Eat?).

Using low-fat foods does not necessarily transform a poor diet into a healthy one or improve overall diet quality, but if used appropriately, fat-modified foods can be part of a healthy diet. For example, if a low-fat salad dressing replaces a full-fat version, it allows you to enhance the appeal of a nutrient-rich salad without as much added fat and calories from the dressing. Low-fat products can also be used in conjunction with weight-loss diets because they are often lower in calories. But check the label. Although most are lower in calories, they are by no means calorie free and cannot be consumed liberally without adding calories to the diet and possibly contributing to weight gain.

CONCEPT CHECK
1. How much fat is recommended in a healthy diet?
2. Which food groups contribute the most foods that are high in saturated fat and cholesterol?
3. How can labels help you identify foods that are low in saturated and trans fat?

 Summary

1 Fats in Our Food  134

• Fat adds calories, texture, and flavor to foods. Some of the fats we eat are visible, but others are hidden.
• Over the past 40 years, Americans have changed the sources of fat in their diets, but the number of grams of fat consumed daily has changed little, as seen in this graph, and the incidence of obesity and other chronic diseases has continued to rise.

U.S. food intake in the 1970s and today • Figure 5.2c
Types of Lipids

- Lipids are a diverse group of organic compounds, most of which do not dissolve in water. Triglycerides, commonly referred to as fat, are the type of lipid that is most abundant in our food and in our adipose tissue. As shown here, a triglyceride contains three fatty acids attached to a molecule of glycerol.

Triglycerides • Figure 5.3

- The structure of fatty acids affects their chemical properties and functions in the body. Each carbon atom in the carbon chain of a saturated fatty acid is attached to as many hydrogen atoms as possible, so no carbon–carbon double bonds form. Saturated fatty acids are found primarily in animal products. Exceptions include saturated plant oils often called tropical oils. A monounsaturated fatty acid contains one carbon–carbon double bond. A polyunsaturated fatty acid contains more than one carbon–carbon double bond. The location of the first double bond determines whether it is an omega-3 or omega-6 fatty acid. The orientation of hydrogen atoms around a carbon–carbon double bond distinguishes cis fatty acids from trans fatty acids. Hydrogenation transforms some carbon–carbon double bonds to the trans configuration.

- A phospholipid contains a phosphate group and two fatty acids attached to a backbone of glycerol. One end of the molecule is water soluble, and one end is fat soluble. Phospholipids therefore make good emulsifiers. In the human body, they are an important structural component of cell membranes and lipoproteins.

- Sterols, of which cholesterol is the best known, are made up of multiple chemical rings. Cholesterol is made by the body and consumed in animal foods in the diet. In the body, it is a component of cell membranes and is used to synthesize vitamin D, bile acids, and some hormones.

Absorbing and Transporting Lipids

- In the small intestine, muscular churning mixes chyme with bile from the gallbladder to break fat into small globules. This allows pancreatic lipase to access triglycerides for digestion. The products of triglyceride digestion, cholesterol, phospholipids, and other fat-soluble substances combine with bile to form micelles, as depicted here, which facilitate the absorption of these materials.

Lipid digestion and absorption • Figure 5.8

- Lipids absorbed from the intestine are packaged with protein to form chylomicrons. The triglycerides in chylomicrons are broken down by lipoprotein lipase on the surface of cells lining the blood vessels. The fatty acids released are taken up by surrounding cells, and what remains is taken up by the liver.

- Very-low-density lipoproteins (VLDLs) are synthesized by the liver. With the help of lipoprotein lipase, they deliver triglycerides to body cells. Low-density lipoproteins (LDLs) deliver cholesterol to tissues by binding to LDL receptors on the cell surface. High-density lipoproteins (HDLs) help remove cholesterol from cells and transport it to the liver for disposal.

Lipid Functions

- Dietary fat is needed for the absorption of fat-soluble vitamins and to provide essential fatty acids. In the body, triglycerides in adipose tissue provide a concentrated source of energy and insulate the body against shock and temperature changes. Essential fatty acids are needed for normal structure and function of cell membranes, particularly those in the retina and central nervous system. Omega-6 and omega-3 polyunsaturated fatty acids are used to synthesize eicosanoids, which help regulate blood clotting, blood pressure, immune function, and other body processes. The ratio of dietary omega-6 to omega-3 fatty acids affects the balance of omega-6 and omega-3 eicosanoids made and hence their overall physiological effects.

- Throughout the day triglycerides are continuously stored in adipose tissue and then broken down to release fatty acids,
CHAPTER 5 Lipids: Fats, Phospholipids, and Sterols

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Heart disease. The total dietary and lifestyle pattern is more important than any individual dietary factor in reducing heart disease risk.

Diet high in fat correlate with an increased incidence of certain types of cancer. In general, the same types of lipids and other dietary components that protect you from heart disease will also protect you from certain forms of cancer.

Fat contains 9 Calories per gram. A high-fat diet may therefore increase energy intake and promote weight gain, but it is not the primary cause of obesity. Consuming more energy than expended leads to weight gain, regardless of whether the energy is from fat, carbohydrate, or protein.

Meeting Lipid Needs 154

- The DRIs recommend that adults consume a diet that provides 20 to 35% of energy from fat and is low in cholesterol, saturated fat, and trans fat. The Dietary Guidelines recommend limiting saturated fatty acid intake to less than 10% of total calories, limiting cholesterol to 300 mg per day, avoiding trans fat.

- The U.S. diet is not too high in fat, but it often does not contain the healthiest types of fats. To reduce saturated fat and cholesterol intake, limit solid fats and choose liquid oils, fish, and nuts and seeds often. Use food labels like the one shown here to avoid processed foods that are high in saturated and trans fat. A diet based on whole grains, fruits, vegetables, and lean meats and low-fat dairy products will meet the recommendations for fat intake.

Lipids on food labels • Figure 5.19a

- Fat replacers are used to create reduced-fat products with taste and texture similar to the original. Some low-fat products are made by using mixtures of carbohydrates or proteins to simulate the properties of fat, and some use lipids that are modified to reduce their digestion and absorption. Products containing fat replacers can help reduce fat and energy intake when used in moderation as part of a balanced diet.
Key Terms

- adipose tissue 144
- alpha-linolenic acid (ω-3-linolenic acid) 145
- antioxidant 154
- arachidonic acid 145
- atherosclerosis 149
- atherosclerotic plaque 149
- cardiovascular disease 148
- cholesterol 140
- chylomicron 142
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- linoleic acid 145
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- lipid bilayer 139
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- macrophage 148
- micelle 142
- monoglyceride 142
- monounsaturated fatty acid 136
- omega-3 fatty acid 137
- omega-6 fatty acid 137
- oxidized LDL cholesterol 148
- phosphate group 139
- phospholipid 136
- plant sterol 140
- polyunsaturated fatty acid 137
- saturated fatty acid 136
- sterol 136
- trans fatty acid 136
- triglyceride 135
- tropical oil 138
- unsaturated fatty acid 137
- very-low-density lipoprotein (VLDL) 144
- chylomicron 142
- phospholipid 136
- plant sterol 140
- saturated fatty acid 136
- sterol 136
- trans fatty acid 136
- triglyceride 135
- tropical oil 138
- unsaturated fatty acid 137
- very-low-density lipoprotein (VLDL) 144

Critical and Creative Thinking Questions

1. Record everything you eat for three days. Use iProfile to determine your nutrient intake. How does your intake of total fat, saturated fat, and cholesterol compare with the recommendations?

2. Using your food record from question 1, list the dairy products in your diet and indicate whether they are full fat or reduced fat. List the grain products you typically consume. How many of them are baked goods with added fats? How many of them are eaten with an added high-fat spread or sauce? Suggest changes you could make to reduce the fats added to your carbohydrates. List the foods in your diet that are from the meat and beans food group. Use iProfile to determine the types and amounts of fats these provide. Suggest some other foods from this group that would increase your intake of monounsaturated and omega-3 fatty acids.

3. Jessica is 18, at a healthy weight, and eats a vegetarian diet. Explain how she could still have high blood cholesterol levels.

4. The table shown here illustrates the percentage of calories from fat in the diets of American men and women and the incidence of obesity among adults between 1971 and 2000. Use these values to construct a graph. Based on your graph, discuss what happened to each over time and how these two factors might be related.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>% Calories from fat (men)</td>
<td>36.9</td>
<td>36.8</td>
<td>33.9</td>
<td>32.8</td>
</tr>
<tr>
<td>% Calories from fat (women)</td>
<td>36.1</td>
<td>36</td>
<td>33.4</td>
<td>32.8</td>
</tr>
<tr>
<td>Percentage of adults who are obese</td>
<td>14.5</td>
<td>15</td>
<td>23.3</td>
<td>30.5</td>
</tr>
</tbody>
</table>

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5. Ka Ming is a second generation Chinese American. At his college health fair a blood cholesterol screening reveals that his total blood cholesterol is 280 mg/100 ml. He is at a healthy weight and does not smoke. He gets little exercise and consumes a diet that is a mixture of American foods and traditional Chinese foods. A medical history reveals that none of Ka Ming’s relatives in China have had cardiovascular disease. Why might the lack of cardiovascular disease in his family history not be a true indication of Ka Ming’s risk?

What is happening in this picture?

This individual has familial hypercholesterolemia, a rare genetic disease in which there are no LDL receptors on cells. It causes cholesterol levels so high that the cholesterol deposits in body tissues, seen here as raised lumps.

Think Critically

1. Why would this condition cause elevated blood cholesterol?
2. How would this condition affect the risk of developing heart disease?

Self-Test

(Check your answers in Appendix K.)

1. What type of fatty acid is labeled C in the illustration?
   a. saturated
   b. monounsaturated
   c. omega-3 polyunsaturated
   d. omega-6 polyunsaturated

2. Which of the following is unlikely to occur after you eat a fatty meal?
   a. Fatty acids stored in adipose tissue are released into the blood and taken up by body cells as an energy source.
   b. The gallbladder releases bile into the small intestine.
   c. Micelles are formed in the small intestine.
   d. Pancreatic lipase releases fatty acids from triglycerides.
   e. The concentration of chylomicrons in the blood increases.

3. Omega-3 fatty acids have a beneficial effect on blood lipid levels but also reduce the risk of cardiovascular diseases because they ________.
   a. inhibit the absorption of cholesterol from the diet
   b. increase the formation of oxidized LDL cholesterol
   c. cause mutations in cellular DNA
   d. break down trans fatty acids
   e. are converted into eicosanoids

4. Which of the following statements about cholesterol is false?
   a. It is used to synthesize vitamin D.
   b. It is needed to make bile.
   c. It is an essential component of animal cell membranes.
   d. It is found in peanut butter, leafy green vegetables, and avocados.
   e. It is needed to make the hormones estrogen and testosterone.

6. Relate the functions of LDL and HDL cholesterol to how levels of each in the blood affect heart disease risk.

7. What are the similarities and differences in how the body responds to a cut on the finger and to an injury to the inside of an artery wall?

8. Why might taking fish oil supplements reduce the rate at which your blood clots?
5. Which two fatty acids are considered essential?
   a. saturated and unsaturated
   b. linoleic and α-linolenic
   c. stearic and palmitic
   d. EPA and DHA
   e. short and medium chain

   Use the diagram to answer questions 6 and 7.

11. Which of the following statements about trans fatty acids is true?
   a. They have carbon–carbon double bonds, with the hydrogen atoms on the same side of the bond.
   b. They have straighter carbon chains than a corresponding cis fatty acid.
   c. They are formed during deep fat frying.
   d. High levels in the diet decrease the risk of heart disease.

12. Based on the label shown here, what is the approximate percentage of calories from saturated fat in this product?
   a. 3.5%  c. 13%  e. 22.5%
   b. 2%    d. 17%

13. Which one of the following statements about micelles is true?
   a. They help facilitate the absorption of lipids in the small intestine.
   b. They help transport lipids in the bloodstream.
   c. They are essential in the diet.
   d. They break the bonds that hold fatty acids to glycerol.
   e. They are transformed into chylomicrons in the blood.

14. Which MyPlate group contains the most foods that are high in saturated fat and cholesterol?
   a. vegetables c. dairy
   b. grains       d. fruit

15. Identify the molecule in the animal cell membrane labeled B.
   a. cholesterol c. starch
   b. protein     d. phospholipid

6. Which of the following statements about dietary sources of fat is true?
   a. Coconut oil is high in polyunsaturated fat.
   b. Canola oil is high in monounsaturated fat.
   c. Olive oil is high in omega-3 fatty acids.
   d. Butter is high in omega-6 fatty acids.
   e. Avocados are high in saturated fat.

7. Which of the following is highest in omega-3 fatty acids?
   a. corn oil  c. flax seed  e. salmon
   b. canola oil d. walnuts

8. Which one of the following is associated with an increased risk of developing heart disease?
   a. a high concentration of HDL in the blood
   b. daily exercise
   c. a high-fiber, low-fat diet
   d. a diet made up mostly of plant foods
   e. a high concentration of LDL in the blood

9. Which of the following contribute to the lower heart disease risk associated with eating nuts?
   a. They are high in monounsaturated fat and omega-3 fatty acids.
   b. They are a good source of fiber and vegetable protein.
   c. They provide antioxidants.
   d. They contain plant sterols.
   e. All of the above are correct.

10. The transport of cholesterol to the liver for elimination is accomplished by ____________.
    a. chylomicrons  c. HDLs
    b. VLDLs        d. LDLs

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**Nutrition Facts**

```
Serving Size: 1 bar (35g)
Servings Per Container: 6

Amount Per Serving

Calories: 140
Calories from Fat: 30

Total Fat: 3.5g (6%)
Saturated Fat: 2g (10%)
Trans Fat: 0g (0%)

Cholesterol: 0mg (0%)
Sodium: 130mg (9%)
Total Carbohydrate: 26g (5%)
Sugars: 13g
Protein: 2g

% Daily Value

Dietary Fiber: 1g

The Planner

Review your Chapter Planner on the chapter opener and check off your completed work.
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