Chapter 10
Lipids: Nature's Flavor Enhancers

Fats and oils, which are known as lipids, serve many important functions in food preparation.

Objectives
After studying this chapter, you will be able to
describe the molecular structure of glycerides, phospholipids, and sterols.define saturated, monounsaturated, and polyunsaturated fatty acids.
list categories of lipids based on physical state and dietary sources.
relate physical characteristics of lipids to their performance in foods.
examine the functions of lipids in food preparation.
analyze the nutritional impact of lipids in the diet.

Key Terms
lipid glyceride fatty acid carboxyl group monoglyceride diglyceride triglyceride nonpolar phospholipid sterol saturated unsaturated monounsaturated polyunsaturated fat
oil melting point hydrogenation marbling solidification point auto-oxidation rancidity antioxidant smoke point flash point essential fatty acid omega-3 fatty acid plaque atherosclerosis lipoprotein
In today's society, much is written about the dangers of fat in the diet. Many weight-loss plans recommend cutting fat and counting fat grams. It is true that too much fat can be harmful. However, fat plays an important role both in food preparation and general health.

In this chapter, you will examine the structure of fat. You will learn how it functions in food preparation and why it is a vital part of a healthful diet. As you study this chapter, it is important to remember that fat does have a place in a healthful diet. The key is to keep everything in balance.

Chemical Structure of Lipids

Lipids are a category of organic compounds that are insoluble in water and have a greasy feel. Fats, oils, shortening, grease, phospholipids, sterols, and cholesterol are all terms used for lipids and their related compounds.

Lipids, like carbohydrates, contain carbon, hydrogen, and oxygen. However, lipids differ from carbohydrates in several ways. Lipids are not polymers, they do not provide structure to food products, and they cannot be dissolved in water.

There are three general types of lipids in foods and the human body. These are triglycerides, phospholipids, and sterols. Each of these types has a unique chemical structure.

The Glycerides

Most lipid molecules found in foods and the body have two basic parts. The base or core of these lipids is a glycerol molecule. Molecules that have a glycerol base are called glycerides. Glycerol has three hydroxyl groups that will react easily with other compounds. See 10-1.

The second part of most lipid molecules is called a fatty acid. Fatty acids are organic molecules that consist of a carbon chain with a carboxyl group at one end. A carboxyl group is a carbon atom, two oxygen atoms, and a hydrogen atom. See 10-2. The carboxyl group of a fatty acid will readily react with a hydroxyl group of glycerol. The products of this reaction are a lipid and water.

Because glycerol has three hydroxyl groups, it can join with one, two, or three fatty acids. A monoglyceride is a glycerol with one fatty acid attached at the site of a hydroxyl group. A diglyceride is a glycerol with two fatty acids attached. Triglycerides have a fatty acid joined at each of the three hydroxyl sites. See 10-3.

Fatty acid chains vary in length from 4 to 24 carbon atoms. There are 20 fatty acids that can combine with glycerol to form lipids.

Most of the lipids found in foods and in the body are triglycerides. Triglycerides can have three different fatty acids attached to the glycerol base. It is also possible for triglycerides to have two or three fatty acids that are identical. With 20 fatty acids to choose from, many combinations of triglycerides are possible. These options create triglyceride molecules with different characteristics. The chemical variations lead to differences in cooking performance, shelf life, and nutritional value. See 10-4.

Fatty acids and glycerol are polar molecules. The bodies of fatty acid are nonpolar. However, the carboxyl groups on fatty acids are slightly positive. The hydroxyl groups on glycerol are slightly negative. When fatty acids are mixed with glycerol, the polar ends
combine. The newly formed lipids have two ends that are nonpolar, or neutral in nature. Because fat molecules are nonpolar, they will not dissolve in water.

Mono- and diglycerides are partially soluble in water because of their hydroxyl groups. Their fatty acids also make these molecules soluble in fat. This dual solubility gives mono- and diglycerides an important function in the food industry. They are often added to processed foods to keep mixtures of water and fats stable. Butter and margarine are examples of foods to which mono- and diglycerides are often added.

**Phospholipids**

A second basic type of lipids is the phospholipids. A phospholipid is a glycerol base with two fatty acids and a phosphorus-containing acid attached. The fatty acids are soluble in fats. The phosphorus-containing acid is soluble in water. This allows phospholipids to mix with both water-based and fat-based substances.

Phospholipids play important roles in the body and in food products. In the body, cell membranes contain lipids, but the fluids on both sides of the membranes are water based. Phospholipids help carry fats back and forth across cell membranes into the water-based fluids. In food products, phospholipids help fats stay mixed in water-based solutions. Phospholipids keep foods like mayonnaise from separating.

**Sterols**

The third general type of lipids is the sterols. The sterols are complicated molecules derived or made from lipids. They include cholesterol, vitamin D, and the steroid hormones, including sex hormones. The most familiar sterol, cholesterol, is a part of every cell in the human body. See 10-5.

**Categories of Lipids**

You need to understand the ways lipids are categorized before you can understand the effects of lipids in food mixtures. Lipids are grouped according to molecular structure, physical state, and dietary sources.

**Categories Based on Molecular Structure**

One way to categorize lipids, or more specifically fatty acids, is by how saturated their carbon chains are with hydrogen atoms. In Chapter 4, you learned that each carbon atom is capable of forming four bonds. If two carbon and six hydrogen atoms combine, all the resulting bonds will be single bonds.
### Common Fatty Acids

<table>
<thead>
<tr>
<th>Abbreviation*</th>
<th>Name</th>
<th>Structural Formula</th>
<th>Melting Point (°C)</th>
<th>Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:0</td>
<td>Butyric</td>
<td>CH₃(CH₂)₄COOH</td>
<td>-4.2</td>
<td>butter</td>
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<tr>
<td>6:0</td>
<td>Caproic</td>
<td>CH₃(CH₂)₆COOH</td>
<td>-3</td>
<td>milk fats, coconut</td>
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<tr>
<td>8:0</td>
<td>Caprylic</td>
<td>CH₃(CH₂)₈COOH</td>
<td>16–16.5</td>
<td></td>
</tr>
<tr>
<td>10:0</td>
<td>Capric</td>
<td>CH₃(CH₂)₁₀COOH</td>
<td>31–32</td>
<td></td>
</tr>
<tr>
<td>12:0</td>
<td>Lauric</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>44</td>
<td>palm and coconut oils</td>
</tr>
<tr>
<td>14:0</td>
<td>Myristic</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>54</td>
<td>nutmeg</td>
</tr>
<tr>
<td>16:0</td>
<td>Palmitic</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>63</td>
<td>milk</td>
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<tr>
<td>18:0</td>
<td>Stearic</td>
<td>CH₃(CH₂)₁₈COOH</td>
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<tr>
<td>20:0</td>
<td>Eicosanoic</td>
<td>CH₃(CH₂)₂₀COOH</td>
<td>74–76</td>
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**Saturated Fatty Acids**

<table>
<thead>
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<th>Abbreviation*</th>
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<th>Structural Formula</th>
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<th>Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:1</td>
<td>Oleic</td>
<td>CH₃(CH₂)₉CH=CH(CH₂)₆COOH</td>
<td>14</td>
<td>milk, corn, cottonseed,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>peanuts, olives,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sesame seeds, sunflowers,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>canola oil</td>
</tr>
<tr>
<td>22:1</td>
<td>Erucic</td>
<td>CH₃(CH₂)₁₂CH</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>=CH(CH₂)₁₀COOH</td>
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</tr>
</tbody>
</table>

**Monounsaturated Fatty Acids**

<table>
<thead>
<tr>
<th>Abbreviation*</th>
<th>Name</th>
<th>Structural Formula</th>
<th>Melting Point (°C)</th>
<th>Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:2</td>
<td>Linoleic</td>
<td>CH₃(CH₂)₉CH=CHCH₂CH=CH(CH₂)₄COOH</td>
<td>-5</td>
<td>corn, cottonseed, olives,</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>peanuts, sesame seeds, sun-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>flowers</td>
</tr>
<tr>
<td>18:3</td>
<td>Linolenic</td>
<td>CH₃(CH₂)₉CHCH₂CH=CHCH₂CH=CH(CH₂)₄COOH</td>
<td>-11</td>
<td>soybeans, wheat germ</td>
</tr>
<tr>
<td>20:4</td>
<td>Arachidonic</td>
<td>CH₃(CH₂)₁₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₆COOH</td>
<td>-49.5</td>
<td></td>
</tr>
</tbody>
</table>

**Polyunsaturated Fatty Acids**

*Abbreviation: This column is a shorthand description of the fatty acid chains. The first number is the number of carbons in the fatty acid. The second number is the number of double bonds.

10-4 These fatty acids commonly combine with glycerol to form a variety of triglyceride molecules.

What happens if only four hydrogen atoms are available? The carbon atoms are still looking to form four bonds. A carbon atom can bond twice to another carbon atom. This will result in the carbon atoms sharing two electrons. When two atoms form two bonds with each other, the bond is called a **double bond**.

In the following examples, the carbon chain on the left contains the maximum number of
hydrogen atoms. The one on the right does not. Notice that each double bond reduces the total number of hydrogen atoms by two.

Fatty acids can be grouped by the number of double bonds in their carbon chains. Fatty acids will have zero, one, or multiple double bonds. The number of double bonds determines how close the carbon chain is to containing the maximum number of hydrogen atoms.

The first group of fatty acids has no double bonds present in the carbon chain. This means the carbon chain contains the maximum number of hydrogen atoms. When fatty acids have the maximum number of hydrogen atoms, they are described as saturated.

Butyric acid is a saturated fatty acid found in butter. Stearic acid is a saturated fatty acid that is a major component of beef fat. Notice these examples of saturated fatty acids are found in animal sources. Generally, lipids found in animal sources are high in saturated fatty acids. See 10-6.

If a fatty acid does not contain all the hydrogen atoms it could contain, it is unsaturated.

Fatty acids that have one double bond in the carbon chain are called monounsaturated. Foods that are high in monounsaturated fatty acids include olive oil, almonds, walnuts, and canola oil.

Polyunsaturated fatty acids have two or more double bonds in the carbon chain. Each double bond bends the fatty acid chain. The bends make it difficult for the molecules to pack together tightly. Safflower, sunflower, and corn oils are all high in polyunsaturated fatty acids.

A single triglyceride molecule can be made of one saturated, one monounsaturated, and one polyunsaturated fatty acid. This molecule would have characteristics of all three types of saturation.

Most lipids contain a combination of saturated, monounsaturated, and polyunsaturated fatty acids. The type of fatty acid present in the largest amounts has the greatest effect on the characteristics of the lipid. See 10-7.

Categories Based on Physical State

One of the easiest ways to categorize lipids is by their physical state at room temperature. Lipids that are solid at room temperature are commonly called fats. If lipids

10-6 Cheese and pepperoni can make pizza a food that is high in saturated fat.
Nutrition News

What Are Trans-Fatty Acids?

Research has indicated that trans-fatty acids might be as harmful to your health as highly-saturated butterfat. Trans-fatty acids are found in many margarines. Until more research is done, some health experts have recommended eating solid margarines in moderation.

What is at the heart of the concern is the shape of unsaturated fatty acids at the double bond site. One of two things can happen when a double bond forms in a fatty acid. As seen in the figure to the right, cis-isomers bend or kink at the bond. Trans-isomers take a fairly linear shape. Isomers are two molecules that have the same molecular formula, but the atoms are arranged in different patterns. Most unsaturated vegetable oils in nature have the cis-formation. The bends and kinks make it difficult for the molecules to move close together and solidify. Trans-fatty acids will solidify at lower temperatures because they are linear. Trans-fatty acids are a product of hydrogenating vegetable oil. Originally it was thought that trans-unsaturated fatty acids would be nutritionally identical to the cis-unsaturated fatty acids. Evidence indicates that the body may not be able to effectively digest the trans-form. These fatty acids could build up in blood vessels, increasing the risk of atherosclerosis. More study needs to be done to understand how the body reacts to trans-fatty acids.

are liquid at room temperature, they are called oils.

The numbers of hydrogen and carbon atoms on a fatty acid chain determine the temperature at which lipids liquefy. Double bonds in the fatty acid chain lower the temperature at which a lipid will be liquid rather than solid. Lipids that are liquid at room temperature have one or more double bonds in the carbon chain of the fatty acids. Polyunsaturated fatty acids become liquid at lower temperatures than saturated and monounsaturated fatty acids. This characteristic is due to the bent shape of the chain and the lower number of hydrogen atoms.

Fats contain mostly saturated fatty acids. Oils contain more monounsaturated and polyunsaturated fatty acids. This means fats have more hydrogen atoms than oils. Therefore, fats are denser and require more energy to liquefy. This causes the melting point of fats to be higher than the melting point of oils. Melting point is the temperature at which a lipid is completely liquid. Although oils are liquid at room temperature, they will solidify if chilled to a low enough temperature. Different types of fats and oils are saturated to different degrees. Therefore, each type of fat or oil has a different melting point. For
instance, oils high in polyunsaturated fatty acids will have lower melting points than oils high in monounsaturated fatty acids.

Oleic acid has one double bond in its carbon chain and is therefore monounsaturated. It is used extensively in the production of margarine. Remember that double bonds lower the melting point of lipids. Therefore, margarines with high oleic acid content will be softer than butter, which contains more saturated fatty acids. These margarines will also melt at lower temperatures than butter. Margarines have been developed with a wide range of melting points. Squeeze margarines
stay fluid in the refrigerator. Baker’s margarine, which is designed for making puff pastry, melts completely at 57°C (135°F). Butter melts at body temperature of 37°C (98°F).

Fats and oils usually come from different sources. Fats usually come from animal sources. Examples include butterfat from milk, lard from pigs, and tallow (used in candles) from animals such as sheep and cattle. Most oils come from plant sources. Examples include corn, soybean, peanut, canola, and olive oils. See 10-8.

Hydrogenated Vegetable Oils

Hydrogenation is the process of adding hydrogen atoms to an unsaturated lipid to increase its saturation level. This process is used to make some oils solid at room temperature. The result is a product that has a higher melting point than the oils. An example is margarine made from 100% corn oil. Solid vegetable shortening is also made from hydrogenated vegetable oils.

Hydrogenation is done by bubbling hydrogen through liquid oil in the presence of a nickel catalyst. The double bonds in the fatty acid chains of the oil break. The chains pick up extra hydrogen atoms, becoming more saturated. The process can be stopped at any point. If oils were to be completely saturated, they would become too brittle for most uses of solid fats.

The most commonly hydrogenated oil is soybean. Cottonseed and palm oils are often added in small amounts.

Advantages of hydrogenated vegetable oils include
- longer shelf life than oil or lard
- greater stability than lard
- lower production costs than lard
- faster dissolving and setting properties in chocolate production

Categories Based on Dietary Sources

Another way to group lipids is based on the food sources from which they come. Triglycerides come from seven main groups of dietary sources. Each group of triglycerides has a similar molecular structure and physical characteristics.

Milkfats come from the milk of cows, goats, and other mammals. Milkfats are high in palmitic, oleic, and stearic acids. The main difference between milkfats and fats such as lard or tallow is the length of the fatty acid chains. Most fatty acids in milk are shorter chains of 4 to 12 carbon atoms.

Lauric acids are the main component of a group of lipids found in palms such as coconut. Lauric acid makes up 40% to 50% of all the fatty acids in this lipid group. Lauric acid has a low melting point. These lipids are the most saturated of the oils found in plants.

Vegetable butters come from the seeds of tropical plants. These lipids have at least one unsaturated and one saturated fatty acid on every molecule. Because the molecular arrangements are so similar, these lipids have a very narrow melting range. The most

![Image of lipids](image)
important member of this group is cocoa butter, which is used frequently in candies.

Oleic-linoleic acids come from corn, peanuts, sunflowers, olives, cottonseeds, and sesame seeds. These lipids make up the largest group of triglycerides. They contain less than 20% saturated fatty acids.

Linolenic acid is found in large amounts in soybeans and wheat germ. Wheat germ needs to be refrigerated after opening. This is because linolenic acid reacts easily with oxygen during storage. This reaction causes flavor changes that are often undesirable. Refrigeration will help prevent these unwanted flavor changes.

Animal fats are found in meats and poultry. They contain large amounts of fully saturated fatty acids. This gives them high melting points. Animal fats are present as visible fat deposits as well as specks and streaks scattered throughout muscle fibers. The specks or streaks of fat in muscle tissue are called marbling. Marbling is an indicator of flavor and tenderness. The more marbling a meat cut has, the more flavorful and tender it will be. However, marbling also indicates a higher fat content.

Marine oils come from fish. These oils contain large amounts of long-chain polyunsaturated fatty acids. These fatty acids have as many as six double bonds each. The high degree of unsaturation makes these oils spoil or develop off flavors and odors very quickly. This is why fish must be eaten or frozen within 24 hours. See 10-9.

Physical Characteristics of Lipids

Three physical characteristics impact the way lipids perform in food products. One is the melting and solidification points of lipids. The second is the nonpolar nature of lipid molecules. The third physical characteristic is the tendency of lipids to react with oxygen.

Differing Melting and Solidification Points

Ice melts at 0°C. Water freezes at 0°C. The melting and freezing points of water are the same temperature. Unlike water, lipids do not have a specific melting point. This is because most lipids are mixtures of different kinds of fatty acids. Because each fatty acid has a different melting point, the lipids in a mixture will melt at different temperatures.

The lipids in a mixture will also become solid at different temperatures. This results in a temperature range between the point at which all lipids are solid and all lipids are liquid. Lipids within this range are a mix of solid and liquid. The temperature at which all lipids in a mixture are in a solid state is called the solidification point. (Lipids are said to solidify rather than freeze.) The solidification point for lipids is lower than the melting point. This is illustrated by the following diagram.
Lipids containing mostly saturated fatty acids have a higher melting point than lipids containing mostly unsaturated fatty acids. This is because the number of hydrogen atoms per carbon atom affects the melting point. The number of carbon atoms in the fatty acid chain also affects the melting point. The shorter the chain of carbon atoms in the fatty acid is, the lower the melting point will be. For example, butter has high levels of butyric acid, which contains 4 carbon atoms. Butter melts at a lower temperature than beef fat. Beef fat is high in stearic acid, which contains 18 carbon atoms. Both butyric and stearic acids are saturated. However, stearic acid’s longer chain of carbon atoms results in a higher melting point than butyric acid.

You may have noticed that vegetable oil becomes cloudy when you refrigerate it. This is because some of the triglycerides have a solidification point that is higher than the temperature in most refrigerators. The oils used in salad dressing have been processed to prevent solidification at refrigerated temperatures. The vegetable oil is chilled until solidification of the higher-melting triglycerides occurs. The oil is then filtered to remove the solid fat crystals. This is why commercial salad dressings are easier to pour after chilling than homemade ones.

**Nonpolar Molecules**

As you recall from Chapter 7, water molecules are polar. This means they have an unequal sharing of electrons. Lipid molecules have an equal or balanced sharing of electrons. This causes lipid molecules to be nonpolar. Substances that are nonpolar dissolve or readily mix with other substances that are nonpolar. Polar compounds dissolve in or readily mix with other polar compounds. However, polar and nonpolar molecules are not attracted to each other. Therefore, water and oil will not mix.

Lipids are very large molecules. The variety and shape of fatty acid chains create spaces between the parts of the molecules. These spaces cause lipids to be less dense than water. These spaces also prevent lipid molecules from packing together tightly. Because lipids are nonpolar, polar water molecules will not slip in and fill the spaces between lipid molecules. This results in the low density of lipids compared to water-based compounds. This is why oil floats on water.

You can demonstrate this physical characteristic of lipids by combining vinegar and oil. The oil will rise to the top. For vinegar and oil to stay mixed in salad dressings, another substance, called an emulsifier, must be added. This substance must have polar and nonpolar portions. See 10-10.

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**Item of Interest**

**Melt in Your Mouth...**

The next time you eat a piece of chocolate, savor the flavor by letting it melt in your mouth. The reason chocolate melts in your mouth is that fat in chocolate has a very narrow melting range. This is because most of the lipids in chocolate have the same chemical structure. The melting point of these lipids is close to body temperature. As the fats melt, they release the chocolate flavor. The melting fat also gives chocolate candies their smooth mouth feel.
Tendency to Deteriorate

An important characteristic of lipids is their tendency to react with oxygen. Auto-oxidation is a complex chain reaction that starts when lipids are exposed to oxygen. The oxygen will bind to the lipid molecules and then to other compounds. Once started, auto-oxidation is like knocking over dominoes. It is hard to stop and spreads quickly.

Auto-oxidation causes lipids to deteriorate. When oxygen is added to lipids, new compounds are formed. These compounds have an unpleasant flavor and odor that is described as rancid. Rancidity is a form of food spoilage, but it poses no short-term health risks. The main problem is the color and flavor changes.

Unsaturated oils are more susceptible to auto-oxidation than saturated fats. This is because unsaturated oils contain double bonds, which are weaker than single bonds. Oxygen can readily bind with lipid molecules at the sites of the double bonds.

Another type of deterioration occurs when triglycerides are hydrolyzed. You recall from Chapter 8 that hydrolysis occurs when a large molecule is divided into smaller parts by adding water. When water is added to lipid molecules, the molecules break apart into free fatty acids and glycerol. The shorter the carbon chains are, the more likely the fatty acids are to become rancid and develop off flavors. Butyric and caproic acids are short-chain fatty acids in butter. They are responsible for the unpleasant odor and flavor that develops when butter becomes rancid. Long-chain fatty acids like stearic, palmitic, and oleic usually do not develop off flavors unless auto-oxidation occurs also.

Oxygen exposure can cause high-fat foods to become rancid. To minimize oxygen exposure, some products are vacuum sealed or flushed with nitrogen gas. Rancidity can also be prevented or slowed by adding antioxidants to lipids. Antioxidants are compounds that will quickly react with oxygen to form new substances. Antioxidants will react with the oxygen before lipids do. Important dietary antioxidants are vitamins A, C, and E.

Storage Tip
Store high-fat foods in a dark, oxygen-free environment. This will slow the development of rancid flavors.

Functions of Lipids in Food Preparation

The structures and characteristics of the various types of fatty acids affect how they perform in food products. Lipids serve six main functions in cooking. Lipids act as heat mediums, tenderizers, aerators, flavor enhancers, lubricants, and as liquids in emulsions.

Transfer Heat
Lipids are an excellent heat medium. They transfer heat from cooking utensils to food quickly, evenly, and at very high temperatures. At normal air pressure, water boils at 100°C and will not get any hotter no matter how long you heat it. The temperature of lipids will continue to increase as heat is
added. Because of this characteristic, lipids will get hot enough to brown food. The exterior of the food will also develop a crisp texture.

Heat cannot be added to lipids indefinitely. Every lipid has a temperature at which the fatty acids begin to break apart and produce smoke. This temperature is called the smoke point. As the fatty acids break down, they combine with oxygen to form new compounds. These compounds have strong, unpleasant flavors. Once oil begins to smoke, breakdown has occurred and the oil should be discarded. It will no longer fry food successfully without creating undesirable flavor and color changes in the food. See 10-11.

Lard has a smoke point of 185°C (365°F). This is the same as the recommended temperature for deep frying. This means you have to heat lard to its smoke point when using it for deep frying. Therefore, you can use it for deep frying only one time for a short period.

If oil is heated long enough, it will become hot enough to burn. The flash point is the temperature at which lipids will flame. If oil is heated without close monitoring, the temperature will rise until small flames appear across the surface. This occurs at around 315°C (600°F).

Successful deep frying requires a hot enough temperature to cook the food all the way through without burning the outside. If food is fried at temperatures below 175°C (350°F), the exterior does not brown fast enough. Excess oil will soak into the food. The result will be pale, soggy food that is extremely high in fat content. If the oil reaches 205°C (400°F), the exterior of the food will begin to burn before the interior is done. The result will be very dark colored food with a raw center.

Using an electric deep fryer can make successful deep frying easier and safer. These appliances are thermostatically controlled. The fryer will automatically turn off the heat when the oil reaches the set temperature. This reduces the risk of starting a kitchen fire.

When cooking at home, you may wish to use a number of guidelines food scientists follow for successful deep frying. Cut foods for deep frying into small even pieces to decrease cooking time. Remove excess moisture from foods to reduce splattering. Cook only a small amount of food at a time. The more food that is added to the hot oil, the more the temperature of the oil will drop. If the oil drops below 175°C (350°F), the food will become soggy.

After coating foods in batter for deep frying, let them sit for 20 to 30 minutes. (This allows the starch in the batter to bind to the food.) Fewer pieces of the batter will break off into the oil and burn.

Do not salt food until after deep frying. Salt pulls water to the surface of the food. This will cause increased splattering when the food is placed in hot oil. Salt also lowers the smoke point of the oil and will, therefore, reduce the time the oil can be used.

**Tenderize**

Fats are used to tenderize baked products. Flour makes up the structure of most baked goods. The protein in flour has the tendency to form long strands. The longer the strands are, the tougher and chewier the food will become. Fat tenderizes by shortening these long strands. (This is why the solid white fat sold for baking is called shortening.) Solid fats coat the flour particles, making the dough slippery. This prevents long protein strands from forming.

The fat to flour ratio of a dough will determine how flaky a baked product is. Biscuits

### Smoke Points of Fats and Oils

<table>
<thead>
<tr>
<th>Lipid</th>
<th>°F</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safflower oil</td>
<td>510</td>
<td>266</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>495</td>
<td>257</td>
</tr>
<tr>
<td>Corn oil</td>
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<td>246</td>
</tr>
<tr>
<td>Peanut oil</td>
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</tr>
<tr>
<td>Sesame oil</td>
<td>420</td>
<td>216</td>
</tr>
<tr>
<td>Vegetable shortening</td>
<td>410</td>
<td>210</td>
</tr>
<tr>
<td>Olive oil</td>
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<td>Lard</td>
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<td>185</td>
</tr>
<tr>
<td>Butter</td>
<td>350</td>
<td>177</td>
</tr>
</tbody>
</table>
have a ratio of about one part fat for eight parts flour. This is just enough fat to give biscuits the ability to pull apart in sheets of moist bread.

Pie crust recipes call for about one part fat for every four parts flour. Too much fat will cause the pie crust to fall apart. Too little fat will cause the pie crust to be tough.

The first step in preparing biscuits and pie crust is cutting the fat into the flour. This step continues until the mixture resembles small peas or coarse crumbs. Cutting in fat distributes it evenly throughout the dough. Overmixing will cause the fat to soften to the point that it will begin to cling together. If worked too long, the fat-flour mixture would form a greasy ball. The dough would no longer be suitable for biscuits or crust.

Puff pastry has a mixture of fat and flour layered between thin sheets of yeast dough. The dough is kneaded to develop its structure, then it is rolled into a thin rectangle. A mixture of two parts fat to one part flour is rolled between waxed paper and chilled. Once this mixture has solidified, it is placed on top of the yeast dough. The dough is then folded, sealed, and rolled thin. The dough is folded and rolled until there are as many as fifty layers of dough and fat. The flakiness of puff pastry, croissants, and Danish result from the thin layers of fat melting during cooking. The dough browns and separates into the characteristic thin, tender, flaky sheets. See 10-12.

In each of these food products, tenderizing is a result of the fat separating but not soaking into the flour. The lipids that work best for this function are the solid fats. The higher the melting point of the fat is, the longer the mixture can be worked without the fat melting into the flour. Butter, regular margarines, lard, and shortenings give the best performance. Whipped and liquid margarines will not work because of their high air and water contents.

Lipids tenderize other baked goods, including cakes, pancakes, muffins, and waffles. Fats aid in giving these products a fluffy, moist texture. The separating of the flour keeps the products tender. Oil can be used instead of fat when the batter is a quick mix type. This type of batter combines the liquids in one bowl and the dry ingredients in another. The two mixtures are then blended.

### Aeration

**Aeration** is the addition of air into a batter. Saturated fats allow tiny air pockets to form when batters are sufficiently beaten. In order for aeration to occur, the fat must be able to hold its shape around the air pockets. This is why oils cannot be successfully substituted for fat in most cake recipes. Because oils are not solid at room temperature, they cannot provide the structure needed to trap air. The oil will start to separate from the mixture before cooking can stabilize the nonpolar molecules throughout the batter. The result is a grainier texturized cake.

Most conventional cake recipes call for the fat and sugar to be creamed (beaten together). The purpose of this step is to aerate the fat. The creaming process requires a fat that will soften but not melt when beaten. Butter remains workable between 18°C and 21°C (65°F and 70°F). At higher temperatures, the fat in butter becomes too liquid to support trapped air cells.

Timing the creaming step is important. Because beating increases friction, it increases the batter temperature. If the temperature goes too high, the fat will melt and the trapped air will be lost. This results in a crumbly, grainy texture.

Another example of aeration in lipids is whipped margarines. Whipped margarine and butter products are made more spreadable by adding air. The fat is beaten until tiny air pockets are trapped throughout.
Unwhipped butter and margarine are often packaged as four quarter-pound sticks. Whipped butter and margarines come six sticks to a pound. The extra volume in the whipped products is due to trapped air. That is why one stick of whipped butter cannot be substituted in recipes for one stick of butter. Whipped products can help lower fat in the diet. They make it seem as if you are using more butter on your food than you really are.

**Enhance Flavor**

An important function of fat in foods is providing flavor. Much of the flavor in food comes from salt, sugar, and fats. Because they want more flavor, most people in the United States get too much of these three ingredients.

Some of the fats in your diet are used as seasonings to flavor foods. People spread butter and margarine on bread and rolls mainly for flavor. Cooks add bacon fat to beans, soups, and sauces for the distinctive flavor it will give the finished product. Chefs cook onions, garlic, celery, and peppers in fat as a first step in preparing many sauces, soups, and casseroles. Fat dissolves and disperses the flavor compounds from the vegetables. The flavor will be stronger than if the vegetables were just simmered in a broth base. Olive oil provides flavor to salad dressings, and sesame oil enhances the taste of many Asian dishes.

There are times when you want to taste the flavor of the main food product and not the fat. When this is the case, it is best to use oils that have little or no flavor of their own. Cottonseed oil is one of the most flavorless of the oils. This is one reason why it is a favorite of potato chip manufacturers. Vegetable shortening, soybean oil, and canola oil are other relatively flavorless fats and oils.

**Lubricate**

Lipids lubricate food components, making it easier for them to slide over one another. This characteristic makes meat easier to chew as the fat content increases. Meat that is marbled has small flecks of fat evenly distributed throughout the muscle fibers. The even distribution of the fat creates a pleasant mouth feel.

Because lipids have a greasy texture, they feel slick or smooth to the tongue and palate. This characteristic causes many foods to seem moister. This is one reason why butter, margarine, and mayonnaise are popular spreads for breads and rolls. These spreads add to the feeling of moistness without making the bread soggy.

**Serve as Liquids in Emulsions**

Lipids are usually one of the two liquids in an emulsion. An *emulsion* is a mixture that contains a lipid and a water-based liquid. This mixture will not stay mixed together unless a compound is added that has a polar and a nonpolar end. Examples of common fat-based emulsions in food are mayonnaise, butter, milk, and bottled salad dressings. Phospholipids are compounds that help create emulsions. You will read more about the chemistry, application, and characteristics of emulsions in Chapter 11.
Lipids in Your Diet

Most people in the United States consume too much saturated fat. On the other hand, some people try to eliminate all fats from their diets. See 10-14. Because lipids are an important part of a healthful diet, it is important to find a balance. To correctly monitor lipids in your diet, you need to understand the functions of lipids in your body. You also need to understand the role of cholesterol and its relation to lipids.

Functions of Lipids in the Body

Lipids have four important functions in your body. The first is as a concentrated source of energy. Lipids have 9 Calories per gram. That is more than twice the energy provided by a gram of sugars or starches. Lipids take longer to digest than carbohydrates and give a feeling of fullness longer. They help provide a steady supply of energy to your body between meals.

Your body stores fat not needed for energy in fat cells. Triglycerides are the body's storage form of fats. There are two kinds of fat cells: white fat cells and brown fat cells. White fat cells are mainly composed of one large droplet of fat. The body tends to hold onto these reserves. The cell expands as fat is added and shrinks when fat is used. The brown fat cells contain many mitochondria. This is the part of the cell in which the body produces energy.

Two other functions of fats in the body are cell production and temperature regulation. A diet that is 100% fat free for extended periods is dangerous. Cell walls are made from a


<table>
<thead>
<tr>
<th>Food Source</th>
<th>Annual Increase per Person</th>
<th>Food Source</th>
<th>Annual Decrease per Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baking and frying fats</td>
<td>5.8 lbs</td>
<td>Table spreads</td>
<td>2.3 lbs</td>
</tr>
<tr>
<td>Salad and cooking oils</td>
<td>8.8 lbs</td>
<td>Margarine</td>
<td>2.2 lbs</td>
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<tr>
<td>Cheese</td>
<td>17 lbs</td>
<td>Cottage cheese</td>
<td>2 lbs</td>
</tr>
<tr>
<td>Fat free milk</td>
<td>2.7 gal</td>
<td>Whole milk</td>
<td>11 gal</td>
</tr>
<tr>
<td>Poultry</td>
<td>31 lbs</td>
<td>Beef, pork, and lamb</td>
<td>21 lbs</td>
</tr>
<tr>
<td>Fish</td>
<td>3 lbs</td>
<td>Eggs</td>
<td>72</td>
</tr>
</tbody>
</table>

Overall Changes

- People have decreased their total fat consumption by 8% of total calories.
- People are drinking 23% less milk and eating 2.5 times more cheese.
- Annual per capita consumption of red meat has decreased by 21 pounds. However, total meat consumption has increased by 13 pounds per person annually.
- Calories consumed when eating out has almost doubled. The percentage of those calories from fat has decreased by 4%. The percentage of calories from fat is over 6% higher than that of home-prepared foods.
- The percentage of calories from fat in foods prepared at home has decreased by over 10%. However, this percentage is still 1.5% above the goal of 30% of total calories from fat.


10-14 Health and nutrition findings toward the end of the twentieth century encouraged many people to change their fat consumption patterns.
combination of lipids and protein. The body also deposits fatty tissue around the vital organs to protect them from injury. Fatty tissue under the skin has two functions: to insulate and to provide a reserve energy supply. Fat helps maintain your body temperature by acting as an insulator that holds in body warmth. Fat reserves in the body provide energy when you consume too few calories or deplete your glycogen stores through exercise.

The last function of fat is to help transport vitamins. Some vitamins are fat-soluble. They need to combine with fat to be transported to where they are needed in the body.

**Essential Fatty Acids**

Fatty acids that cannot be produced by the human body are called *essential fatty acids*.

The only two fatty acids the body cannot make are linoleic acid and linolenic acid. Both of these fatty acids are polyunsaturated and are found in most plant and fish oils. They are essential for growth and development. Linoleic acid is found in large amounts in corn, cottonseed, and soybean oils. Chicken is another good source of linoleic acid. Linolenic acid is found in canola oil, soybean oil, walnuts, and fish.

**Omega-3 Fatty Acids**

Studies have been done on Greenlanders and Inuits. Researchers have tried to find out why these groups have low rates of heart disease in spite of high-fat diets. Most of the fat in their diets has been found to come from fish. Fish are very high in the omega-3 fatty acids.

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**Nutrition News**

**Carbohydrates vs Fats**

*Question: Which is more fattening, 100 calories of carbohydrates or 100 calories of fat?*

Recent research with rats has revealed that people may gain more weight from fat calories than from carbohydrate calories.

The toast on the left has 100 calories worth of fat from butter. The toast on the right has 100 calories worth of carbohydrates from jam.

This is because fats require less energy than carbohydrates require to be converted for storage in the body.

When 100 calories of fat is digested, the triglycerides break into fatty acids and glycerol. These parts pass through the intestinal wall into the bloodstream, where they can quickly recombine. The recombined fat goes into fat storage cells if it is not needed for energy. It takes 3 of the 100 calories to digest the fat and then store it.

Carbohydrates that are not needed for energy can also be stored as fat in the body. However, to change 100 calories of carbohydrates from starch into fat, the body must first break down the starch. Once the starch is broken into individual sugar molecules, the sugar is dismantled. Then it must be assembled into fatty acid chains. The fatty acids join to a glycerol and then are stored as fat. This process uses 23 of the 100 calories.

If you eat 100 calories of fat you do not need, 97 calories are stored as fat. If you eat 100 calories of carbohydrates you do not need, the body will first store it as glycogen. If glycogen stores are full, the carbohydrate is changed to fat. Only 77 calories are left to be stored as fat.

*Answer: Fat calories are more fattening!*
**Omega-3 fatty acids** have a double bond between the third and fourth carbon atoms from the end with the methyl group (CH₃).

Further study is needed to understand how omega-3 fatty acids work in reducing heart disease. However, research indicates these fatty acids help lower triglyceride levels in the blood and slow the growth of plaque in the arteries.

Fatty fish are high in two kinds of omega-3 fatty acids, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Recent research on fatty acids from fish sources seems to indicate that EPA and DHA strengthen brain-cell membranes improving cell-to-cell communication. They may also reduce joint inflammation and prevent heartbeat irregularities and mental decline.

Researchers are now recommending two to four meals (eight ounces) of fatty fish per week. Fish that have pink or red flesh are higher in omega-3 fatty acids than fish with white flesh. Albacore tuna, salmon, lake trout, and sardines are good sources, 10-15. Canola oil, flaxseed, and walnuts are good sources of alpha-linolenic acid that can become omega-3 fatty acid in the body.

The Role of Cholesterol

Cholesterol is used to build cell membranes. Up to 25% of all cell walls are cholesterol. Cholesterol is a rigid molecule that helps solidify cell walls. Because cholesterol is insoluble in water, it adds stability to the cell’s structure. The body makes cholesterol from lipids.

Too much cholesterol in the blood results in lipids and cholesterol being deposited on artery walls. These deposits are called plaque. Because cholesterol is rigid and insoluble in water, these deposits reduce the elasticity of artery walls. This hardening of the arteries is known as atherosclerosis. Blood pressure climbs as the heart works harder to force blood through the narrowing arteries. This disease is the leading cause of heart attacks and stroke.

Cholesterol is transported throughout the body by lipoproteins. Lipoproteins are clusters of lipid and protein molecules. Low-density lipoproteins (LDL) carry cholesterol from the liver. High-density lipoproteins (HDL) find unneeded cholesterol and return it to the liver. HDL and LDL work together to keep cholesterol levels in balance. Too much LDL can clog arteries, increasing the risk for heart attack or stroke. High levels of HDL appear to protect against heart attack. An optimal level for LDL is less than 100 mg/dL and greater than 40 mg/dL for HDL.

The average adult consumes 300 mg of cholesterol a day. The liver makes another 1,000 mg from fats. Although high cholesterol intake is not wise, it is not the only problem. A higher level of LDL means a higher risk of developing atherosclerosis. To a small degree, you can lower LDL through your diet. However, the most successful means of changing HDL and LDL levels appears to be regular exercise and maintaining a healthy weight.

A number of tips can help people limit the fats and cholesterol in their diets. It is important to monitor overall fat intake, not just cholesterol. This is because saturated fats increase the liver’s production of LDLs. High-fat diets can cause buildups of plaque to begin during the teen years.

Choosing lowfat and fat free foods is one way to limit fat intake. Food scientists have been busy developing hundreds of new products. The scientists are trying to meet the consumer demand for lowfat versions of high-fat favorites.
Some vegetable oils have “cholesterol free” on their labels. Such labels are intended to make products appear more healthful. However, all vegetable oils are cholesterol free. Cholesterol is found only in animal sources, such as meats, dairy products, and egg yolks.

Keep in mind that many cholesterol-free foods are high in fat. Remember the body can change fat into cholesterol. Beware of foods whose label reads “pure vegetable oil.” Many of these foods contain high levels of coconut and palm oils. These tropical oils are more economical than other vegetable oils, but they are highly saturated. This makes them as likely to raise blood cholesterol levels as animal fats.

Health Tip
A high-fiber diet can help trap dietary cholesterol and move it through the body. This keeps the digestive tract from absorbing some of the cholesterol from foods.

Unsaturated Oils
Heart disease has been found to be low among people in the Mediterranean region. Their diets are not low in fat. However, most of the fat consumed is from olive oil. The very low levels of saturated fatty acids in olive oil are an important factor. The most important factor, however, appears to be the high number of monounsaturated fatty acids.

Polyunsaturated oils lower LDL, however, they also lower the beneficial HDL. Monounsaturated oils lower LDL without lowering HDL. This is why some health professionals recommend olive and canola oils as the preferred oils in a healthful diet.

Olive oil has two disadvantages. It has a distinctive flavor that is popular in salads but may not be suitable in all foods. It also has a low smoke point. This makes it a poor choice for deep frying. However, it can be used successfully for stir-frying because of the short cooking time.

Dietary Recommendations
What is the balance when it comes to fat in the diet? The recommended guidelines are 20%-35% of calories should come from fat. Children and adolescents typically require the higher percentage of calories in their diets from fat. Adults whose body mass index (BMI) is in the low to mid 20’s should stay under 30% of their calories from fat. People who are overweight should keep their fat intake around 20%. Most fats in the diet should come from sources of polyunsaturated and monounsaturated fatty acids. A fat-free diet does not provide the essential fatty acids needed for new cell growth and other body functions.