

Chapter Summary

Fats and oils are forms of lipids. Lipids include triglycerides, phospholipids, and sterols. Triglycerides are the most common dietary fat and are composed of glycerol and three fatty acids. The fatty acids can be classified on the basis of chain length, level of saturation, and shape. Saturated fatty acids have no double bonds and are solid at room temperature. Mono-unsaturated fatty acids contain one double bond, and polyunsaturated acids contain more than one double bond; both are liquid at room temperature. A *cis* fatty acid has hydrogen atoms on the same side of the double bond, while a *trans* fatty acid has hydrogen located on opposite sides of the double bond. Trans fats, made from oils, are solid at room temperature. Essential fatty acids—linoleic and alpha-linolenic acid—must be obtained from food and are necessary for growth and health. Linoleic acid is found in vegetable and nut oils, while alpha-linolenic acid is found in dark green, leafy vegetables, flax, soy, canola, and fish oil. Phospholipids replace one fatty acid in a triglyceride with a phosphate-containing compound, making them water soluble. Sterols have a multiple ring structure. The most commonly occurring dietary sterol is cholesterol. The majority of fat digestion and absorption occurs in the small intestine. Bile, made in the liver and stored in the gallbladder, breaks down the fat into droplets. Pancreatic enzymes then digest triglycerides into free fatty acids and monoglycerides. After absorption through enterocytes by micelles, they are transported in the bloodstream by lipoproteins called chylomicrons. Fats have several important roles in the body. They provide energy and essential fatty acids, transport fat-soluble vitamins, regulate cell function, maintain cell membrane integrity, protect vital organs, and contribute to flavor and satiety of meals. The fats we eat can either contribute to health or increase our risk of disease. The AMDR for fat is 20–35% of total energy.

Recommendations also include minimizing saturated and *trans* fatty acid intake. Adequate intake of essential fatty acids is also necessary. Five to 10% of energy intake should be in the form of linoleic acid and 0.6% to 1.2% as alpha-linolenic acid. Diets high in saturated and *trans* fat increase the risk of cardiovascular disease, as does obesity, inactivity, smoking, high blood pressure, and diabetes. Inflammation is an indicator that the arterial walls have been damaged. High levels of LDL-cholesterol and low levels of HDL-cholesterol increase risk of heart disease. Research on dietary fat and cancer risk is controversial, except for prostate cancer, where the risk is higher with the intake of animal fats.

Nutrition Myth or Fact addresses the question: Are saturated fats bad or benign?

Learning Objectives

After studying this chapter, the student should be able to:

1. List and describe the three types of lipids found in foods (pp. 166–176).
2. Discuss how the level of saturation of a fatty acid affects its shape and the form it takes (pp. 168–171).
3. Explain the derivation of the term *trans* fatty acid and how *trans* fatty acids can negatively affect health (pp. 170–171).
4. Identify the two essential fatty acids, their chemical structure, and their beneficial functions (pp. 171–174).
5. Describe the steps involved in fat digestion, absorption, transport, and uptake (pp. 176–181).
6. List at least three physiologic functions of fat in the body (pp. 182–185).
7. Identify the DRIs for total fat, saturated fat, and the two essential fatty acids (pp. 185–188).
8. Distinguish between common food sources of fats considered beneficial and those considered less healthful (pp. 188–194).
9. Describe the role of blood lipids and dietary fats in the development of cardiovascular disease (pp. 194–205).
10. Identify lifestyle recommendations for the prevention or treatment of cardiovascular disease (pp. 201–205).

Key Terms

alpha-linolenic acid	high-density lipoprotein	monounsaturated fatty acids
atherosclerosis	hydrogenation	phospholipids
chylomicron	invisible fats	polyunsaturated fatty acids
cardiovascular disease	linoleic acid	saturated fatty acids
docosahexaenoic acid (DHA)	lipids	short-chain fatty acids
eicosapentaenoic acid (EPA)	lipoprotein	sterols
essential fatty acids	lipoprotein lipase	triglyceride
fatty acids	long-chain fatty acids	very-low-density lipoprotein
glycerol	low-density lipoprotein	visible fats
	medium-chain fatty acids	
	micelle	

Chapter Outline

I. What Are Lipids?

- A. Lipids are a large, diverse group of water-insoluble substances.
- B. Lipids come in different forms.
 1. Lipids occur in the body as adipose tissue, part of cell membranes, and as steroids.
 2. Lipids in food are known as fat and may be solid or liquid at room temperature.

- C. Triglycerides are the most common food-based lipid.**
1. Triglycerides consist of three fatty acids attached to a glycerol backbone.
 - a. Fatty acids are long chains of carbon atoms bound to each other as well as to hydrogen atoms.
 - b. Glycerol is an alcohol composed of three carbon atoms.
 2. Fatty acids vary in chain length.
 - a. Short-chain fatty acids are fewer than 6 carbons in length.
 - b. Medium-chain fatty acids are 6 to 12 carbons in length.
 - c. Long-chain fatty acids are 14 or more carbons in length.
 - d. Chain length determines method of digestion and absorption and how fats function in the body.
 3. Fatty acids vary in level of saturation.
 - a. Saturated fatty acids (SFAs) have no double bonds between carbons.
 - b. Monounsaturated fatty acids (MUFAs) have one double bond in the carbon chain.
 - c. Polyunsaturated fatty acids (PUFAs) have more than one double bond in the carbon chain.
 4. Fatty acid carbon bonding affects shape.
 - a. Saturated fatty acids always form straight, rigid chains that pack tightly together and are usually solid at room temperature.
 - b. Each double bond in unsaturated fatty acids produces a kink, which prevents tight packing, making them liquid at room temperature.
 - c. Unsaturated fatty acids may be *cis* or *trans*, and most *trans* fats are produced by hydrogenation.
 - i. If only some of the double bonds are broken during hydrogenation, the fat produced is partially hydrogenated.
 - d. Both saturated and trans fatty acids increase blood cholesterol.
 5. Some triglycerides contain essential fatty acids.
 - a. Fatty acids with double bonds closer to the methyl end are essential because the body cannot produce them and they must be obtained from food.
 - b. Essential fatty acids (EFAs) are precursors to eicosanoids, which are essential to growth and health.
 - c. The two EFAs are linoleic and alpha-linolenic acid.
 - i. Linoleic acid, known as omega-6 fatty acid, is found in nut and vegetable oils.
 - ii. Alpha-linolenic acid, known as omega-3, is found in dark leafy vegetables, flaxseed, soybean, walnut, and canola oil.
 - iii. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) found in fish reduce the risk of heart disease.
- D. Phospholipids combine lipids with phosphate.**
1. Phospholipids are water soluble.
 2. The body produces phospholipids, so they are not essential.
 3. Phospholipids transport fat in the bloodstream, regulate transport of substances in and out of the cell, help in the digestion of dietary fats, and aid in bile production.
- E. Sterols have a ring structure.**

1. Cholesterol is the most common sterol in the diet.
2. Plant sterols appear to block absorption of dietary cholesterol.
3. Our body synthesizes cholesterol in the liver and intestines, so it is not essential to the diet.
4. Cholesterol is very important to cellular and body function.

Key Terms: lipids, triglyceride, glycerol, fatty acid, short-chain fatty acids, medium-chain fatty acids, long-chain fatty acids, saturated fatty acid (SFA), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), hydrogenation, essential fatty acids (EFAs), linoleic acid, alpha-linoleic acid (ALA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), phospholipids, sterols

Figures:

Figure 5.1: A triglyceride is composed of one molecule of glycerol and three fatty acid chains.

Figure 5.2: Examples of levels of saturation among fatty acids

Figure 5.3: Major sources of dietary fat.

Figure 5.4: Structure of a *cis* and a *trans* polyunsaturated fatty acid.

Figure 5.5: The two essential fatty acids.

Figure 5.6: The structure of a phospholipid.

Figure 5.7: Sterol structure.

II. How Does the Body Break Down Lipids?

- A. Although lingual lipase does break down small amounts of lipids in the mouth, and the stomach reduces lipids to smaller droplets, digestion of lipids essentially begins in the small intestine.
- B. The gallbladder, liver, and pancreas assist in fat digestion.
 1. Because lipids are not water soluble, their digestion requires bile from the gallbladder and digestive enzymes from the pancreas.
 2. Hormones cause the gallbladder to contract and release bile into the small intestine.
 3. The liver produces bile and sends it to the gallbladder for storage.
 - a. Lecithins enable bile to break lipids into smaller droplets with greater surface area.
 4. Pancreatic enzymes break fatty acids away from their glycerol backbone.
 - a. Each lipid requires a specific digestive enzyme.
 - b. Each triglyceride is broken down into two fatty acids and a monoglyceride.
 - c. Cholesterol esters and phospholipids are also broken down by specific enzymes.
 5. The end products of digestion are much smaller molecules that can be more easily captured and transported to the enterocytes for absorption.
- C. Absorption of lipids occurs primarily in the small intestine.
 1. Micelles transport lipids through the mucosal lining.
 2. Lipids are packaged as lipoproteins before transport.
 - a. In the enterocytes, triglycerides and cholesterol esters are re-created and enclosed in phospholipids and protein to form chylomicrons.
 - b. Chylomicrons transport dietary fat through the lymphatic system to the bloodstream.

- c. The triglycerides in chylomicrons are used by cells throughout the body and are released with the help of an enzyme called lipoprotein lipase (LPL).
 - d. As the body cells take up the fatty acids, the chylomicrons decrease in size, and the chylomicron remnants are removed from the blood by the liver.
 - i. Chylomicrons clear the bloodstream within six to eight hours normally.
 - 3. Short- and medium-chain fatty acids are more readily absorbed and transported because they do not have to be incorporated in chylomicrons.
- D. Fat is stored in adipose tissues for later use.**
- 1. Fat can be used by body cells as a source of energy.
 - 2. Fat can be used to make lipid-containing compounds in the body.
 - 3. Fat can be stored in muscle or adipose tissue as a triglyceride for later use.
 - 4. The primary storage site for triglycerides is the adipose cells.
 - a. Physically active individuals' bodies preferentially store triglycerides in muscle tissue for more rapid access to energy stores.
 - b. Fat stored in adipose tissues can also be used for energy during exercise, but it must be broken down first and then transported to muscle cells.

Key Terms: micelle, lipoprotein, chylomicron, lipoprotein lipase

Nutrition Animations: Fat Digestion; Lipid Absorption (located in IR-DVD folder).

Figures:

Figure 5.8: Lipid Digestion Overview

Figure 5.9: Action of bile salts, pancreatic lipase, and micelles in lipid digestion and absorption.

Figure 5.10: Structure of a lipoprotein.

Figure 5.11: The reassembly of the lipid components into a chylomicron.

Figure 5.12: Diagram of an adipose cell.

III. Why Do We Need Lipids?

A. Lipids provide energy.

- 1. Fat provides 9 kilocalories per gram, twice the energy of protein and carbohydrate.
- 2. Lipids supply energy when we are at rest.
 - a. Fat requires oxygen to burn, and the body delivers plenty of oxygen when it is resting.
 - b. Thirty to 70% of the energy used at rest comes from lipids.
- 3. Lipids fuel physical activity.
 - a. Epinephrine stimulates fat breakdown and signals the pancreas to decrease insulin production, thus inhibiting fat storage.
 - b. Fatty acids, released from the adipose cells, are delivered to the muscle cells attached to albumin.
 - c. The longer you exercise, the more fat you use for energy.
 - d. The more physically fit you are, the more fat you can use for energy.
- 4. Lipids stored in body fat provide energy for later use.
 - a. Stored fat is necessary when food intake is inadequate and when glycogen stores are low.

b. Although too much fat stored in adipose tissue can be harmful, some fat storage is necessary.

B. Essential fatty acids contribute to important biological compounds.

C. Dietary fat enables the transport of fat-soluble vitamins (A, D, E, and K).

D. Lipids help maintain cell function and provide protection to the body.

1. Lipids maintain fluidity and flexibility of the cell membrane.

2. Lipids are primary components of the tissues of the nervous system.

3. Adipose tissue pads and insulates our bodies and protects our organs.

E. Fats contribute to the flavor texture, and satiety of foods.

1. Fats help us to feel satiated because they are energy dense.

Figure:

Figure 5.13: Various Sources of energy used during exercise.

IV. How Much Dietary Fat Should We Eat?

A. The AMDR for fat is 20–35% of total energy.

1. Intake of saturated and *trans* fatty acids should be minimized.

2. Athletes benefit from lower fat intake, 20–25% of total energy.

3. Diets below 20% total energy as fat do not promote weight loss and may be harmful.

B. Dietary reference intakes have been established for essential fatty acids.

1. The adequate intake for linoleic acid is 11 to 17 grams per day for men and 11 to 12 grams per day for women (or 5–10% of energy).

2. The adequate intake for alpha-linolenic acid is 1.6 grams per day for men and 1.1 grams per day for women (or 0.6–1.2% of energy).

3. Most Americans eat within the recommended percentage of fat but eat the wrong types.

C. Limit Saturated and *Trans* Fat

1. Diets high in saturated and *trans* fatty acids can increase the risk for cardiovascular disease.

2. Reduce intake of saturated fats.

a. The recommended intake of saturated fat should be less than 7% to 10% of total energy intake, Americans typically consume more.

3. Avoid *trans* fatty acids.

a. *Trans* fatty acids should be consumed at an absolute minimum.

b. Make sure to avoid products with partially hydrogenated oils (PHOs).

D. By keeping intake of saturated fats in recommended range excessive levels of blood cholesterol can be avoided.

1. There appears to be no link between dietary cholesterol and cardiovascular disease.

E. Select beneficial fats.

1. Eat more sustainable fish.

a. Certain types of fish may contain high levels of toxins, but plenty of choices are safe to consume.

2. Pick plants.
 - a. Replace animal-based foods with those derived from plants as a strategy to include more healthful fats in your diet.
3. Shop for lower-fat options.
4. Don't be fooled by added fats.
 - a. Visible fats are fats we can see in our foods or see added to foods.
 - b. Invisible fats are fats that are hidden in prepared and processed foods.
 - c. Processed foods that are made with fat replacers are often high in calories.
5. Be careful when you are eating out.
6. Be aware of fat replacers.
 - a. Fat replacers have not proved to be the answer to the obesity epidemic.
 - b. Olestra, a common fat replacer, no longer carries a warning about gastrointestinal side effects, but its use is limited.
 - c. Newer fat replacers are protein-based and decrease fat and calories without compromising flavor and texture.

Key Terms: visible fats, invisible fats

Nutrition Animation: Fats in Food (located in IR-DVD folder).

Figures and Tables:

Figure 5.14: Reducing Saturated Fat

Figure 5.15: Labels for two types of wheat crackers.

Table 5.1: Omega-3 Fatty Acid Content of Selected Foods

Table 5.2: Comparison of Full-Fat, Reduced-Fat, and Low-Fat Foods

V. What Role Do Lipids Play in Cardiovascular Disease and Cancer?

A. Cardiovascular disease involves the heart or blood vessels.

1. It is a general term used to refer to any abnormal condition involving dysfunction of the heart and blood vessels.
 - a. The three most common forms are coronary heart disease, stroke, and hypertension (high blood pressure).
2. Atherosclerosis is narrowing of the arteries.
 - a. It is a condition in which arterial walls accumulate deposits of lipids and scar tissue, which build up to a degree that they impair blood flow.
 - b. The blockages created by atherosclerosis can lead to heart attack, sudden cardiac arrest, or stroke.
3. There are a number of risk factors for cardiovascular disease.
 - a. Nonmodifiable risk factors include age, male gender, and family history.
 - b. Modifiable risk factors include:
 - i. Obesity
 - ii. Physical inactivity
 - iii. Smoking
 - iv. Type 2 diabetes
 - v. Inflammation
 - vi. Abnormal blood lipids

4. Blood lipids play a role in cardiovascular disease.
 - a. Because lipoproteins are soluble in blood they are called “blood lipids.”
 - b. The names of the various types of lipoproteins reflect their proportions of lipids.
 - i. Chylomicrons have the lowest density at 85% triglyceride.
 - ii. Very-low-density lipoproteins (VLDLs) are those in which more than half of their substance is triglyceride. Diets high in fat, sugars, and simple sugars, and Calories can increase the production of VLDLs.
 - iii. Low-density lipoproteins (LDLs) result from VLDLs releasing their triglyceride load; hence LDLs are higher in cholesterol, phospholipids, and protein, and are somewhat more dense than VLDLs. Diets high in saturated and *trans* fat decrease the removal of LDLs.
 - iv. High-density lipoproteins (HDLs) are small, dense, and have a low cholesterol content and a high protein content. High blood levels of HDLs are associated with a low risk for coronary artery disease.
 - v. Total serum cholesterol reflects the relative balance in an individual between their dietary cholesterol consumption and their body’s production of cholesterol. In people whose dietary cholesterol intake doesn’t decrease their production, total body cholesterol levels rise.
5. Dietary fats play a role in cardiovascular disease.
 - a. High saturated fat and *trans* fatty acid intake raises total LDL and VLDL cholesterol, raising the risk of coronary artery disease.
 - b. Omega-3 fatty acids decrease inflammation and triglycerides and increase HDL cholesterol, positively affecting blood lipid values and lowering CAD risk.
6. Lifestyle changes can prevent or reduce cardiovascular disease.
 - a. Follow DRIs for total fat, saturated fat, and *trans* fat.
 - b. Increase dietary intake of whole grains, fruits, and vegetables to increase fiber.
 - c. Make sure to consume the RDA of vitamin B6, B12, and folate to help maintain low blood levels of the amino acid homocysteine.
 - d. Select and prepare foods with less salt.
 - e. Eat smaller meals and snacks throughout the day instead of eating most of your Calories in the evening before bed.
 - f. Add plant sterols to your diet.
 - g. Maintain blood glucose and insulin concentrations within normal ranges to prevent high triglycerides.
 - h. Maintain a healthy body weight.
 - i. Maintain an active lifestyle.
 - j. Moderate alcohol consumption.
 - k. Do not smoke.
 - l. The DASH diet has been effective in lowering blood lipids and blood pressure.
7. Prescription medications can reduce cardiovascular disease risk.
 - a. Statins block an enzyme in the cholesterol synthesis pathway and have an important anti-inflammatory effect.
 - b. Bile acid sequestrants reduce the total cholesterol pool in the body.
 - c. Nicotinic acid, niacin, favorably affects all blood lipids.

8. Does a high-fat diet cause cancer?

- a. Research on dietary fat and cancer risk is controversial, except for prostate cancer, where the risk is higher with the intake of animal fats.

Key Terms: cardiovascular disease, atherosclerosis, very-low-density lipoprotein (VLDL), low-density lipoprotein (LDL), high-density lipoprotein (HDL)

Nutrition Animation: Lipoproteins: VLDL, LDL, and HDL (located in IR-DVD folder)

Figures:

Figure 5.16: Atherosclerosis

Figure 5.17: The chemical components of various lipoproteins.

Figure 5.18: Lipoprotein Transport and Distribution

Activities

1. Mix oil and water together in a clear glass to demonstrate their immiscibility. Then add soap or egg to the mixture to demonstrate the action of bile.
2. Using the fat content of the following menu or one of your own choosing, demonstrate how much fat is consumed daily by a typical American. Bring waxed paper, shortening, and a tablespoon or 1/4 cup measure to class. Every 100 fat Calories equals 1 tablespoon of fat. Measure out the tablespoons of fat onto the waxed paper. For instance, the menu below is 1,400 fat Calories, so you would measure out 14 tablespoons of fat. In the United States the percentage of total Calories from fat has decreased, but the total number of Calories has increased in the past two decades. This demonstration makes a good discussion starter on the topic.

Typical Menu

Breakfast	Cereal and Milk Coffee w/Cream and Sugar
Lunch	Bacon Cheddar Hamburger Curly Fries, Regular size Coke
Dinner	Chicken Fettuccini Alfredo Broccoli 2% Milk
Snack	Potato Chips and Dip
Total calories: 2,400	
Total fat calories: 1,400	

3. Ask each student to predict the lowest and highest fat entrée from their favorite fast-food restaurant. Have them find out by bringing in a Nutrition Fact Sheet from the restaurant or finding the information on the Web (two sites that provide this information include www.foodfacts.com and www.fatcalories.com). Compile a list of the various foods, including:

- a. total Calories
 - b. Calories from fat
 - c. grams of fat
 - d. grams of saturated fat
 - e. percent of Calories from fat (students will need to calculate this value: Calories from fat/total Calories)
4. Bring in sample lipid profiles. Have students work in small groups to determine ways to improve the profile and lower risk of cardiovascular disease by changing lifestyle and dietary habits. Note: You will need to discuss ways to lower triglycerides prior to this exercise.
 5. The Mediterranean diet has received extensive publicity as a heart-healthy diet. Ask students to determine the factors that make it a heart-healthy plan. Does it meet the 2010 Guidelines? In what ways would the Mediterranean diet be easy to follow? In what ways would the Mediterranean diet be difficult to follow? Overall, how do the relative strengths and weaknesses of this approach stack up as a practical eating plan for students? Explore these issues.
 6. Have students learn about the various fat replacers and their use in foods over the past 10 years. What are the merits and drawbacks of incorporating them into the American diet?

Diet Analysis Activity

7. Using the nutritional assessment previously completed, students should note the following:
 - a. How many grams of fat do you consume daily?
 - b. What percentage of your daily Calories comes from fat?
 - c. How many grams of saturated fat do you consume daily?
 - d. How many grams of cholesterol do you consume daily?
 - e. Do your intakes meet recommendations for these nutrients?
 - f. What three foods that you consumed contained the highest level of fat? How many grams of fat were in each food?
 - g. What changes can you make in your diet to more closely meet fat and cholesterol recommendations?

Nutrition Debate Activity

8. Either in small groups or as a class, debate: Would a “fat tax,” a tax on fatty foods, reduce obesity and heart disease in the United States? Students will need to research their position and come prepared. Questions that may arise include: How high would the tax need to be to make a difference? How would the government decide which foods to tax? Would a rebate for healthy choices be more effective? How would it affect the economy? What other issues can the students identify that would be raised by such an approach?

Web Resources

American Heart Association

www.heart.org/HEARTORG

National Heart, Lung, and Blood Institute

www.nhlbi.nih.gov

MEDLINE Plus Health Information

www.nlm.nih.gov/medlineplus

National Institutes of Health

www.nih.gov
