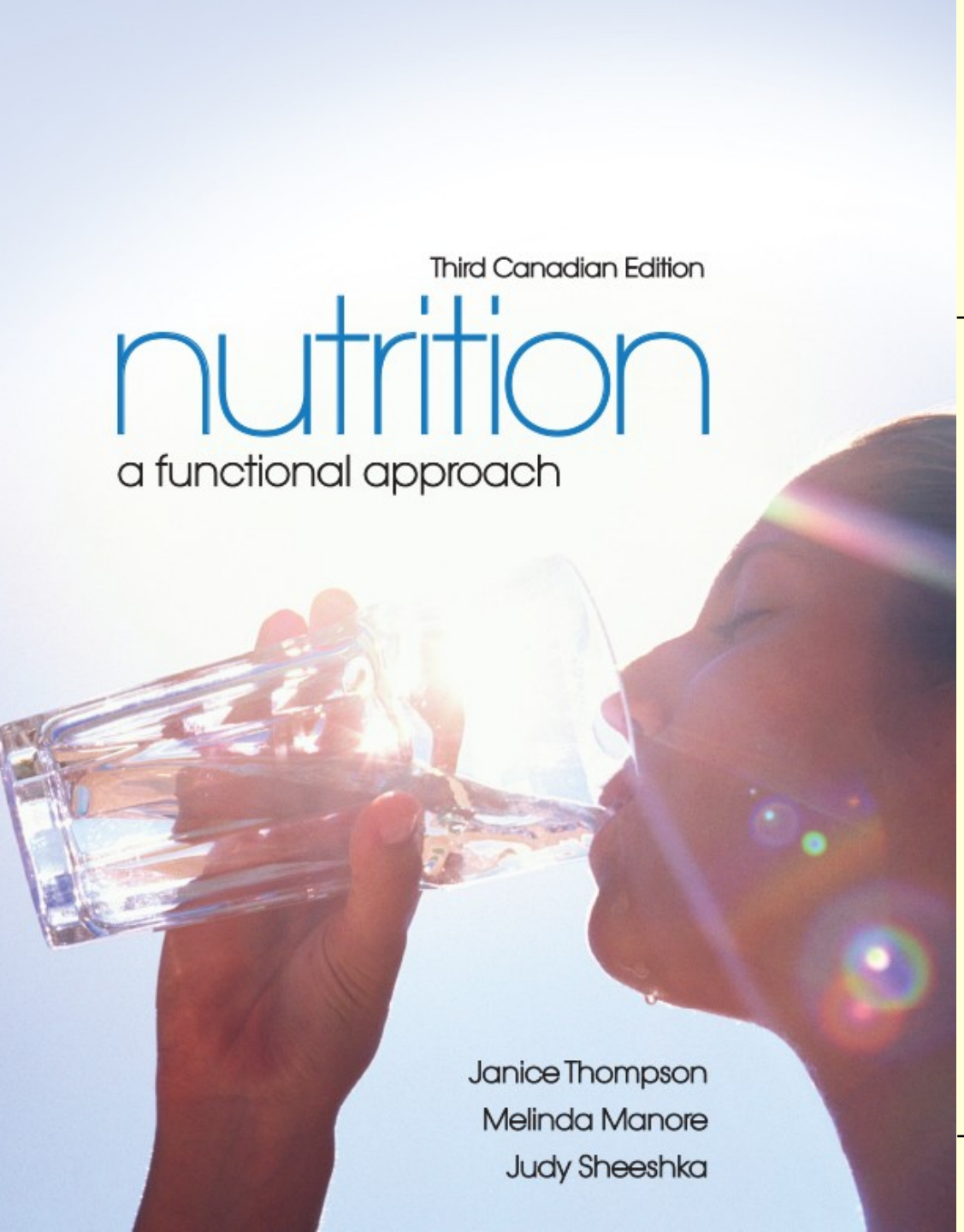


CHAPTER

5

Fats: Essential Energy-Supplying Nutrients and In Depth

What Are Fats?

Fats are one type of lipid

Lipids: diverse class of molecules that are insoluble in water

- Lipids (fats) do not dissolve in water

3 types of lipids are found in foods

- Triglycerides
- Phospholipids
- Sterols

Triglycerides

Triglycerides are composed of

- 3 fatty acid molecules
  - Fatty acids: long chains of carbon atoms surrounded by hydrogen atoms
- 1 glycerol molecule
  - Glycerol: a 1-carbon alcohol that is the backbone of a triglyceride

Triglycerides

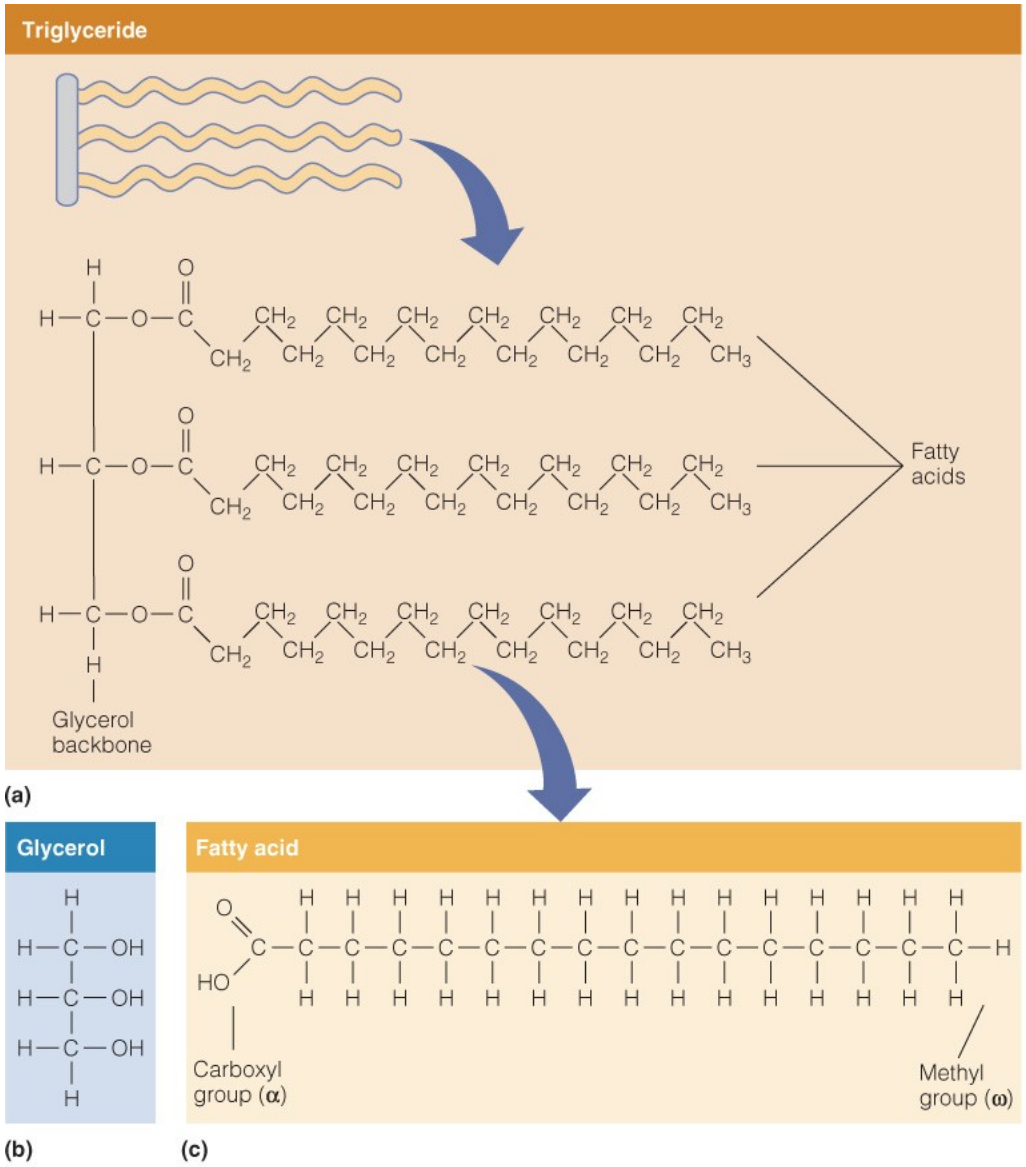


Figure 5.1 **(a)** A triglyceride consists of three fatty acids attached to a three-carbon glycerol backbone. **(b)** Structure of glycerol. **(c)** Structure of a fatty acid showing the carboxyl carbon (α) and the methyl carbon (ω) ends.

Source: (Thompson, Janice; Manore, Melinda; Vaughan, Linda, The Science of Nutrition, 2nd Ed., ©2011. Reprinted and Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.)

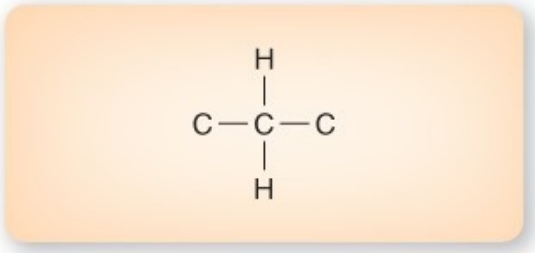
Figure 5.1

Triglycerides

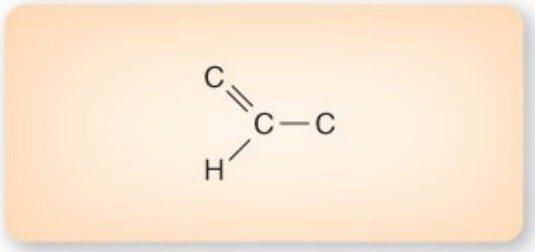
Fatty acids can differ in

- Length of their carbon chain
  - Short (<6), medium (6–12), or long (>14)
- Level of saturation
  - Saturation refers to how many hydrogen atoms surround each carbon
- Shape

Fatty Acids



(a) Saturated fatty acid



(b) Unsaturated fatty acid

Figure 5.2 An atom of carbon has four attachment sites. In fatty acid chains, two of these sites are filled by adjacent carbon atoms. **(a)** In saturated fatty acids, the other two sites are always filled by two hydrogen atoms. **(b)** In unsaturated fatty acids, at one or more points along the chain, a double bond to an adjacent carbon atom takes up one of the attachment sites that would otherwise be filled by hydrogen.

Figure 5.2

Triglycerides

Saturated fatty acids have hydrogen atoms surrounding every carbon in the chain; they have no double bonds

Monounsaturated fatty acids lack hydrogen atoms in one region; they have one double bond

Polyunsaturated fatty acids lack hydrogen atoms in multiple locations; they have two or more double bonds

Note: Each double bond causes the loss of two hydrogen atoms

Triglycerides

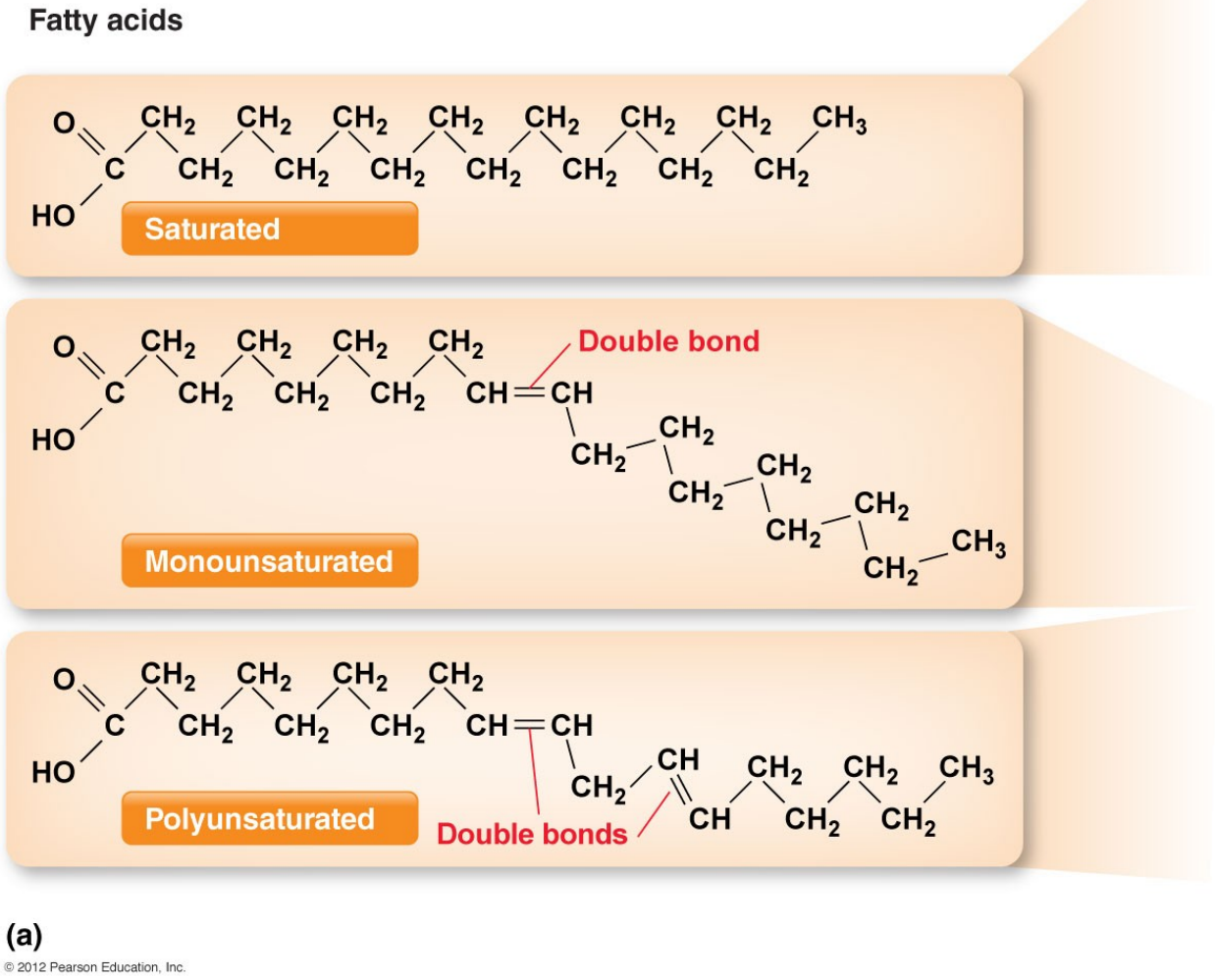
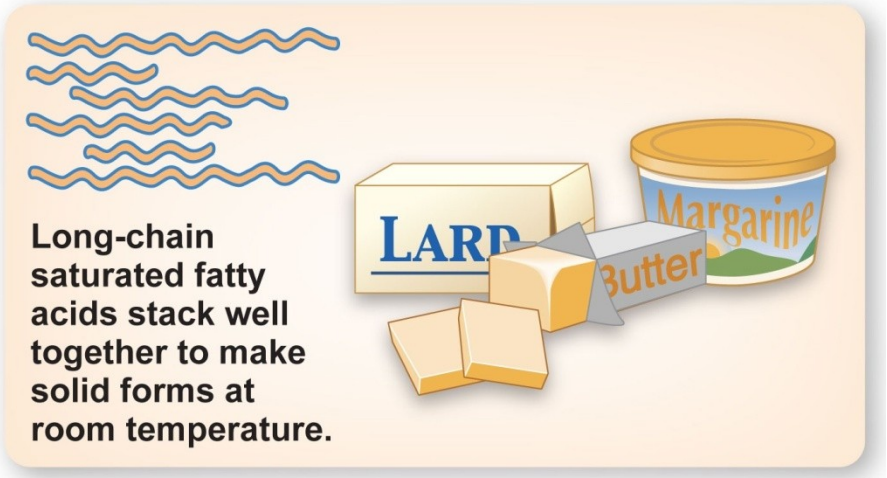


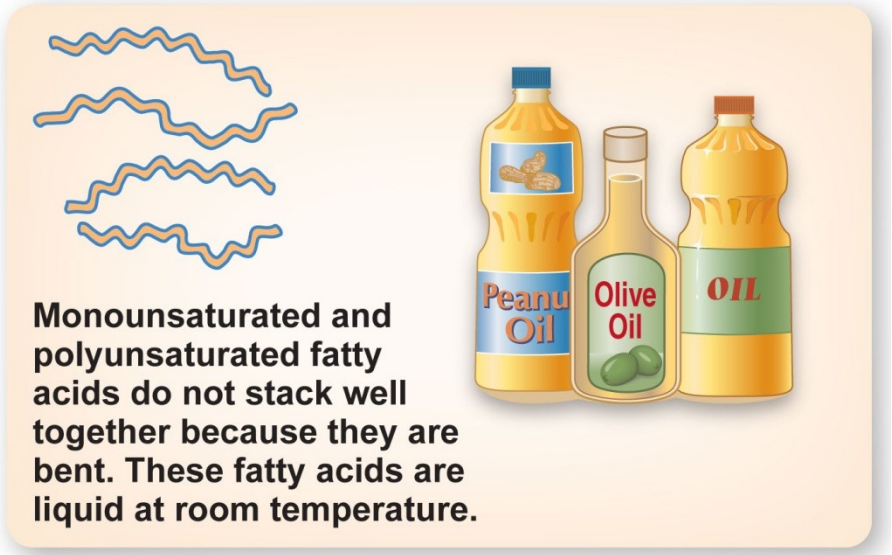
Figure 5.3a

Triglycerides



(b)

Figure 5.3 b



(c)

Figure 5.3 c

Major Sources of Dietary Fat

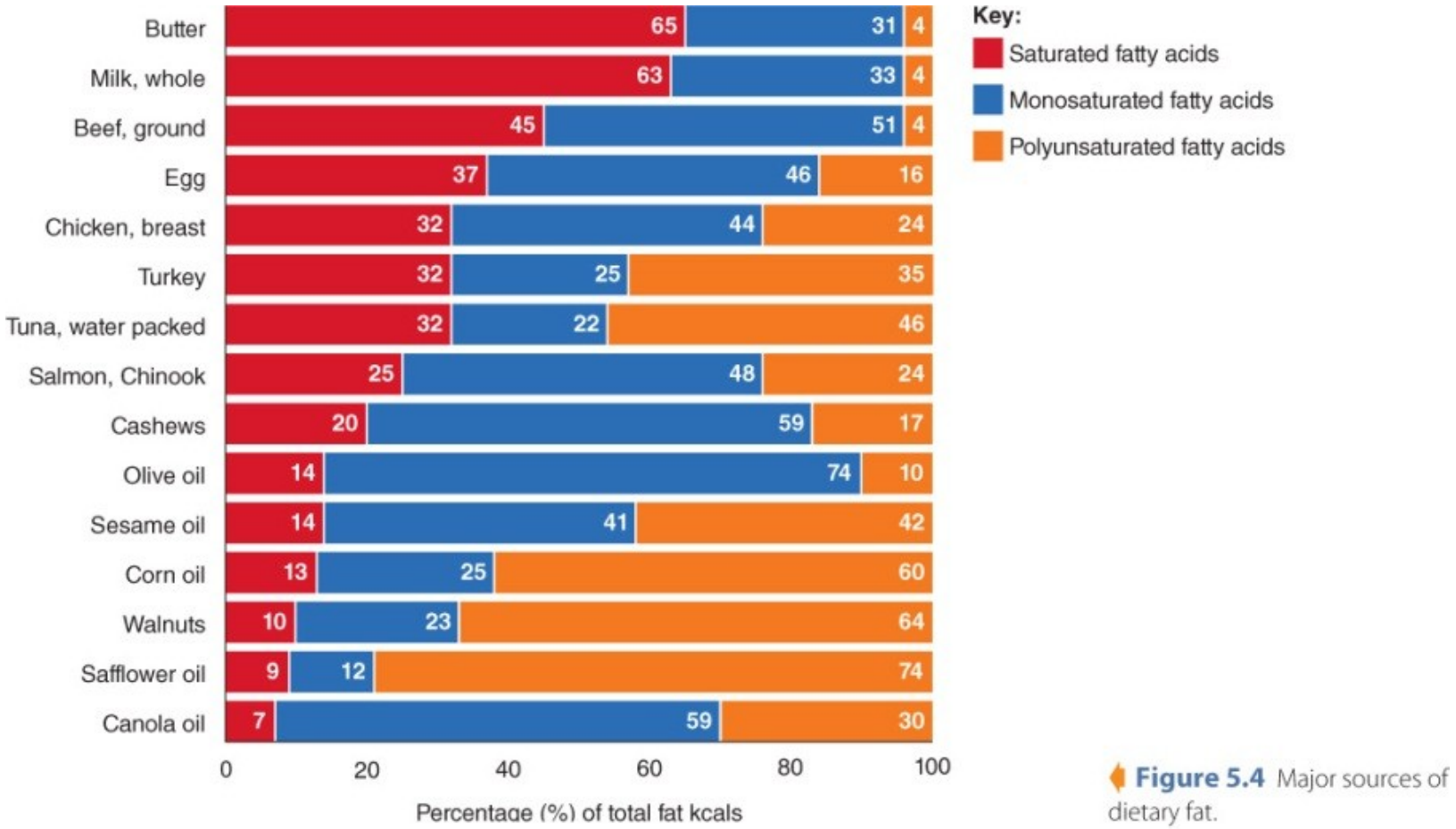


Figure 5.4 Major sources of dietary fat.

Figure 5.4

Triglycerides

The shape of a triglyceride is determined by the saturation of the carbon chains

Saturated fatty acids can pack tightly together and are solid at room temperature

- e.g., coconut oil, animal fats, butter, and lard are high in saturated fatty acids

Triglycerides

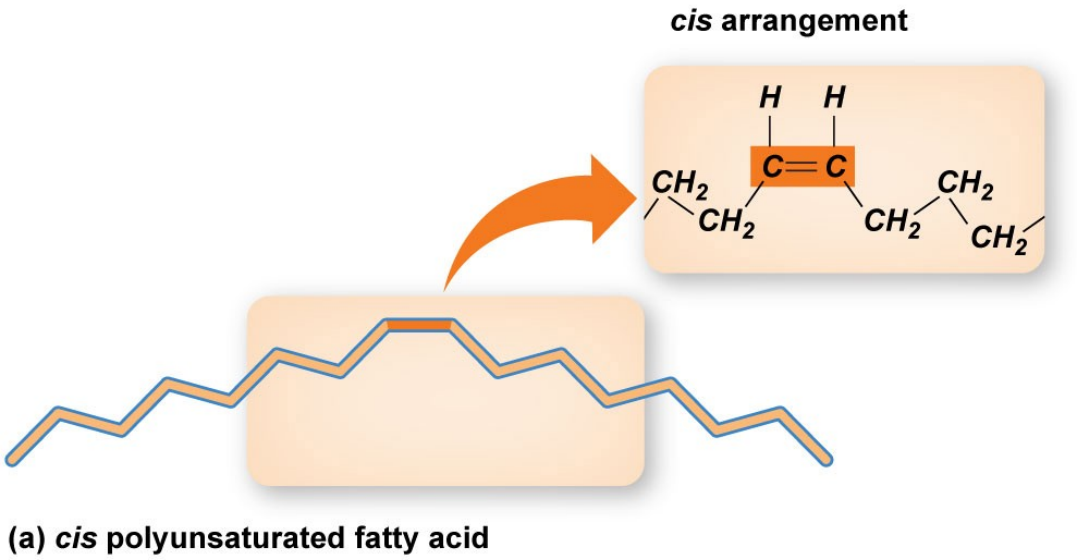
Unsaturated fatty acids do not stack together well and are liquid at room temperature

- Unsaturated fatty acids are the predominant type in plants
- 2 exceptions are coconut and palm kernel oil

The hydrogen atoms at the unsaturated region can be arranged in different positions

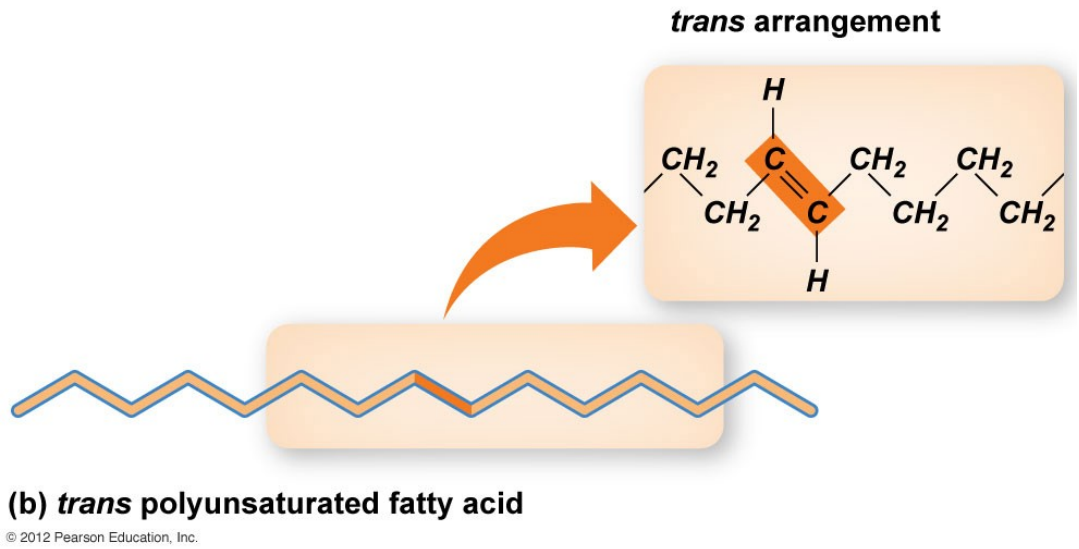
- *Cis:* same side of the carbon chain
- *Trans:* opposite sides of the chain

Triglycerides



(a) *cis* polyunsaturated fatty acid

Figure 5.5 a



(b) *trans* polyunsaturated fatty acid

Figure 5.5 b

Triglycerides

Hydrogenation: the addition of hydrogen atoms to unsaturated fatty acids

- Converts liquid fats (oils) into a semisolid (spreadable) or solid form
- Used to create margarine from plant oil
- Often creates *trans* fatty acids
- Listed on the food label as partially hydrogenated oil

Trans Fats

- Collective term to define fats with *trans* double bonds
- Some *trans* fatty acids are naturally found in cow's milk, beef, and lamb, BUT the majority of *trans* fatty acids are produced by manipulating the fatty acids during food processing
- The 2 types of *trans* fats have very different effects on cardiovascular health

Triglycerides and Health

Saturated and industrial *trans* fats are harmful to health and appear to change cell membrane function

- Saturated and *trans* fats lower “good” cholesterol and raise the “bad” cholesterol
- As of January 2006, *trans* fat content is required on the food label

Triglycerides and Health

BUT, naturally occurring *trans* fats may actually be good for the heart, and may behave more like polyunsaturated fats than saturated fats

Phospholipids

Phospholipids

- Composed of
  - Glycerol backbone
  - 2 fatty acids
  - Phosphate
- Soluble in water
- Manufactured in our bodies so they are not required in our diet
- Important components of cell membranes

Phospholipids

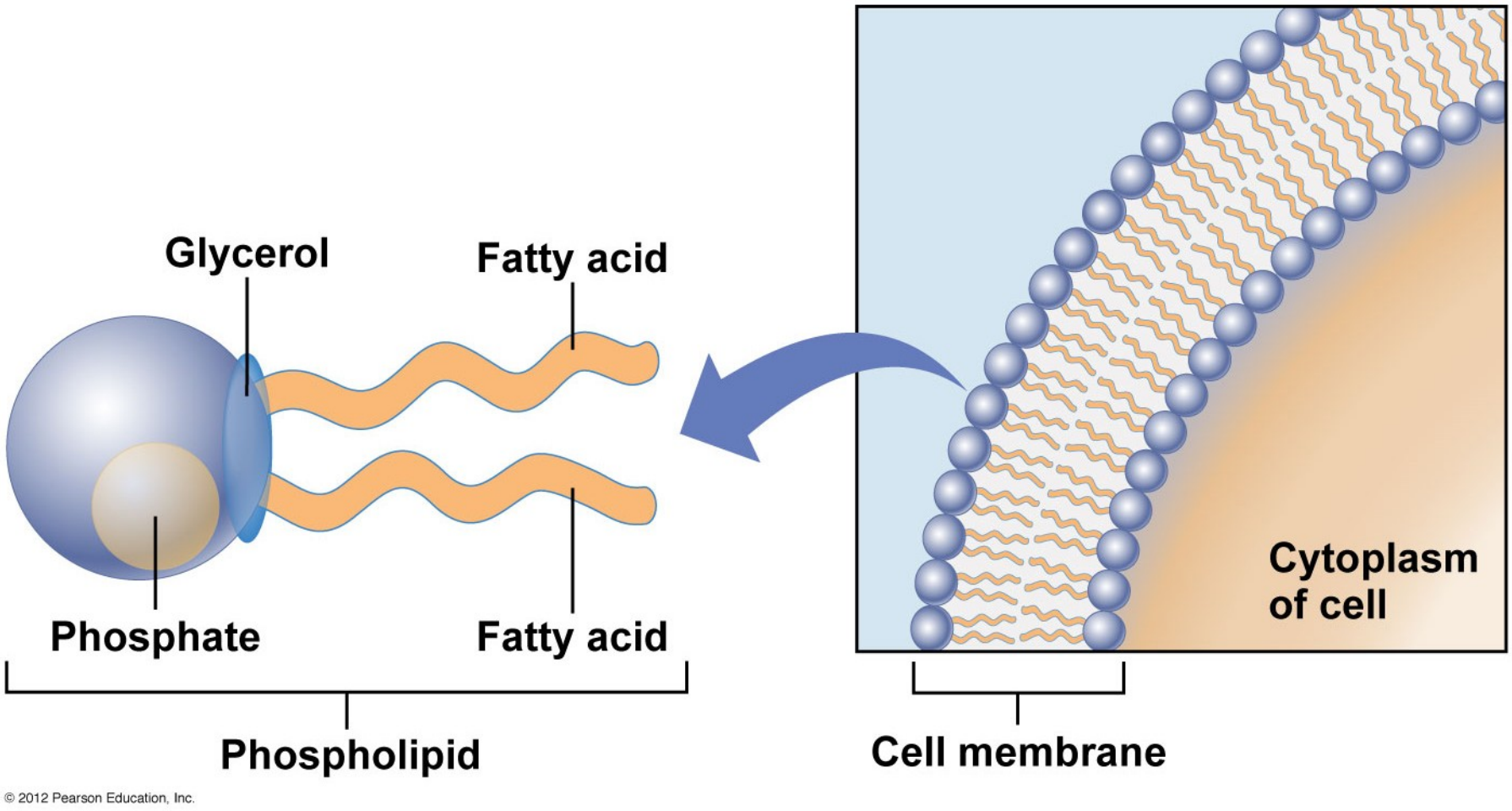


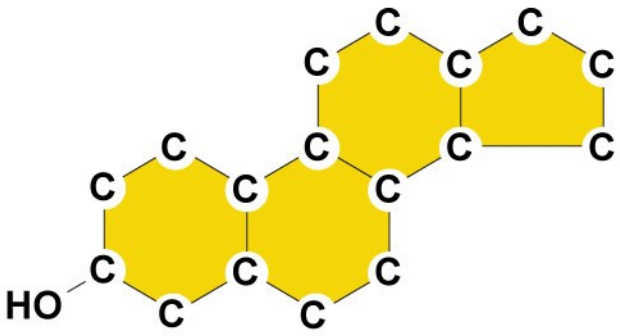
Figure 5.6

Sterols

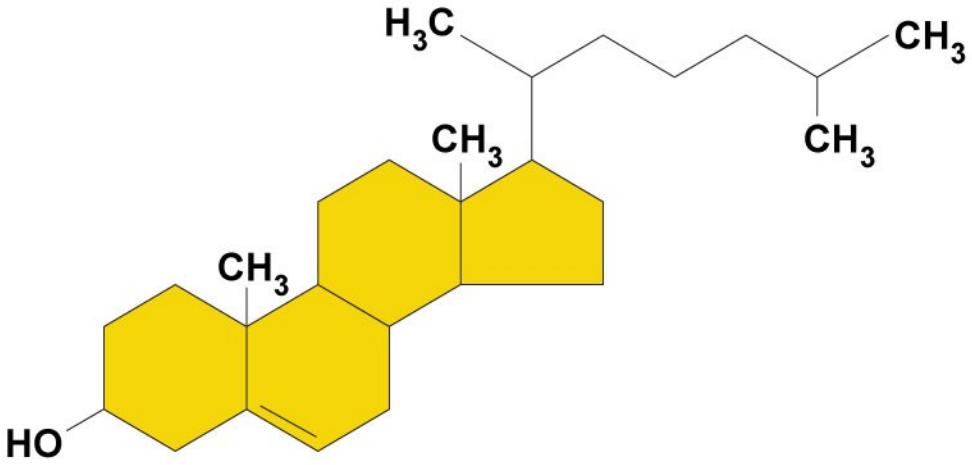
Sterols: lipids containing multiple rings of carbon atoms

- Essential components of cell membranes and many hormones
- Manufactured in our bodies and therefore are not essential components of our diet
- Cholesterol is the major sterol found in the body

Sterols



(a) Sterol ring structure



(b) Cholesterol

Figure 5.7

How Does Our Body Break Down Fats?

Lipids are not digested and absorbed easily because they are insoluble in water

No digestion of lipids occurs in the watery environments of the mouth or stomach

Digestion of lipids begins in the small intestine

Digestion of Fats

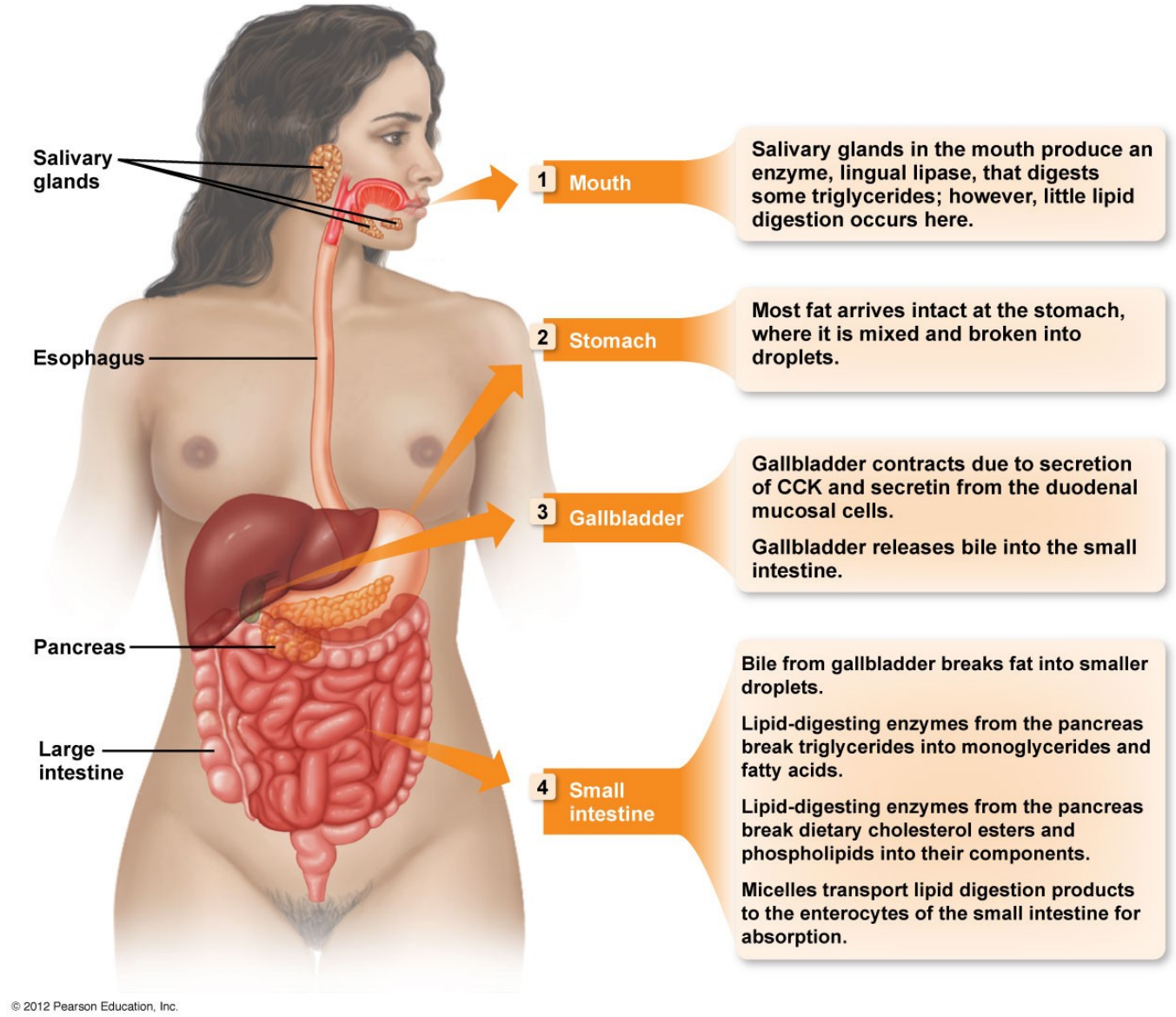


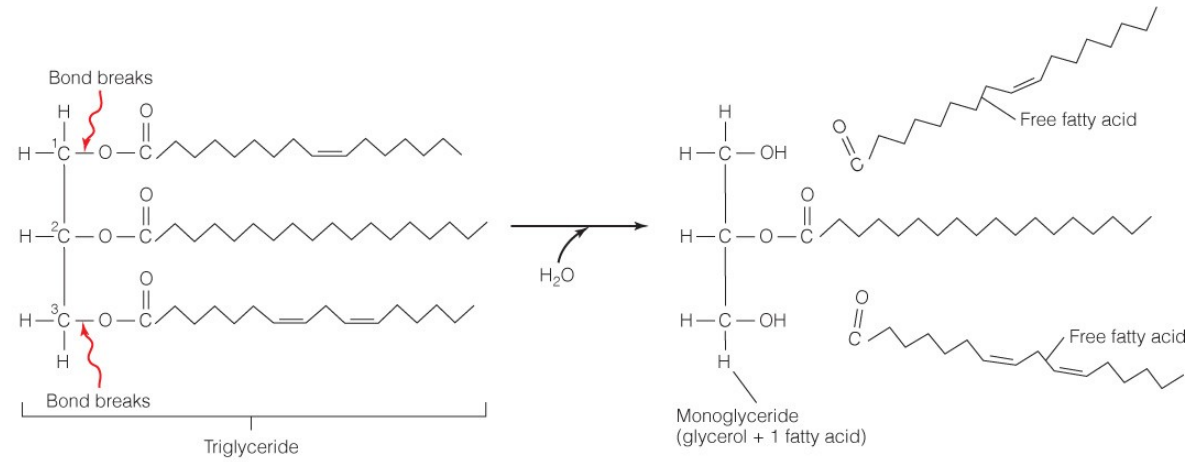
Figure 5.8

Digestion of Fats

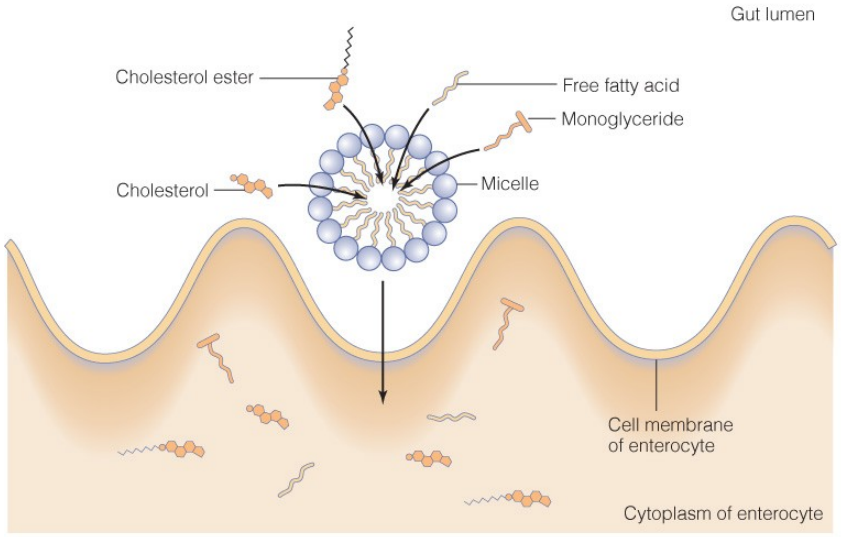
As fat enters the small intestine:

- Bile is secreted from the gall bladder into the small intestine
- Bile is produced by the liver and stored in the gall bladder
- Bile disperses fat into smaller fat droplets
- Pancreatic enzymes break triglycerides into 2 separate fatty acids and a monoglyceride
- Fat enters the mucosal cell as a micelle (fatty acids, monoglycerides, phospholipids, and sterols)

Digestion of Fats



(a) Triglyceride digestion



(b) Micelle transport into enterocyte

Figure 5.9 Lipid digestion and absorption. **(a)** in the presence of enzymes, triglycerides are broken down into fatty acids and monoglycerides. **(b)** These products, along with free cholesterol and other products, are trapped in the micelle, a spherical compound made up of bile salts and phospholipids. The micelle then transports these lipid digestion products to the intestinal mucosal cell, and these products are then absorbed into the cell.

Figure 5.9 a, b

Digestion of Fats

In the intestinal mucosal cell:

- Fatty acids are reattached to the monoglyceride to re-form triglycerides
- A small amount of protein is added to the lipids, forming a chylomicron
- Chylomicron: a lipoprotein produced by cells lining the small intestine
  - Composed of triglycerides surrounded by phospholipids and proteins
  - Soluble in water

Structure of a Lipoprotein

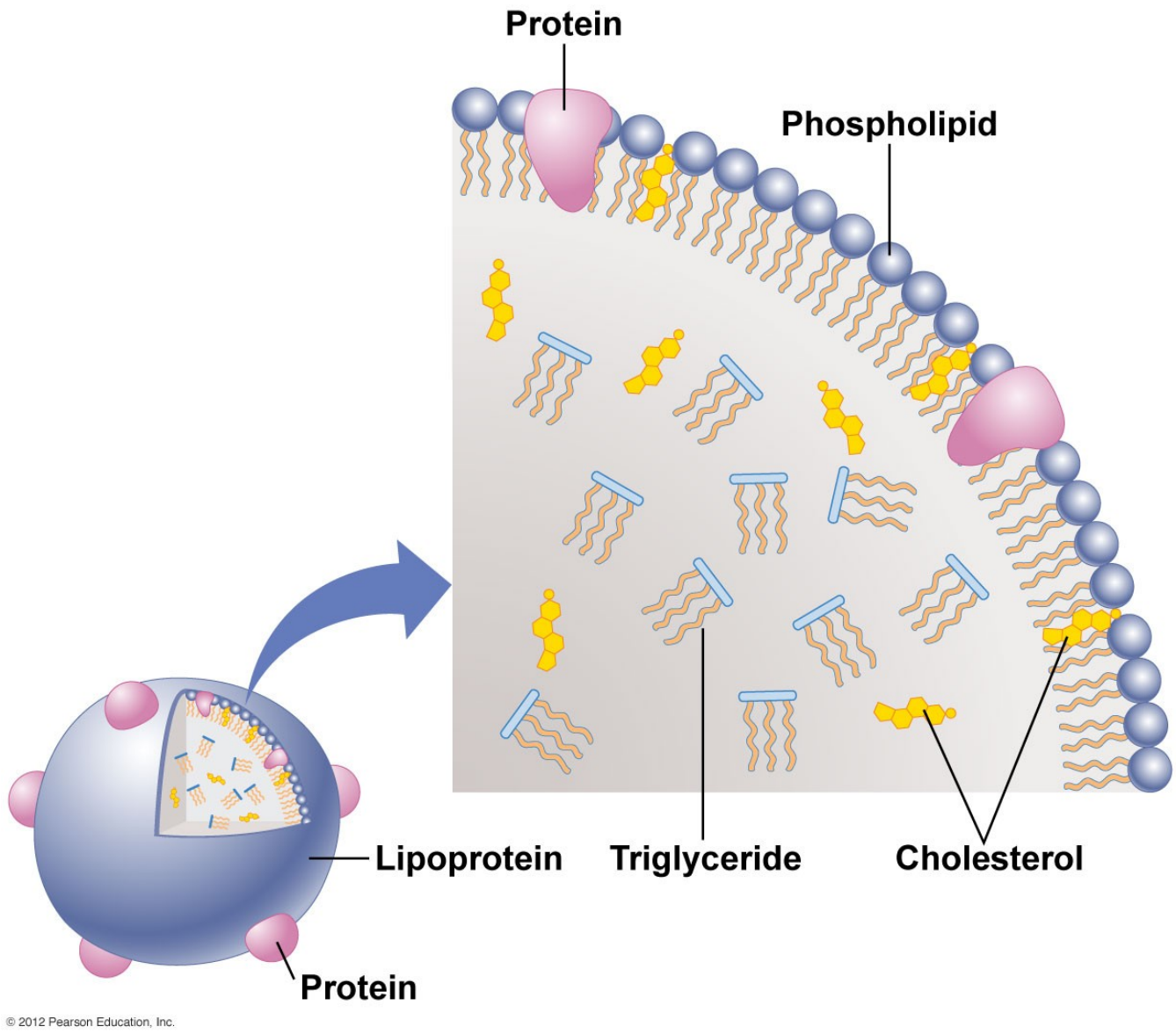


Figure 5.10

Digestion of Fats

Chylomicrons are the transport vehicles that remove absorbed fats from the small intestine

- Travel through the lymphatic system
- Are transferred to the bloodstream

Short- and medium-chain fatty acids are absorbed more quickly because they are not arranged into chylomicrons

Digestion of Fats

- Once the chylomicron gets to a cell in the body, the triglycerides in the chylomicrons must be disassembled by lipoprotein lipase into 2 fatty acids and a monoglyceride before they can pass through the cell membrane
- After entering the cell, the 2 fatty acids and monoglyceride re-form a triglyceride
- The triglyceride can be
  - Used immediately for energy
  - Used to make lipid-containing compounds
  - Stored in liver and muscle cells

The Role of Fat

Energy

- Fat is very energy dense, containing 37 kJ/(9 kcal)/gram
- Much of the energy used during rest comes from fat
- Fat is used for energy during exercise, especially after glycogen is depleted
- Fat is also used for energy storage

The Role of Fat

Fat-soluble vitamins

- Vitamins A, D, E, and K are soluble in fat; fat is required for their transport

Fat is essential to many body functions

- Cell membrane structure
- Nerve cell transmissions
- Protection of internal organs
- Insulation to retain body heat

The Role of Fat

Fat provides flavour and texture to foods

Fat contributes to making us feel satiated because

- Fats are more energy dense than carbohydrates or protein
- Fats take longer to digest

Fats Contain Essential Fatty Acids

Essential fatty acids

- 2 fatty acids cannot be synthesized in the body and must be obtained in the diet

Linoleic and alpha-linolenic acid are essential (required in the diet) fatty acids; they are converted into important regulatory compounds in the body

Fats Contain Essential Fatty Acids

Linoleic acid (omega-6 fatty acid)

- Found in vegetable and nut oils
- Converted by the body to arachidonic acid, which is involved in blood clotting and blood pressure

Fats Contain Essential Fatty Acids

Alpha-linolenic acid (omega-3 fatty acid)

- Found in dark green leafy vegetables, fish and fish oils, and flax and flaxseed oil
- Converted to EPA and DHA, which are important regulators of inflammation, blood clotting, and blood pressure

Fats Contain Essential Fatty Acids

Figure 5.14 The two essential fatty acids: linoleic acid, an omega-6 fatty acid with 18 carbons and two double bonds, C18:2n-6, and alpha-linolenic acid, an omega-3 fatty acid with 18 carbons and three double bonds, C18:3n-3.

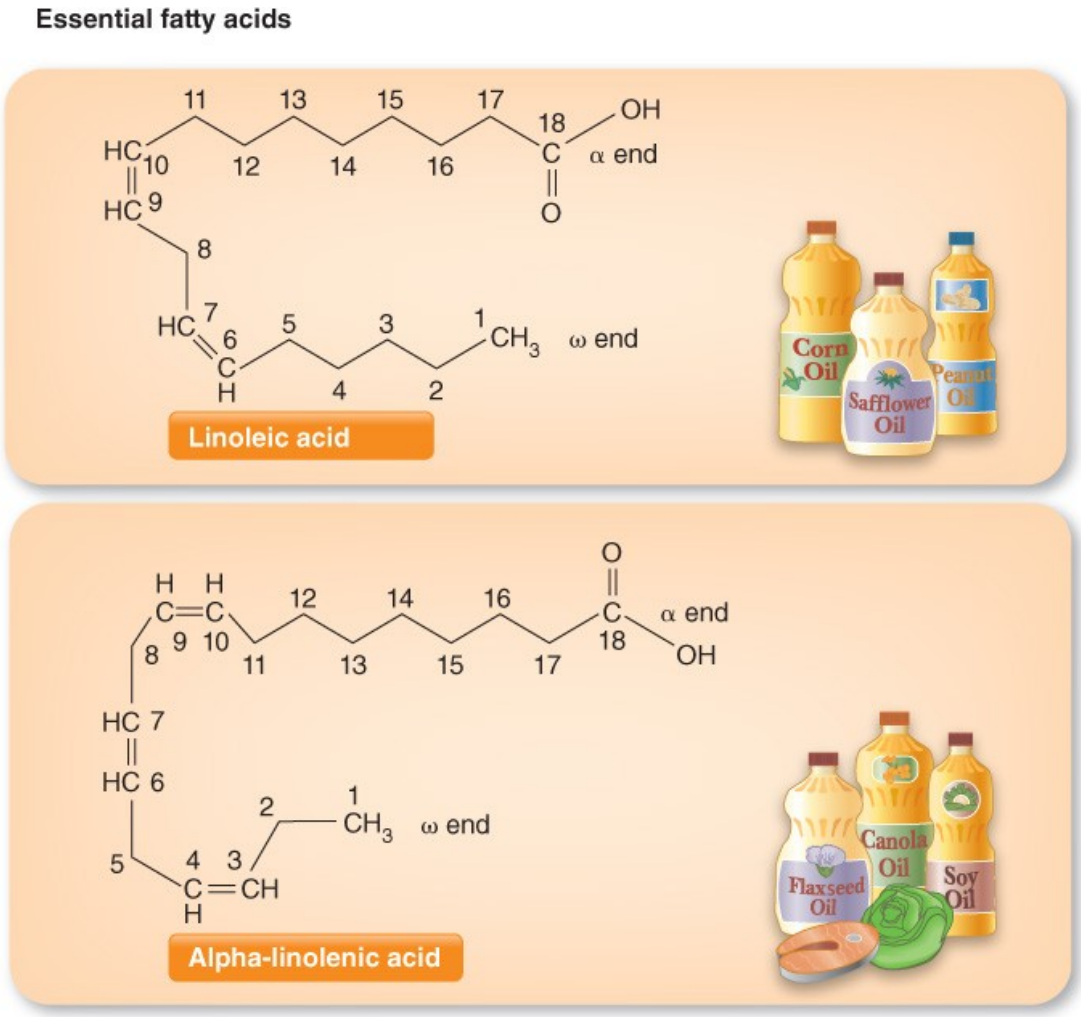


Figure 5.14

How Much Fat Should We Eat?

The AMDR for fat

20%–35% of calories should be from fat

Athletes and highly active people may need more energy from carbohydrates and can reduce their fat intake to 20%–25% of total calories

Current Advice: Limit Saturated Fatty Acids and *Trans* Fats

- New research suggests natural *trans* fats may actually protect against CVD

- Not all saturated fatty acids behave in the same way

- Now there is strong evidence that saturated fats have NO significant relationship to CVD (2010)

What is the Role of Saturated Fat in Cardiovascular Disease?

- The effect of lowering saturated fatty acid intakes may depend upon what replaces the saturated fat

- The relationship between saturated fatty acids and CVD varies, depending upon how CVD is measured

What is the Role of Saturated Fat in Cardiovascular Disease?

What Does This Mean?

- Advice to eat less saturated fatty acid to lower the risk of CVD may be too simplistic

- More research is needed to understand what happens when saturated fatty acids are replaced with monounsaturated fatty acids, polyunsaturated fatty acids, and carbohydrates

Avoid Industrial *Trans* Fatty Acids

- Many health professionals feel diets high in *trans* fatty acids increase the risk of heart disease even more than diets high in saturated fat (2009)

- Health Canada requires food manufacturers to list the amount of *trans* fatty acids/serving on the Nutrition Facts table

- Globally, legislators and food policy experts are lobbying for the labelling of *trans* fatty acids on menus and/or the elimination of industrial *trans* fatty acids from restaurants and other ready-to-eat foods

Recognize the Fat in Foods

- Visible fats are those we can see in foods or can easily see have been added to foods, such as dressing, chicken skin, and so on

- Hidden fats are those added to processed or prepared foods to improve texture or taste, which we may not be aware of, or that occur naturally

Select Beneficial Fats

- Switch to healthful fats without increasing total fat intake
- Increase intake of omega-3 fatty acids (see Table 5.2, next slide)
- Healthful fats include essential fatty acids, but also polyunsaturated and monounsaturated fats in general

Select Beneficial Fats

TABLE 5.2 Omega-3 Fatty Acid Content of Selected Foods

Food Item	Total Omega-3	DHA	EPA*
	g/serving		
Flaxseed oil, 15 mL (1 Tbsp)	7.25	0.00	0.00
Salmon oil (fish oil), 15 mL (1 Tbsp)	4.39	2.48	1.77
Sardine oil, 15 mL (1 Tbsp)	3.01	1.45	1.38
Flaxseed, whole, 15 mL (1 Tbsp)	2.50	0.00	0.00
Herring, Atlantic, broiled, 90 g (3 oz.)	1.83	0.94	0.77
Anchovies w/oil, each	1.76	0.65	1.10
Herring oil, 15 mL (1 Tbsp)	1.53	0.57	0.85
Salmon, Coho, steamed, 90 g (3 oz.)	1.34	0.71	0.46
Canola oil, 15 mL (1 Tbsp)	1.28	0.00	0.00
Sardines, Atlantic, w/ bones and oil, 90 g (3 oz.)	1.26	0.43	0.40
Trout, rainbow fillet, baked, 90 g (3 oz.)	1.05	0.70	0.28
Walnuts, English, 15 mL (1 Tbsp)	0.66	0.00	0.00
Halibut, fillet, baked, 90 g (3 oz.)	0.53	0.31	0.21
Shrimp, canned, 90 g (3 oz.)	0.47	0.21	0.25
Tuna, white, in oil, 90 g (3 oz.)	0.38	0.19	0.04
Crab, Alaska King, steamed, 90 g (3 oz.)	0.36	0.10	0.25
Scallops, broiled, 90 g (3 oz.)	0.31	0.14	0.17
Tuna, light, in water, 90 g (3 oz.)	0.23	0.19	0.04
Avocado, Calif., fresh, whole	0.22	0.00	0.00
Spinach, cooked, 250 mL (1 cup)	0.17	0.00	0.00

Note: *EPA = eicosapentaenoic acid; DHA = docosahexaenoic acid.
Data from Food Processor SQL, Version 10.3, ESHA Research, Salem, OR.

Table 5.2

Select Beneficial Fats

DRI for Linoleic Acid

AI: 14 – 17 g/day for adult men

11 – 12 g/day for adult women

DRI for Alpha-Linoleic Acid

AI: 1.6 g/day for adult men

1.1 g/day for adult women

In Depth: Cardiovascular Disease

Cardiovascular disease

- Dysfunction of the heart or blood vessels
- Can result in heart attack or stroke

In Depth: Cardiovascular Disease

The 3 most common forms of cardiovascular disease are

- Coronary heart disease
- Stroke
- Hypertension

In Depth: Cardiovascular Disease

Atherosclerosis is a disease in which artery walls build up lipid deposits and scar tissue, impairing blood flow

The stiffness that results is commonly called “hardening of the arteries”

The result is that the heart must work harder to push blood through the vessels

In Depth: Cardiovascular Disease

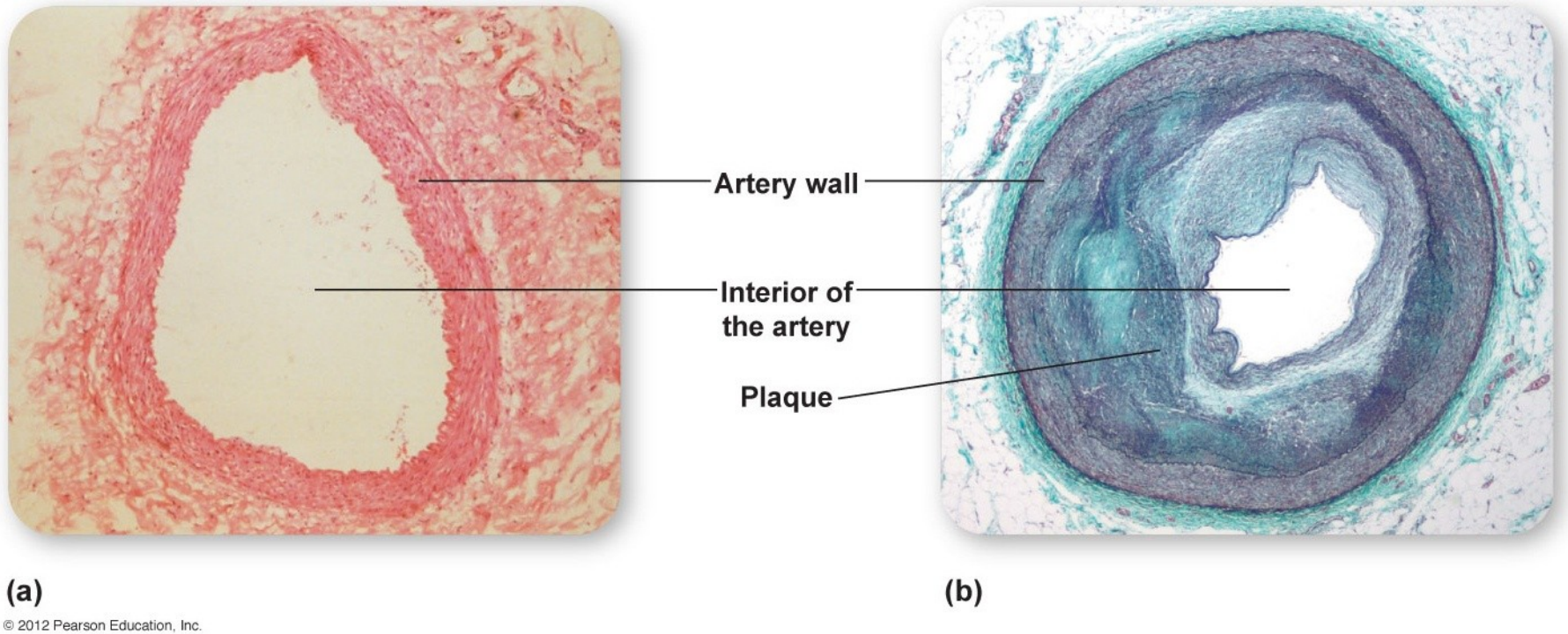


Figure 1 a In Depth

Figure 1 b In Depth

In Depth: Cardiovascular Disease

Hypertension is one of the major risk factors for heart disease and stroke

Approximately 1 in 5 Canadian adults have hypertension

It functions as a warning sign for a person’s risk for developing heart disease or stroke

For many people, hypertension is hereditary; for others, it can be induced through poor nutrition and exercise habits, or a combination of poor habits and heredity

In Depth: Cardiovascular Disease

Modifiable risk factors for cardiovascular disease include

- Being overweight
- Physical inactivity
- Smoking
- Diabetes
- Inflammation
- Abnormal blood lipids

In Depth: Cardiovascular Disease

The intake of certain types of fats can protect against heart disease

Diets high in omega-3 fatty acids (along with moderate exercise) can reduce inflammation and increase HDL (“good”) cholesterol levels

Low-density lipoproteins (LDLs) are often called “bad” cholesterol because of their role in transporting cholesterol throughout the body

The Chemical Components of Lipoproteins

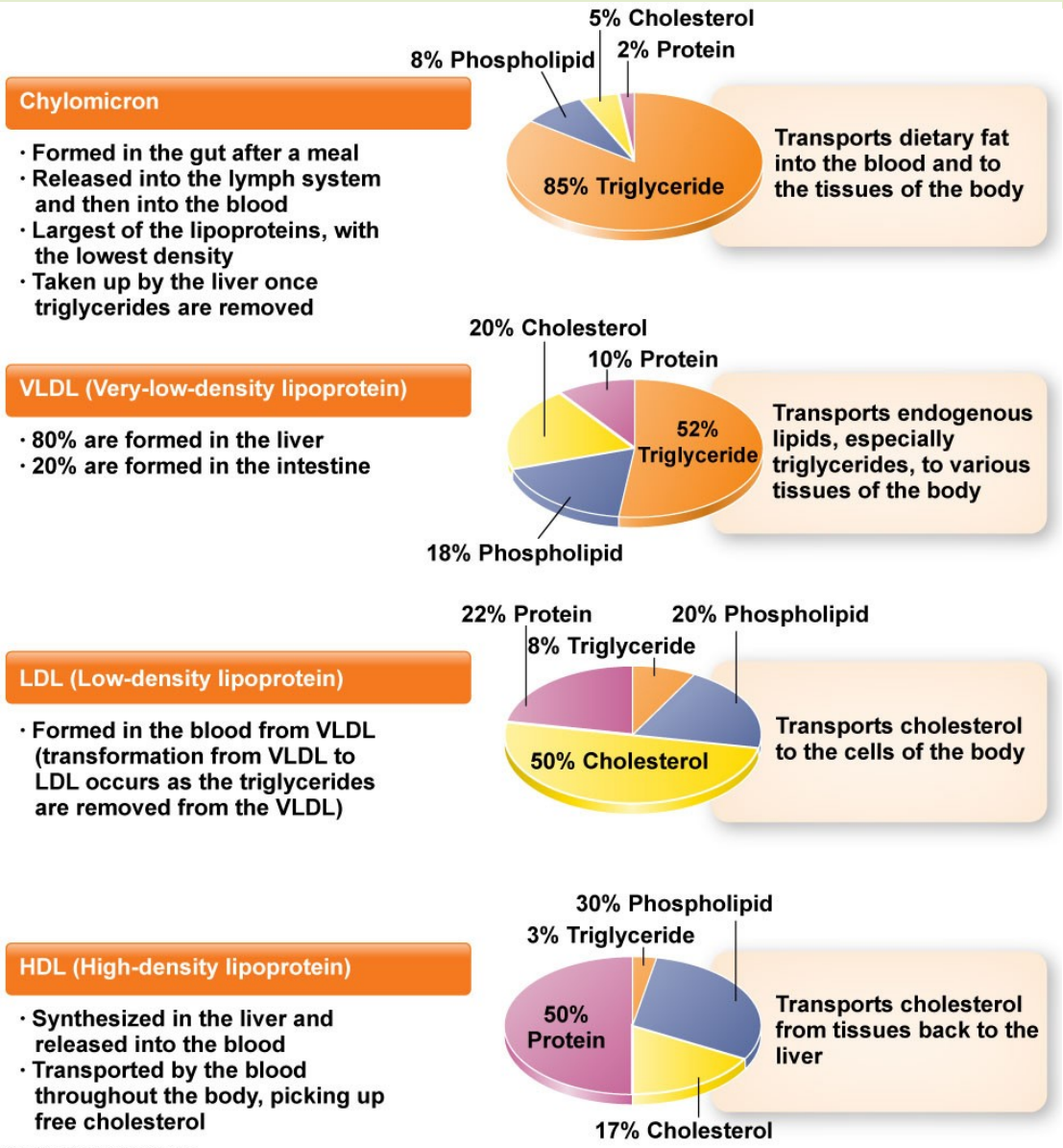


Figure 2 In Depth

Descriptions and Functions of Various Blood Lipoproteins

TABLE 1 Descriptions and Functions of the Various Blood Lipoproteins

Lipoprotein	Description	Primary Function
Chylomicrons	Formed in the gut after a meal, these lipoproteins are released into the lymph system and then into the blood Largest of the lipoproteins, with the lowest density After triglycerides are removed from this lipoprotein, a chylomicron remnant remains and is taken up by the liver	Transports dietary fat into the blood and transports it to the tissues of the body
Very low-density lipoproteins (VLDLs)	Formed in the liver (80% of production) and the intestine (20% of production)	Transports endogenous lipids, especially triglycerides, to the various tissues of the body
Low-density lipoproteins (LDLs)	Formed in the blood from VLDL Transformation from VLDL to LDL occurs as the triglycerides are removed from the VLDL	Transports cholesterol to the cells of the body
High-density lipoproteins (HDLs)	Synthesized in the liver and released into the blood Move in the blood through the body, picking up free cholesterol	Transports cholesterol from tissues back to the liver

Source: Based on information from Heart and Stroke Foundation of Canada, Living with Cholesterol: Cholesterol and Healthy Living; p. 183: Based on Heart and Stroke Foundation of Canada, Cholesterol Article Updates, Nov. 7, 2005. www. heartandstroke.ca.

Table 1 In Depth

In Depth: Cardiovascular Disease

Lifestyle changes to help prevent or

Control cardiovascular disease

- Don’t smoke
- Have a healthy diet
- Achieve and maintain a healthy body weight
- Participate in regular physical activity

In Depth: Cardiovascular Disease

Prescription medications can improve blood lipids and blood pressure

- for some individuals, lifestyle changes are not enough to control lipids
- a variety of medications can be prescribed
- however, individuals taking such medications should also continue to practice healthy lifestyle changes