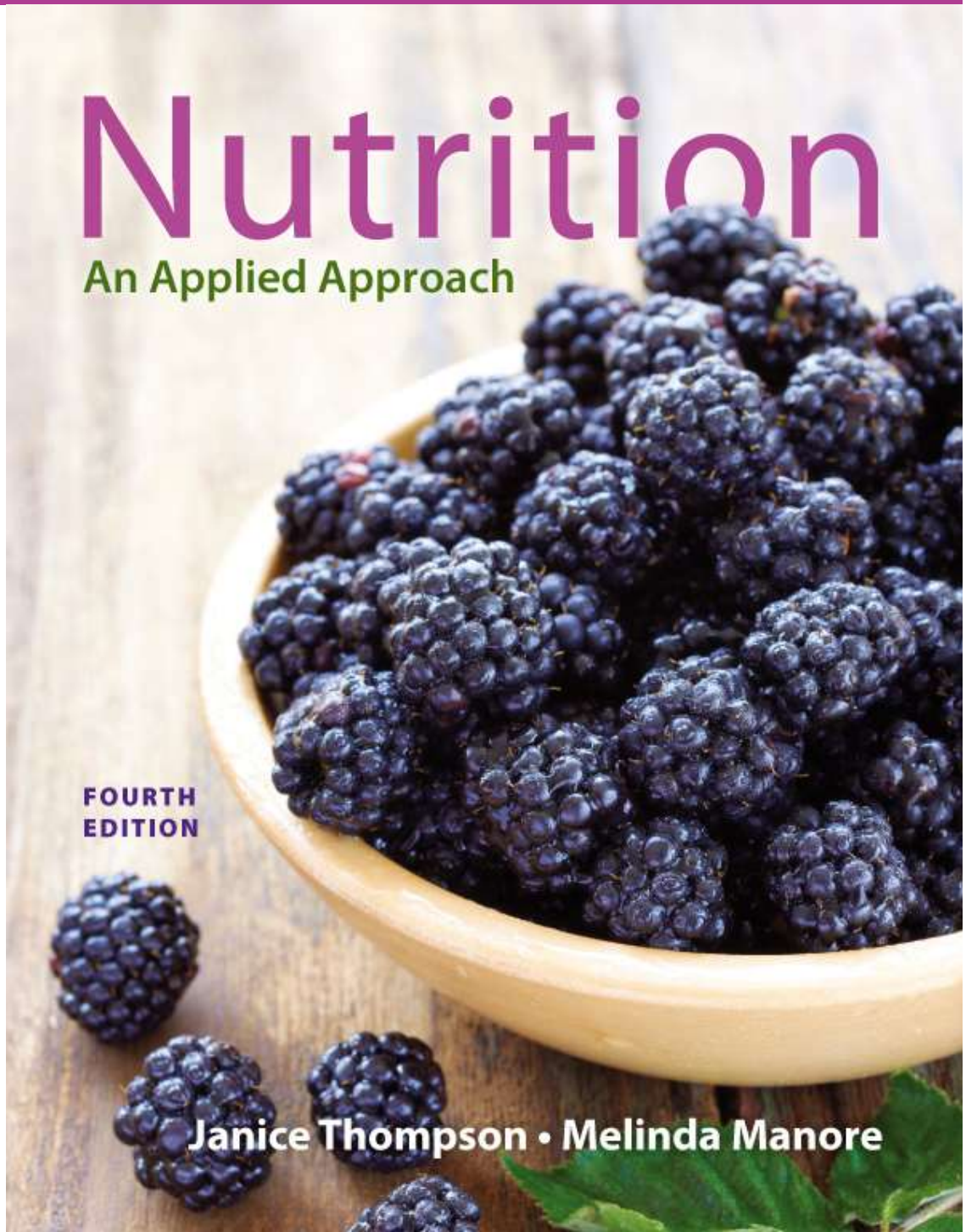
Chapter 5: Fats: Essential Energy-Supplying Nutrients, and In Depth 5.5, Cardiovascular Disease



What Are Fats?

- Fats are one type of lipid

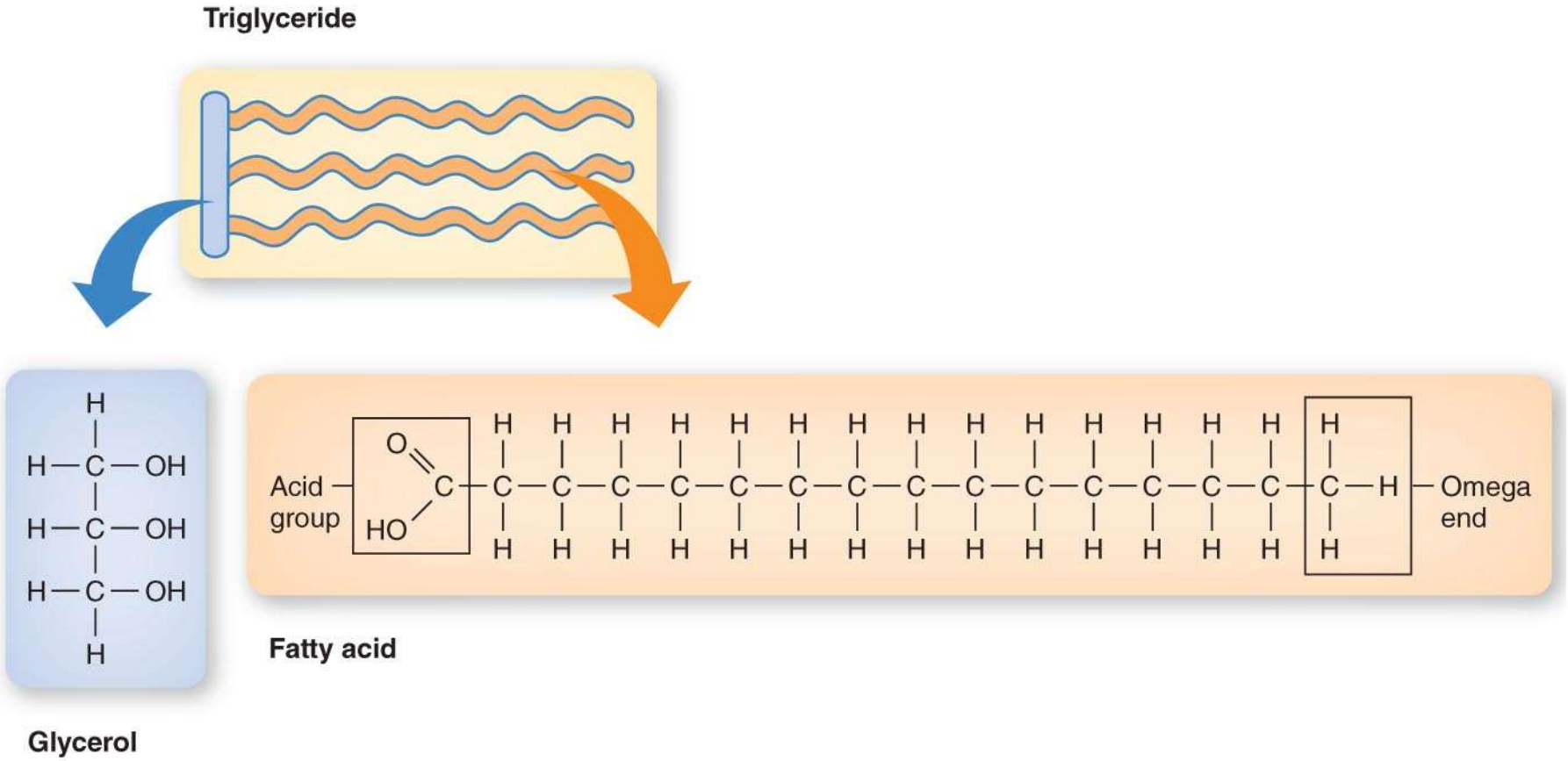
- Lipids: diverse class of organic substances that are insoluble in water
  - Lipids (fats) do not dissolve in water

Triglycerides

- Most of the fat we eat is in the form of triglycerides
  - About 95% of the fats we consume

- Triglycerides are composed of
  - Three fatty acid molecules
    - Fatty acids: long chains of carbon atoms surrounded by hydrogen atoms
  - One glycerol molecule
    - Glycerol: a three-carbon alcohol that is the backbone of a triglyceride

Triglycerides

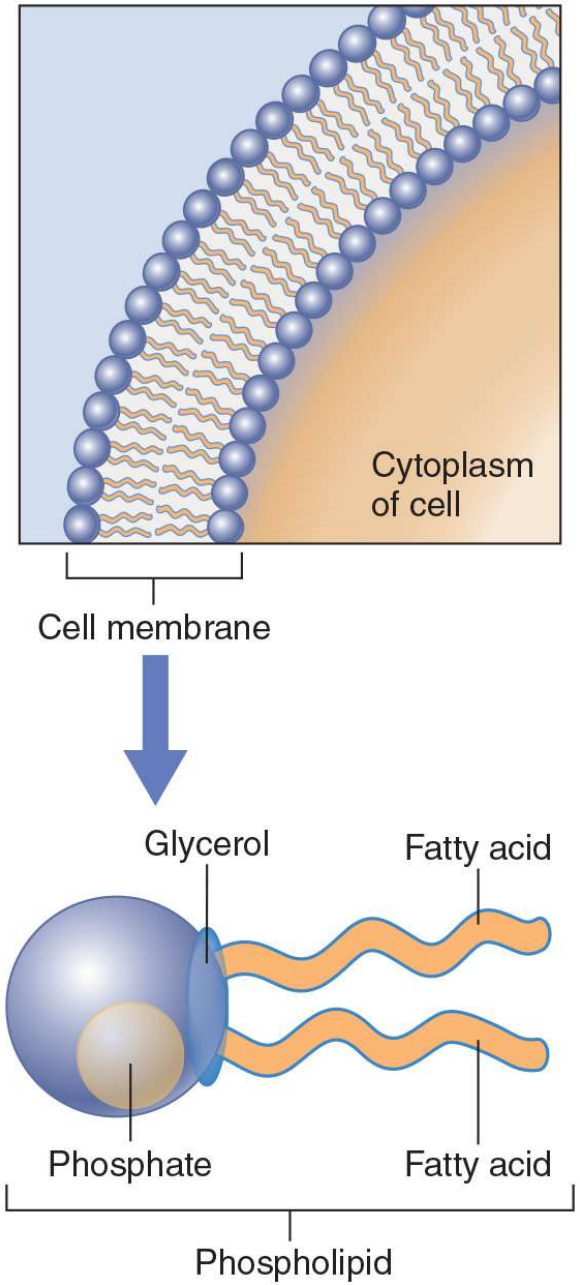


Phospholipids

Phospholipids

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

Phospholipids (cont.)

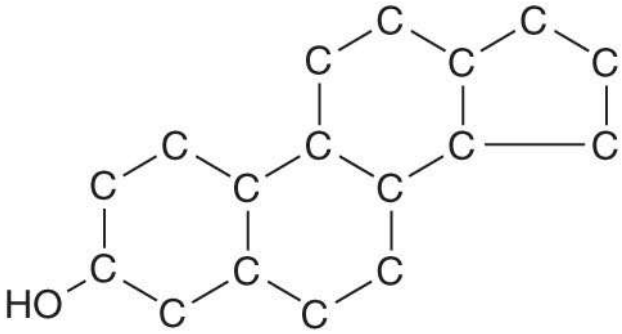


Sterols

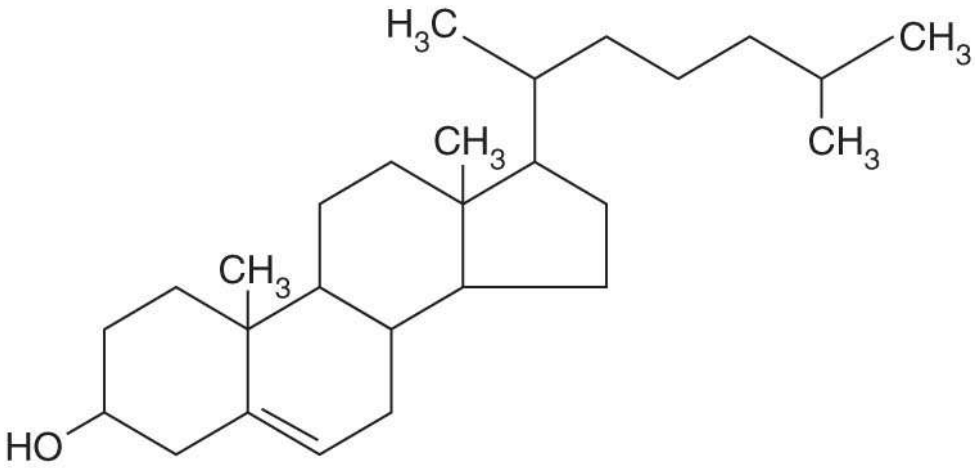
Sterols: lipids containing multiple rings of carbon atoms

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

Sterols



(a) Sterol ring structure



(b) Cholesterol

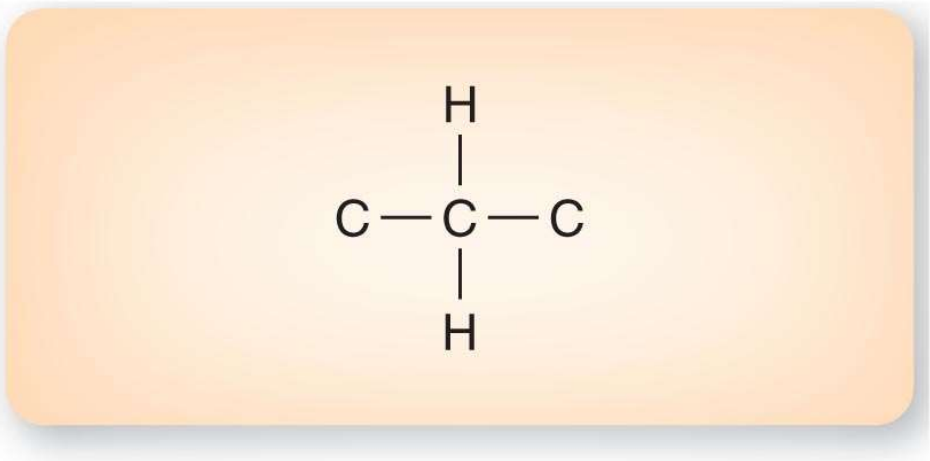
Triglycerides

- Fatty acids can differ in
  - Length of their carbon chain
    - Short (<6 carbons), medium (6–12 carbons), or long (>13 carbons)
  - Level of saturation
    - Saturation refers to how many hydrogen atoms surround each carbon
  - Shape

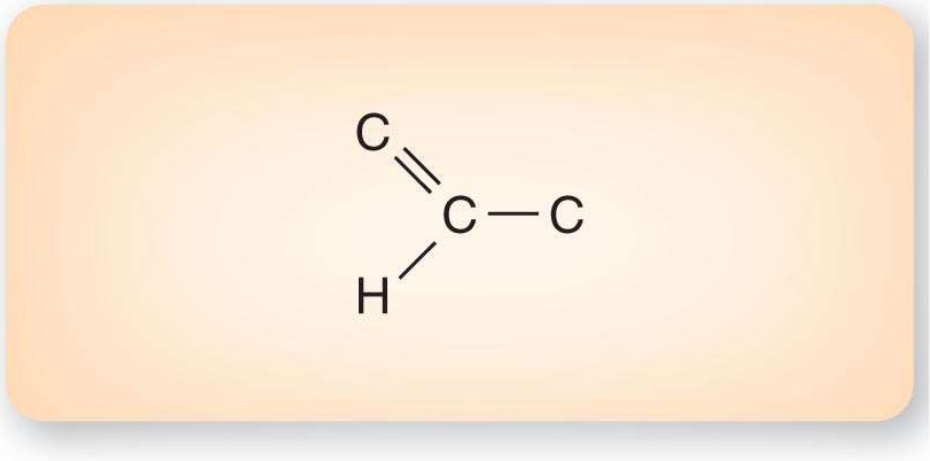
Triglycerides (cont.)

- 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

Saturated and Unsaturated Fatty Acids

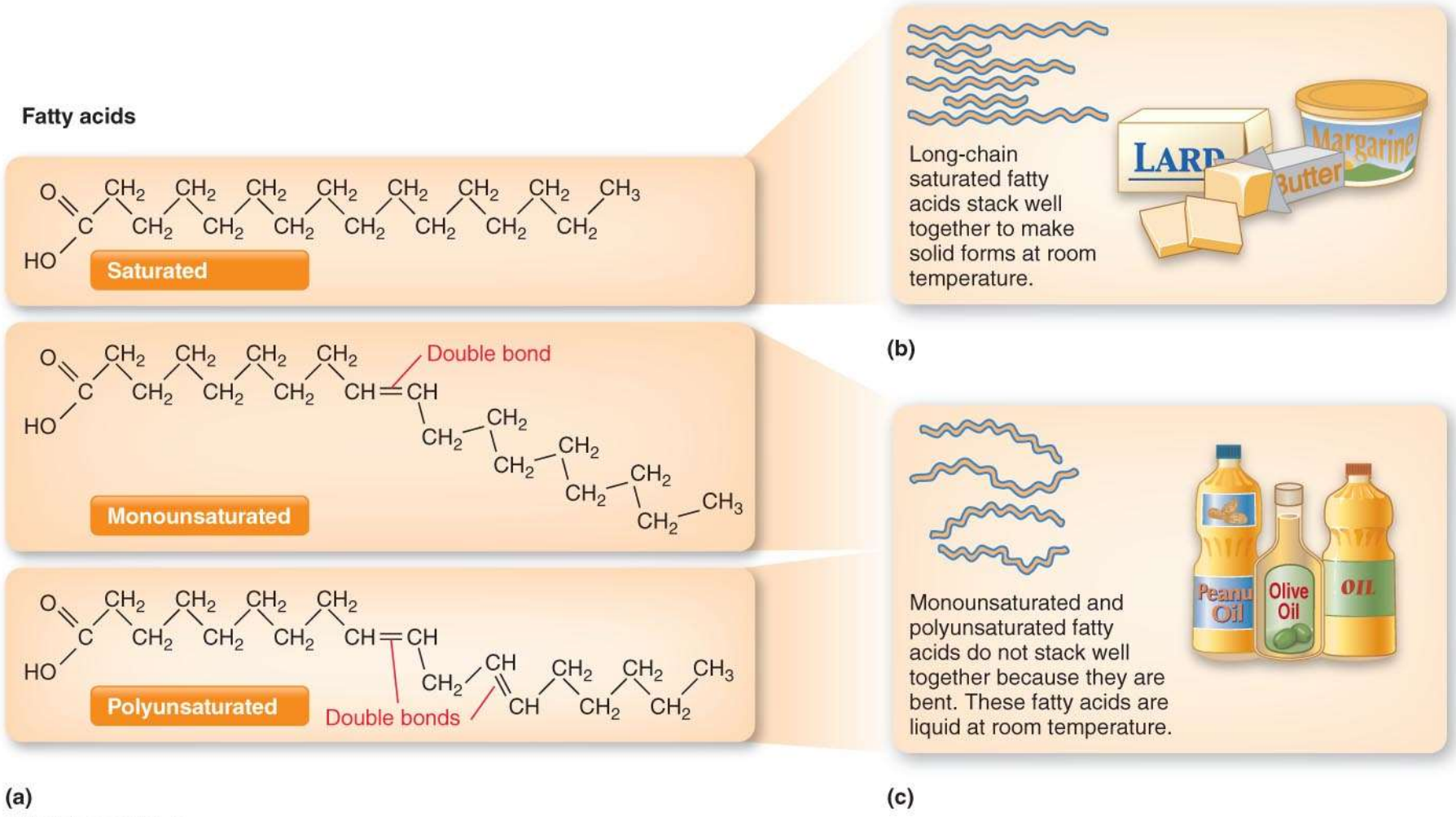


(a) Saturated fatty acid

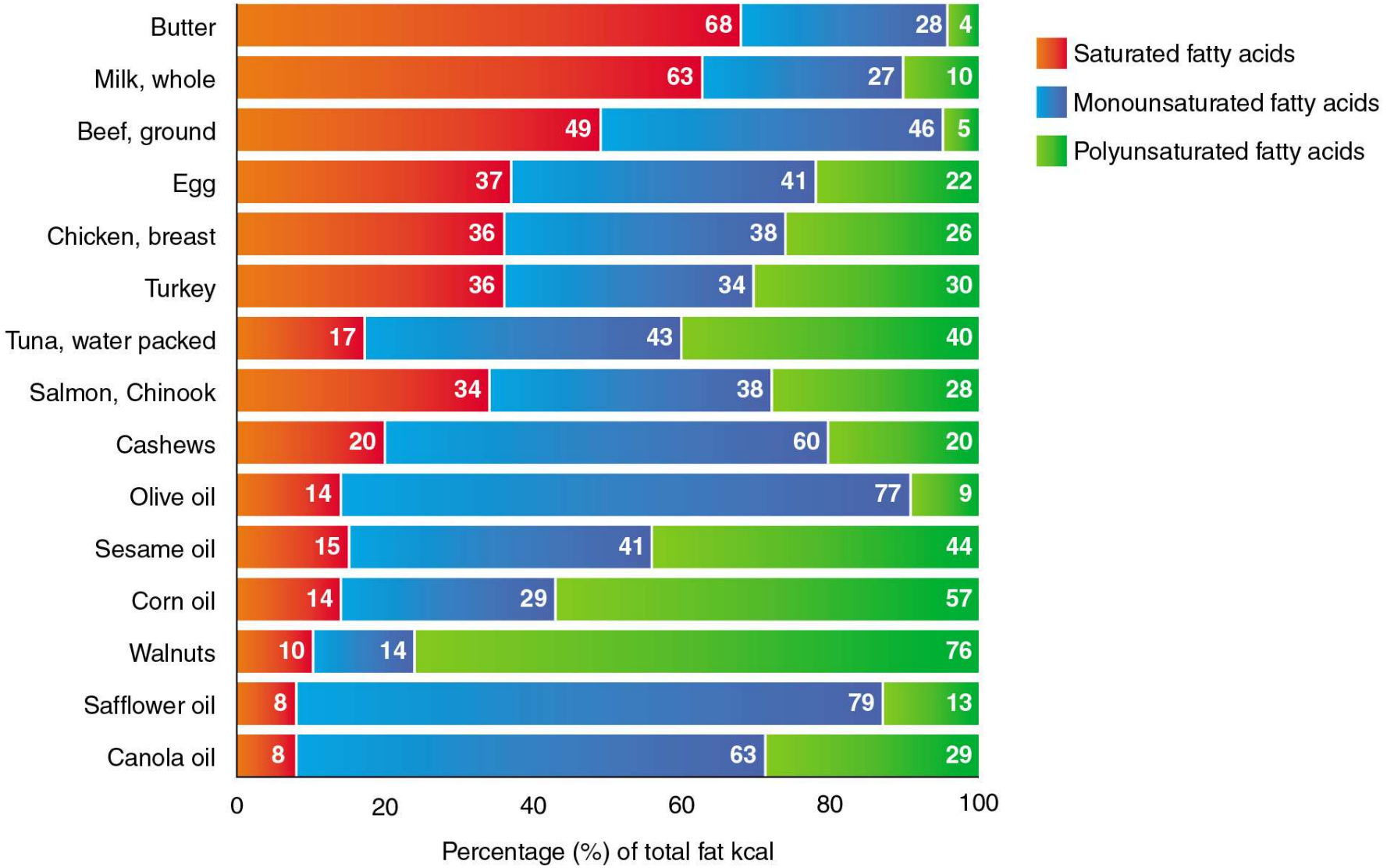


(b) Unsaturated fatty acid

Levels of Saturation Among Fatty Acids



Major Sources of Dietary Fat



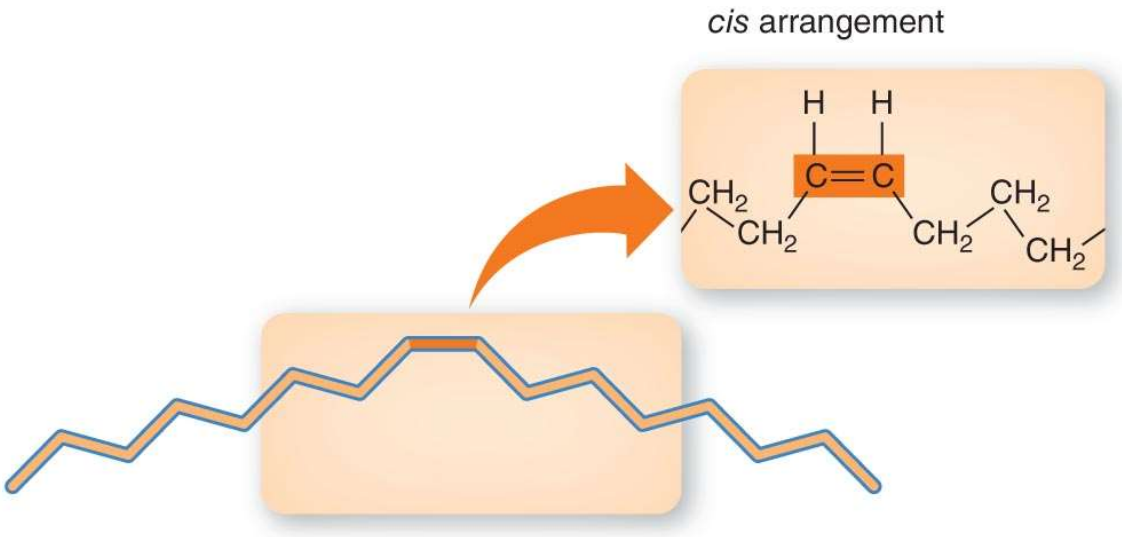
Triglycerides

- 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
  - For example, coconut oil, animal fats, butter, and lard are high in saturated fatty acids

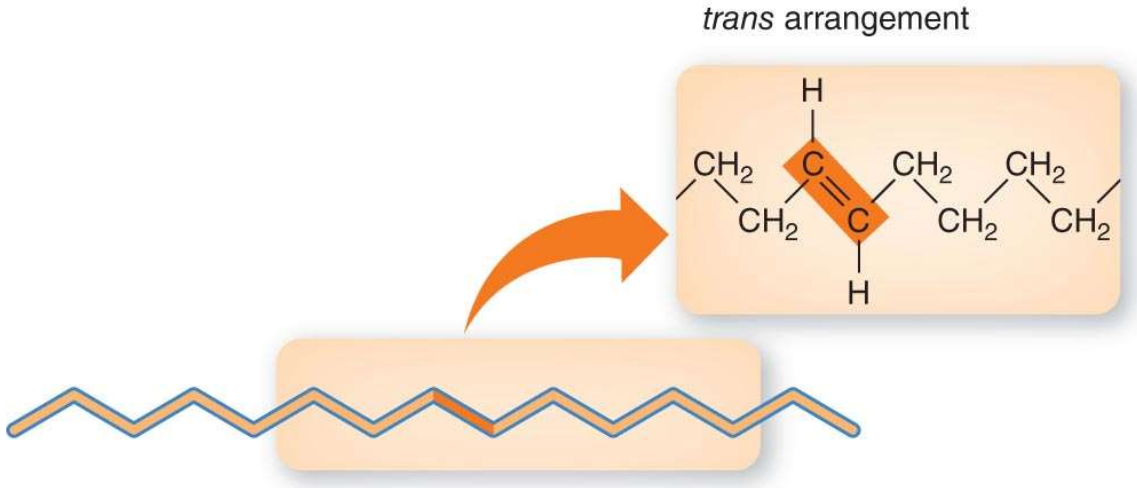
Triglycerides (cont.)

- Unsaturated fatty acids do not stack together well and are liquid at room temperature
  - Unsaturated fatty acids are the predominant type in plants
  - Two 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 carbon chain

Cis and *Trans* Polyunsaturated Fatty Acids



(a) *cis* polyunsaturated fatty acid



(b) *trans* polyunsaturated fatty acid

Triglycerides (cont.)

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 food labels as partially hydrogenated oil

Essential Fatty Acids

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

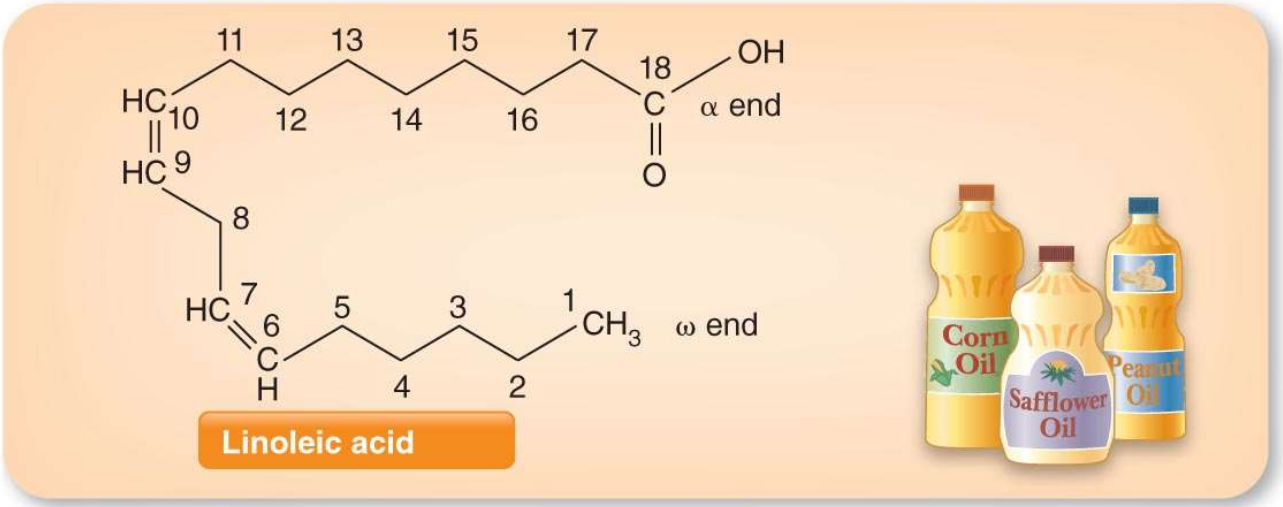
- Omega-6 and omega-3 fatty acids
- They are precursors to biological compounds called *eicosanoids,* which regulate cellular function

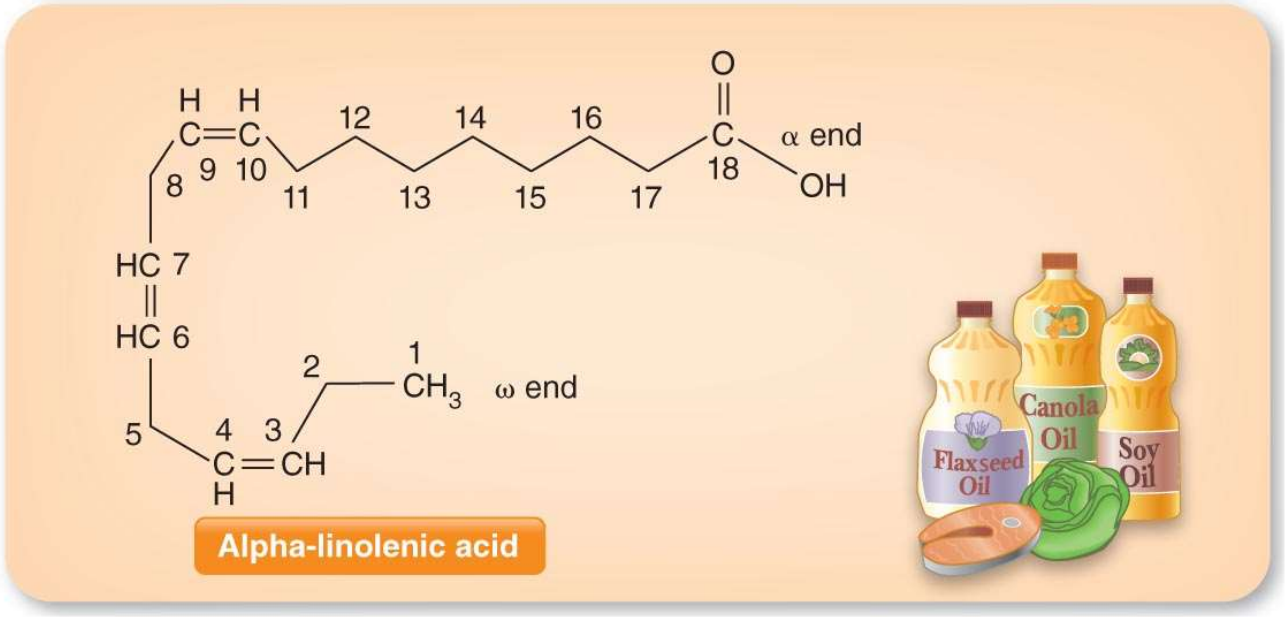
Essential Fatty Acids (cont.)

- Linoleic acid is found in vegetable and nut oils
- Alpha-linolenic acid (ALA) is derived from dark-green leafy vegetables, flaxseeds and flaxseed oil, soybeans and soybean oil, walnuts and walnut oil, and canola oil
- Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have important health benefits and are found in fish, shellfish, and fish oils

Essential Fatty Acids

Essential fatty acids



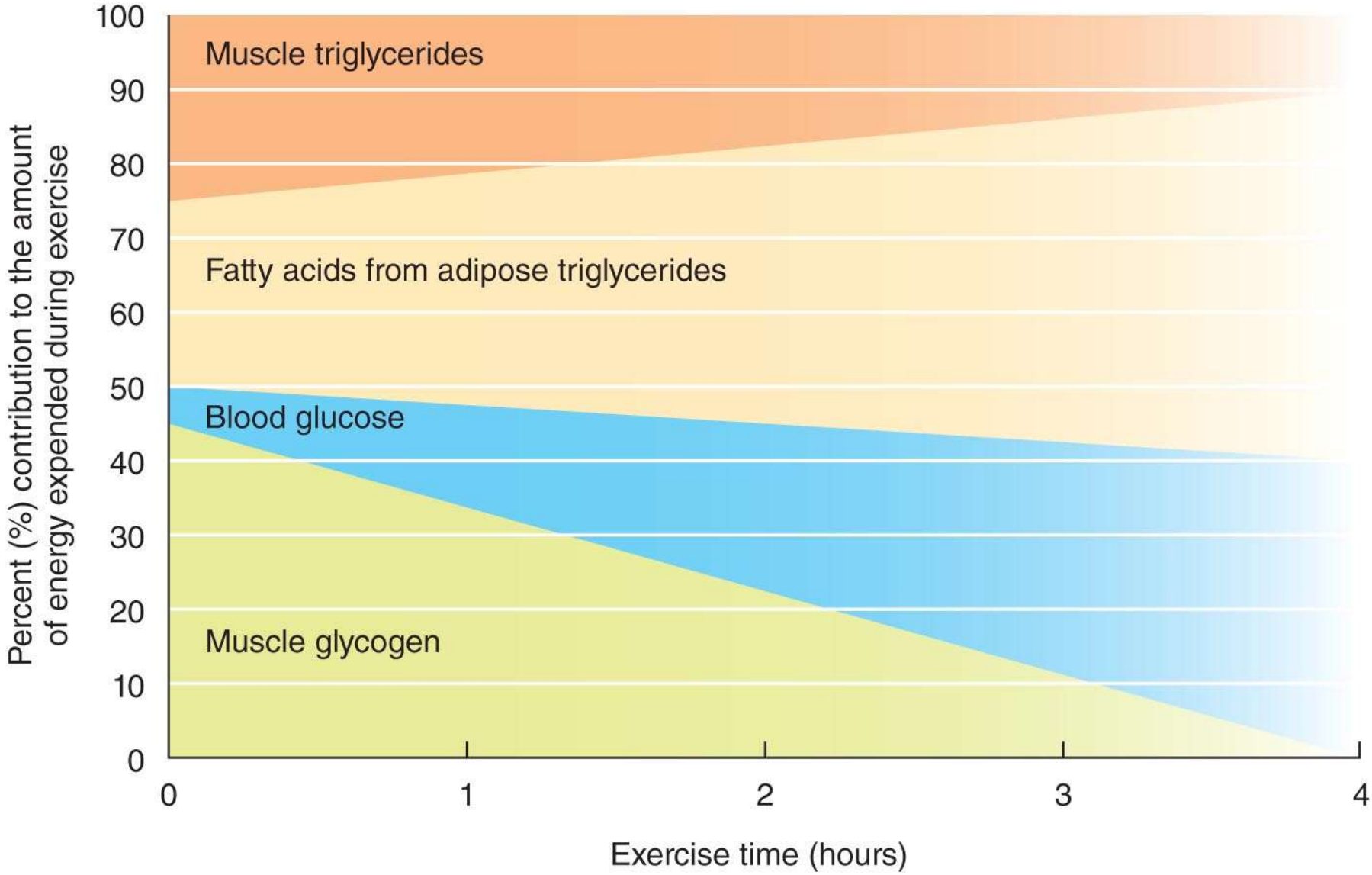


Why Do We Need Fats?

Energy

- Fat is very energy dense, providing 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

Fat Is Used for Energy During Exercise



Why Do We Need Fats?

- 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

Why Do We Need Fats? (cont.)

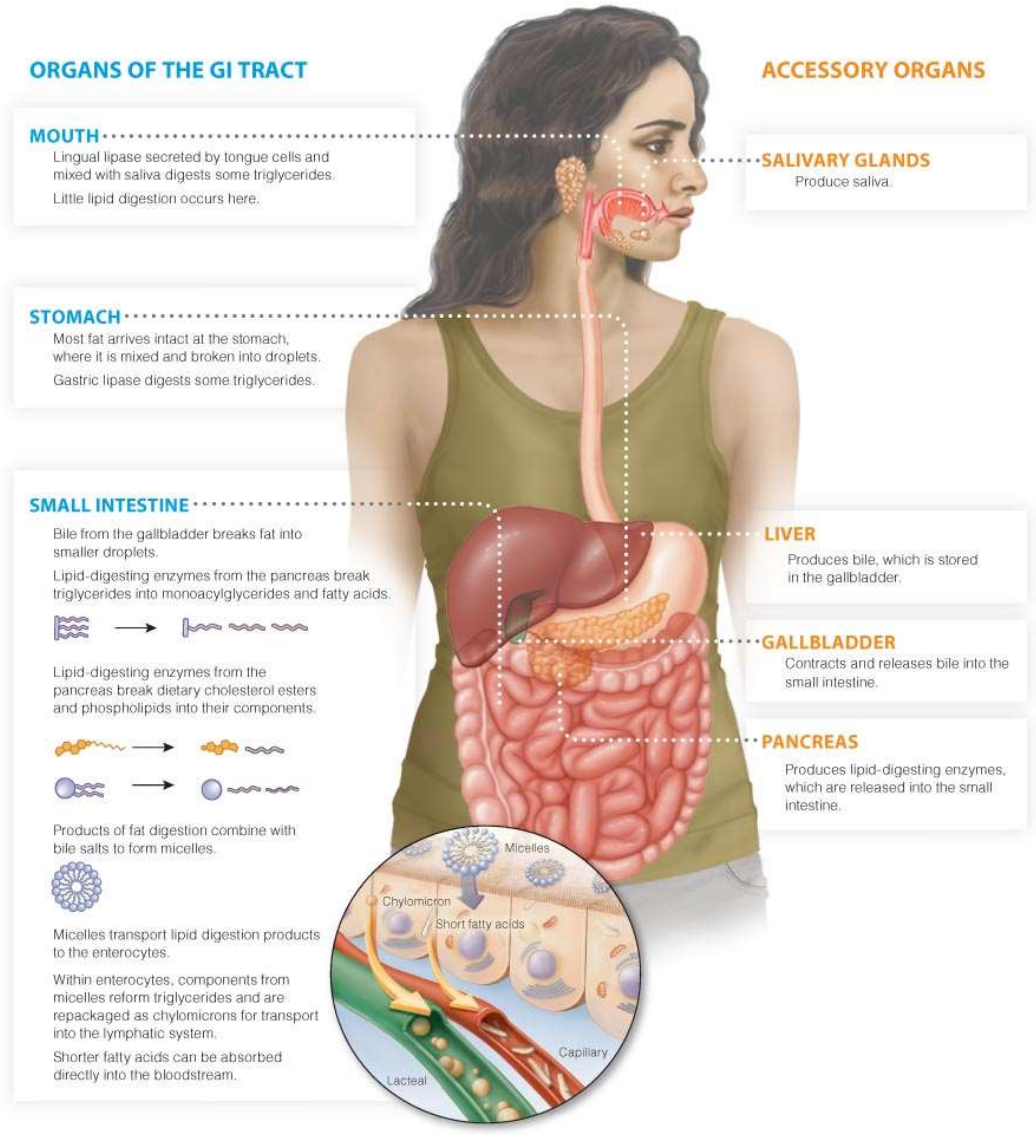
- Fat provides flavor and texture to foods
- Fat contributes to making us feel satiated
  - Fats are more energy dense than carbohydrates or protein
  - Fats take longer to digest

How Does Our Body Process Fats?

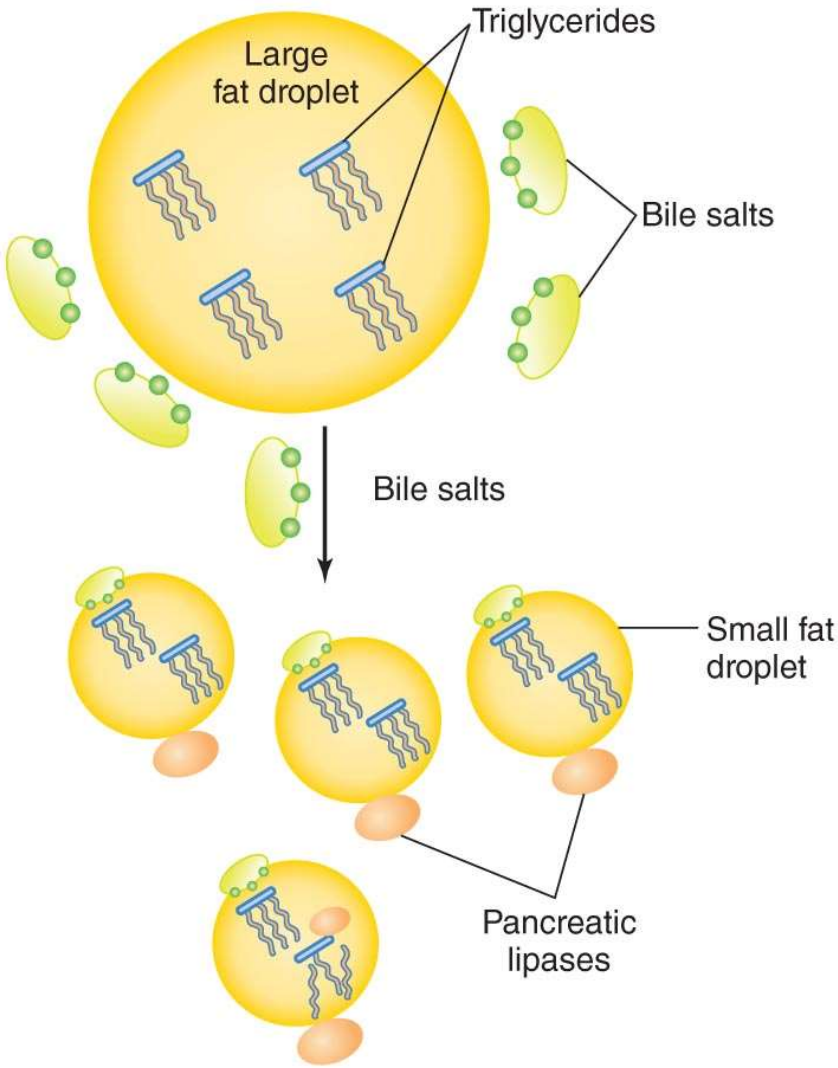
- As fat enters the small intestine:
  - Bile is secreted from the gallbladder into the small intestine
  - Bile is produced by the liver and stored in the gallbladder
  - Bile disperses fat into smaller fat droplets
  - Pancreatic enzymes break triglycerides into two separate fatty acids and a monoglyceride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

Digestion of Fats

The majority of lipid digestion takes place in the small intestine, with the help of bile from the liver and digestive enzymes from the pancreas. Micelles transport the end products of lipid digestion to the enterocytes for absorption and eventual transport via the blood or lymph.

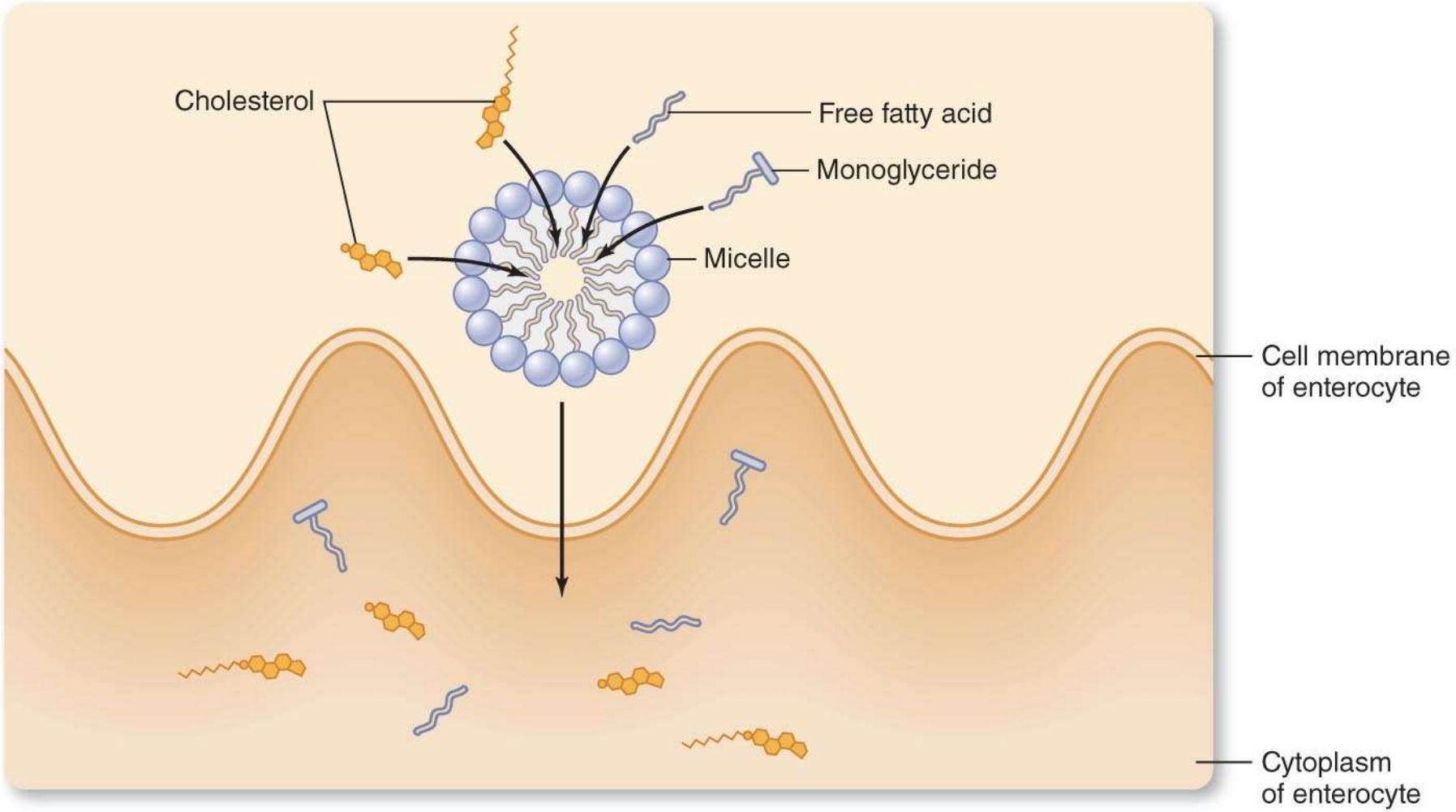


Digestion of Fats (cont.)



(a) Fat is emulsified by bile salts, then triglycerides are broken apart by pancreatic lipase.

Digestion of Fats (cont.)

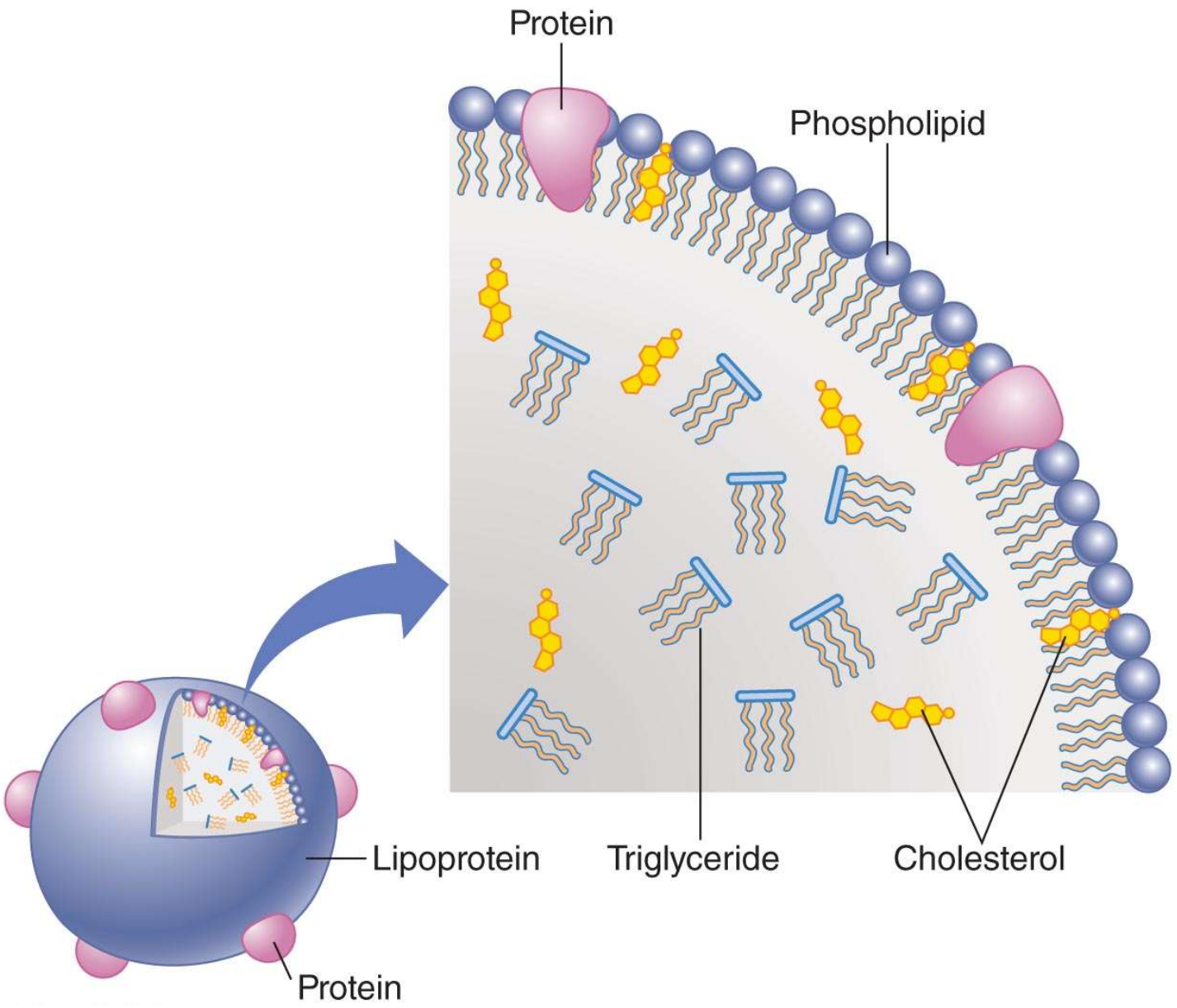


(b) Micelle transports lipid digestoin products to the enterocyte for absorption.

How Does Our Body Process 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



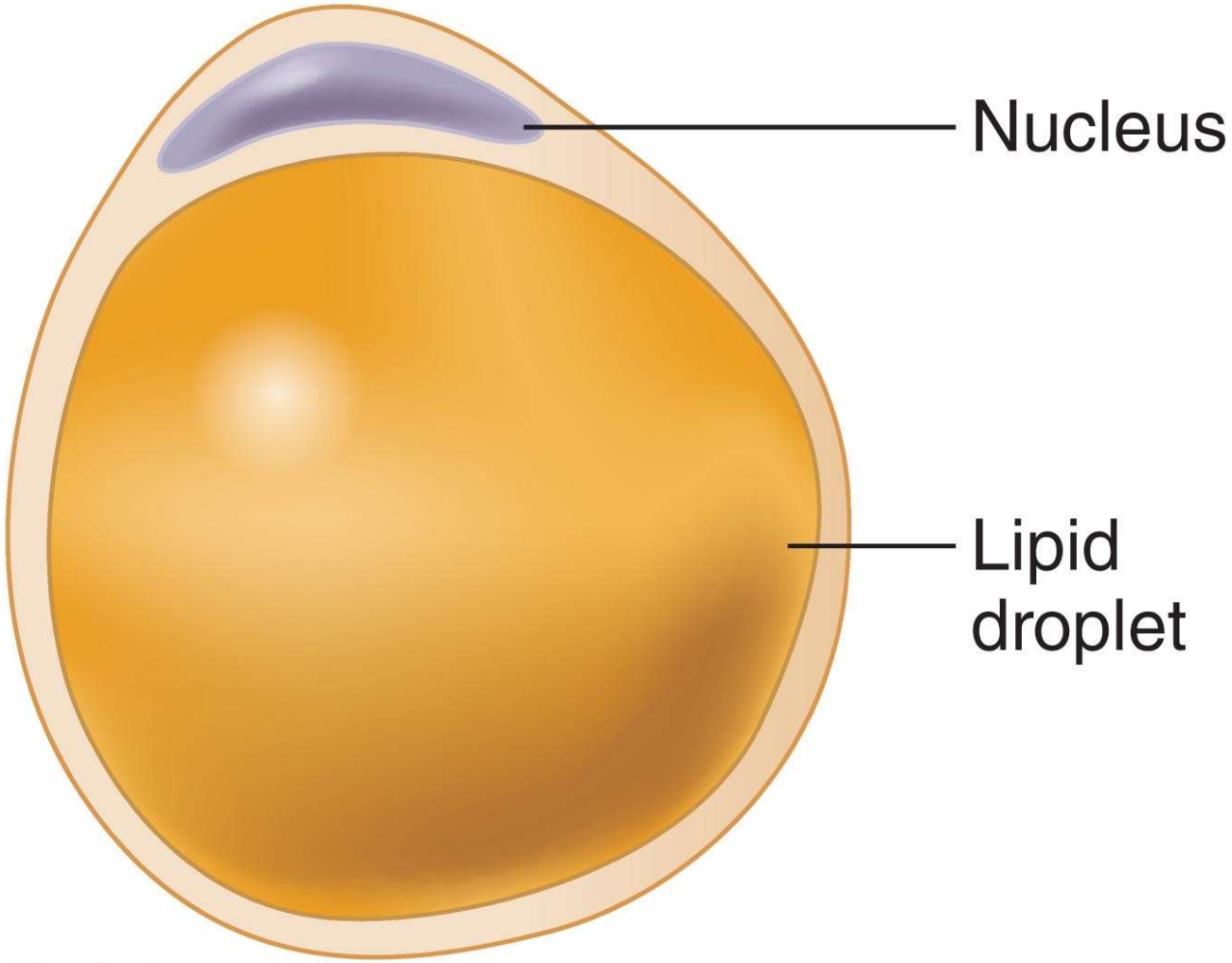
How Does Our Body Process Fats?

- 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

How Does Our Body Process Fats? (cont.)

- Once the chylomicron gets to a cell in the body, the triglycerides in the chylomicrons must be disassembled by lipoprotein lipase into two fatty acids and a monoglyceride before they can pass through the cell membrane
- After entering the cell, the two 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

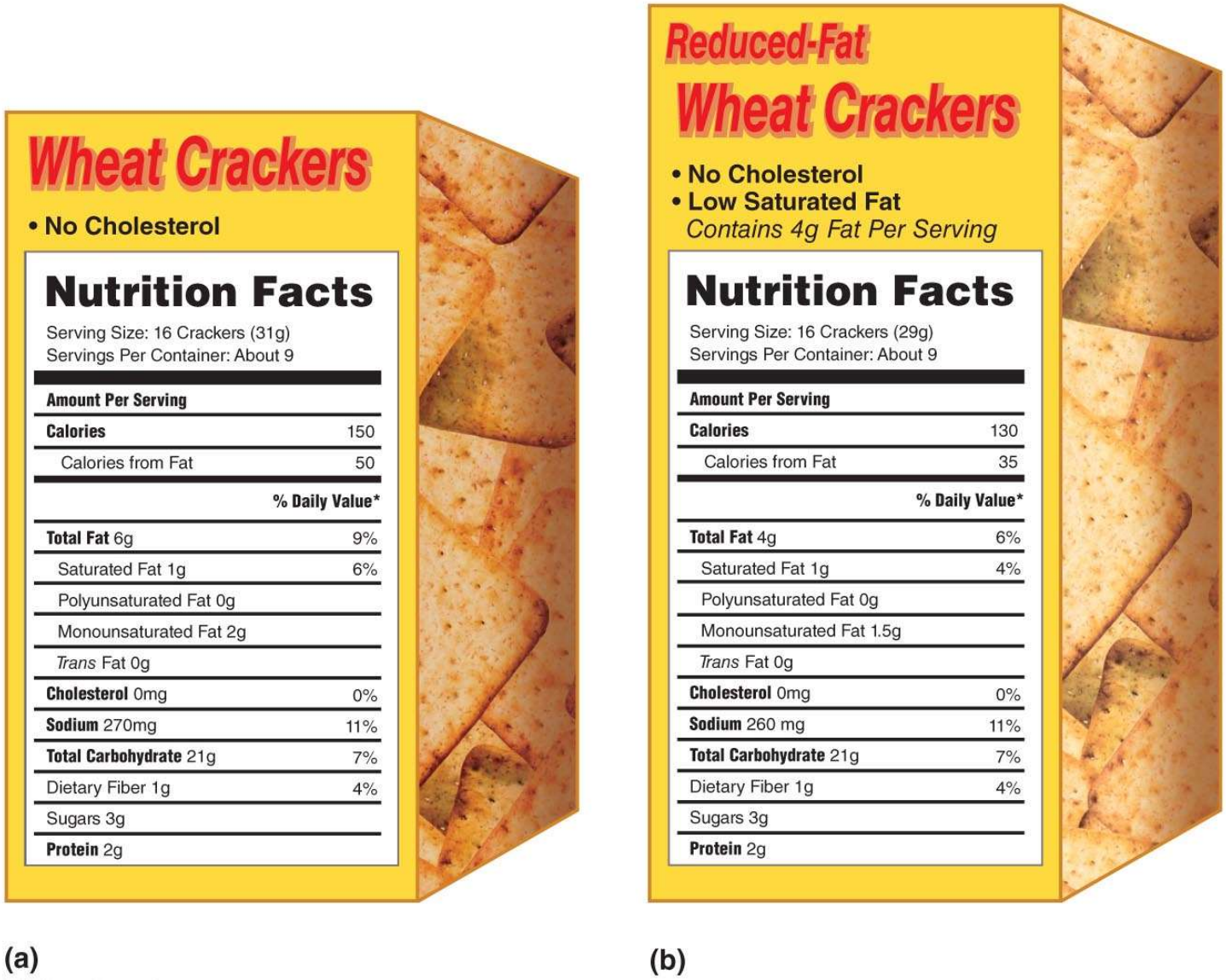
Diagram of an Adipose Cell



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 or chicken skin
- 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
- Read the Nutrition Facts Panel on foods carefully
  - Lower-fat versions of foods may not always be lower in Calories

How Much Fat Is in This Food?



How Much Fat Should We Eat?

- The Acceptable Macronutrient Distribution Range (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

How Much Fat Should We Eat?

- The type of fat consumed is important
  - Intake of saturated and *trans* fatty acids should be minimized as much as possible
  - We typically get enough linoleic acid in our diets from salad dressings, vegetable oils, margarines, and mayonnaise
  - To ensure an adequate amount of omega-3 fatty acids, we need to consume more dark-green leafy vegetables, walnuts, flaxseeds, and fish or fish oils

Essential Fatty Acids

- Linoleic Acid (omega-6)
  - AI is 14-17g per day for men and 11-12 g per day for women
- Alpha-linolenic acid (omega-3)
  - AI is 1.6g per day for men and 1.1g per day for women

Omega-3 Fatty Acid in Foods

TABLE 5.1 Omega-3 Fatty Acid Content of Selected Food

Food Item	Total Omega-3	DHA grams	EPA
	per serving		
Flaxseed oil, 1 tbsp.	7.25	0.00	0.00
Salmon oil (fish oil), 1 tbsp.	4.39	2.48	1.77
Sardine oil, 1 tbsp.	3.01	1.45	1.38
Flaxseed, whole, 1 tbsp.	2.50	0.00	0.00
Herring, Atlantic, broiled, 3 oz	1.83	0.94	0.77
Salmon, Coho, steamed, 3 oz	1.34	0.71	0.46
Canola oil, 1 tbsp.	1.28	0.00	0.00
Sardines, Atlantic, w/ bones & oil, 3 oz	1.26	0.43	0.40
Trout, rainbow fillet, baked, 3 oz	1.05	0.70	0.28
Walnuts, English, 1 tbsp.	0.66	0.00	0.00
Halibut, fillet, baked, 3 oz	0.53	0.31	0.21
Shrimp, Canned, 3 oz	0.47	0.21	0.25
Tuna, white, in oil, 3 oz	0.38	0.19	0.04
Crab, Alaska King, steamed, 3 oz	0.36	0.10	0.25
Scallops, broiled, 3 oz	0.31	0.14	0.17
Smart Balance Omega-3 Buttery Spread (1 tbsp.)	0.32	0.01	0.01
Tuna, light, in water, 3 oz	0.23	0.19	0.04
Avocado, Calif., fresh, whole	0.22	0.00	0.00
Spinach, cooked, 1 cup	0.17	0.00	0.00
Eggland's Best, 1 large egg, with omega-3	0.12	0.06	0.03

Note: EPA = Eicosapentaenoic acid; DHA = docosahexaenoic acid.

Data adapted from: Food Processor SQL, Version 10.3, ESHA Research, Salem, OR, and manufacturer labels.

Limit Saturated and *Trans* Fats

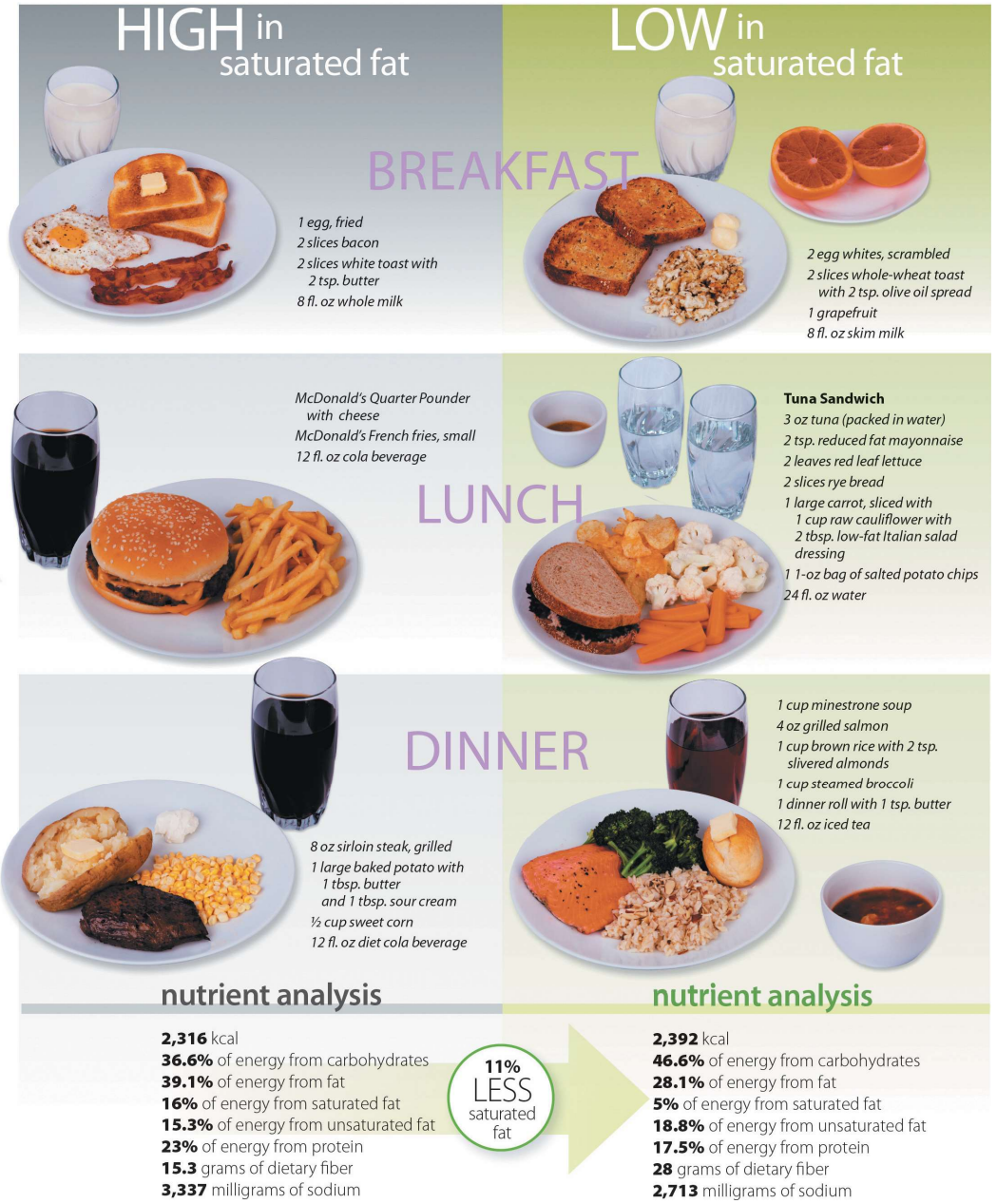
- Reduce your intake of saturated fats
  - Be conscious of the saturated fat content of meats, baked goods and snack goods, and foods including vegetables that are fried, breaded, or drenched in sauce
- Avoid *trans* fatty acids
- Limit your intake of dietary cholesterol, which will also help limit your intake of saturated fats

Select Beneficial Fats

- Consume and cook with leafy green vegetables, avocados, soybeans, soybean oil, and flaxseed oil
- Add walnuts, almonds, flaxseeds, and chia seeds to your diet, and try almond milk in your cereal
- Consider including fish in your diet at least twice a week or consider taking a fish oil supplement
  - Fish can contain mercury, PCBs, and other environmental contaminants, so be selective

Reducing Saturated Fat

a day of meals



Fat Replacers

- Snack foods are frequent targets for fat replacers, substances that can reduce the fat content
- Fat replacers such as olestra have not proved very popular or effective because of potential gastrointestinal side effects
- Our growing obesity problems indicate that fat replacers do not help Americans lose weight

Role of Fats in Chronic Disease

- The chronic disease most closely associated with diets high in saturated fat is cardiovascular disease
- The role of dietary fat in the development of cancer has been extensively researched, but the relationship between some cancer types and dietary fats is controversial (e.g., breast cancer)
- The strongest association between dietary fat and cancer is for prostate cancer

In Depth: Cardiovascular Disease

Cardiovascular disease (CVD)

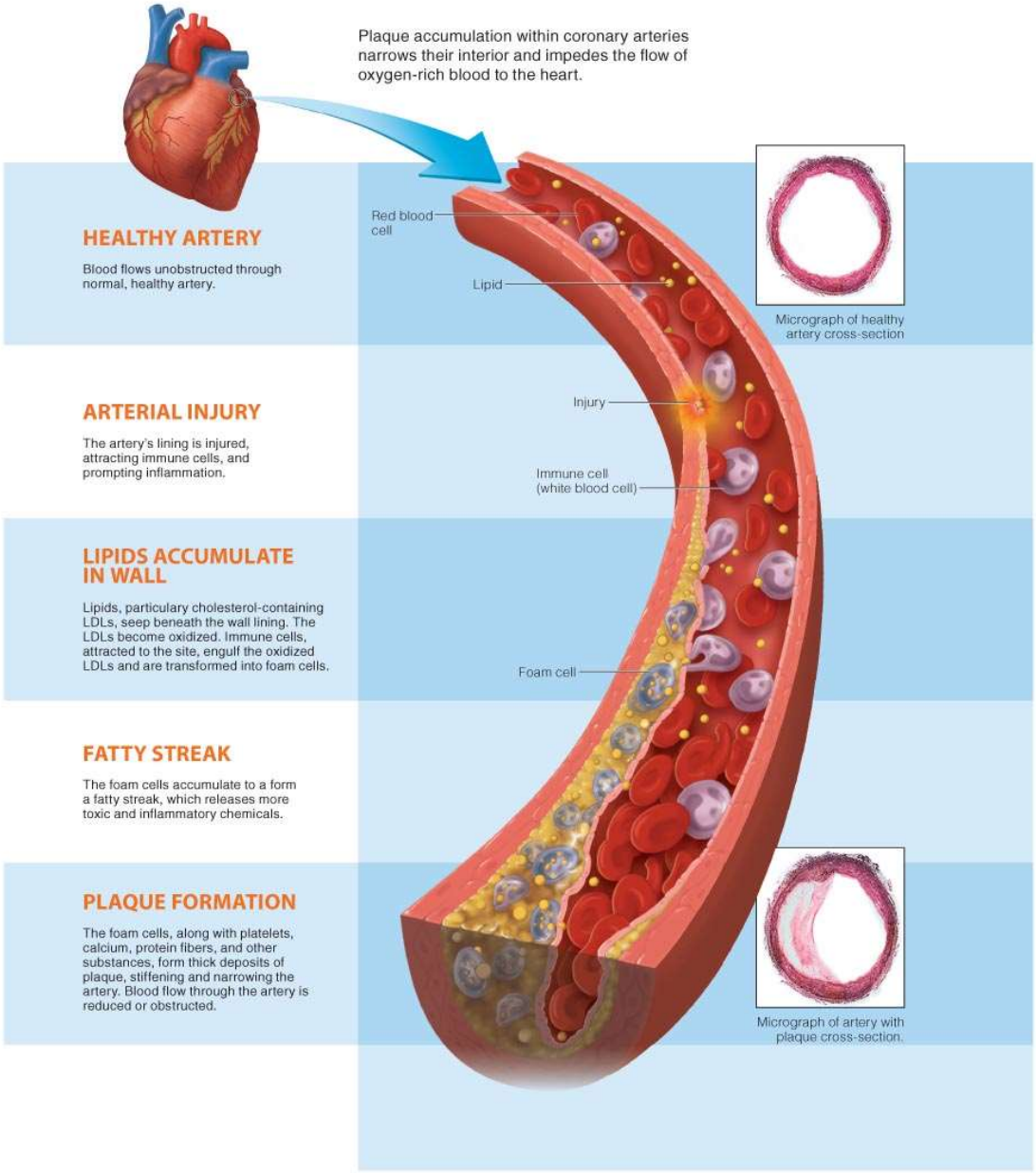
- Dysfunction of the heart or blood vessels
- The most common forms:
  - Coronary heart disease, or coronary artery disease
  - Stroke
  - Hypertension, or high blood pressure
  - Peripheral vascular disease

In Depth: Cardiovascular Disease (cont.)

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 (cont.)



In Depth: Cardiovascular Disease (cont.)

Hypertension is a major chronic disease in the United States

- 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 (cont.)

- Modifiable risk factors for cardiovascular disease include
  - Being overweight
  - Physical inactivity
  - Smoking
  - Type 2 diabetes mellitus
  - Inflammation in the body
  - Abnormal blood lipids

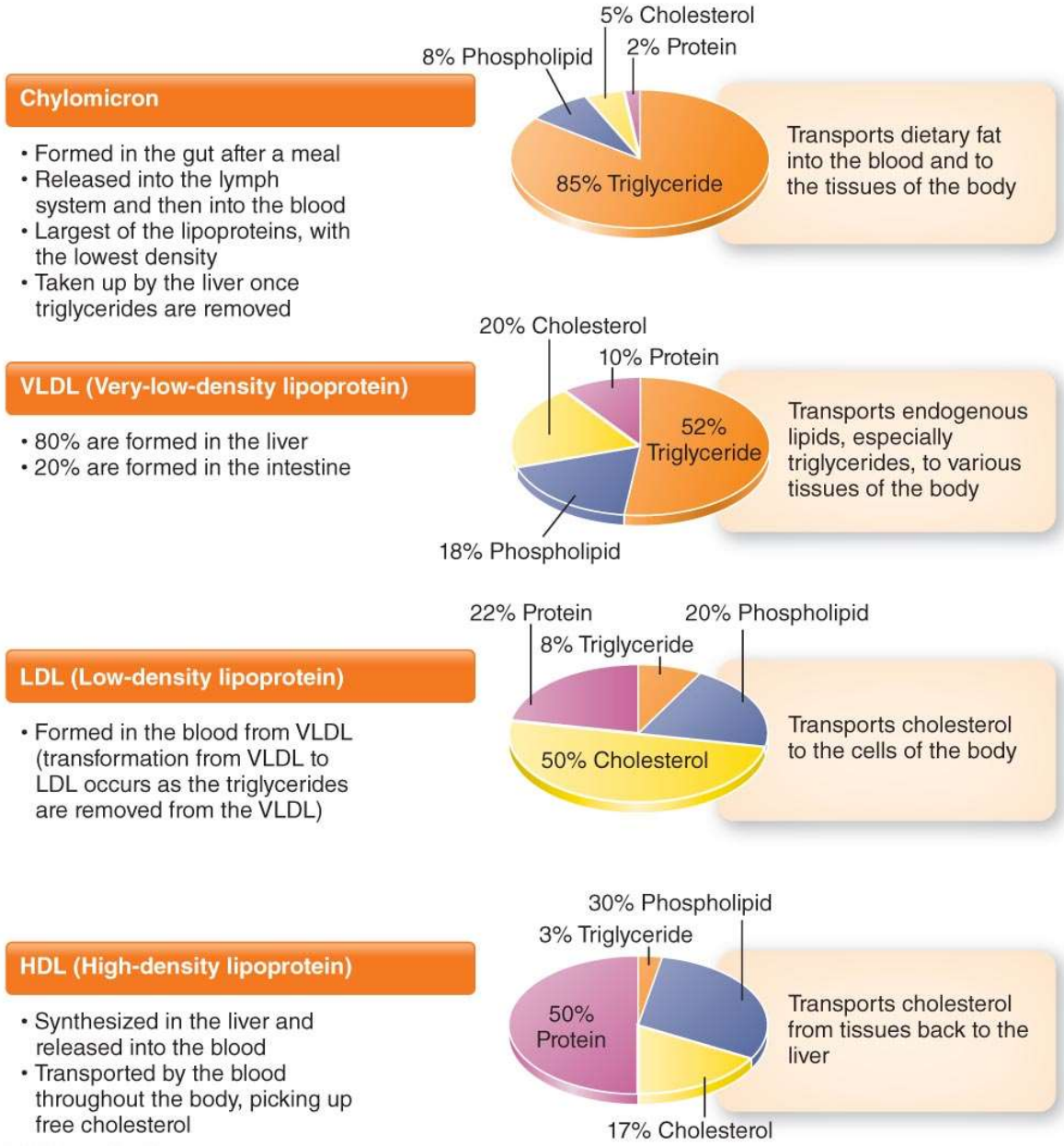
In Depth: Cardiovascular Disease (cont.)

- 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

In Depth: Cardiovascular Disease (cont.)

- Diets high in saturated fats
  - Decrease the removal of LDLs from the blood
  - Contribute to the formation of plaques that can block arteries
  - Increase triglyceride levels (chylomicrons and very-low-density lipoproteins, or VLDLs)

The Chemical Components of Lipoproteins



Lipoprotein Compounds

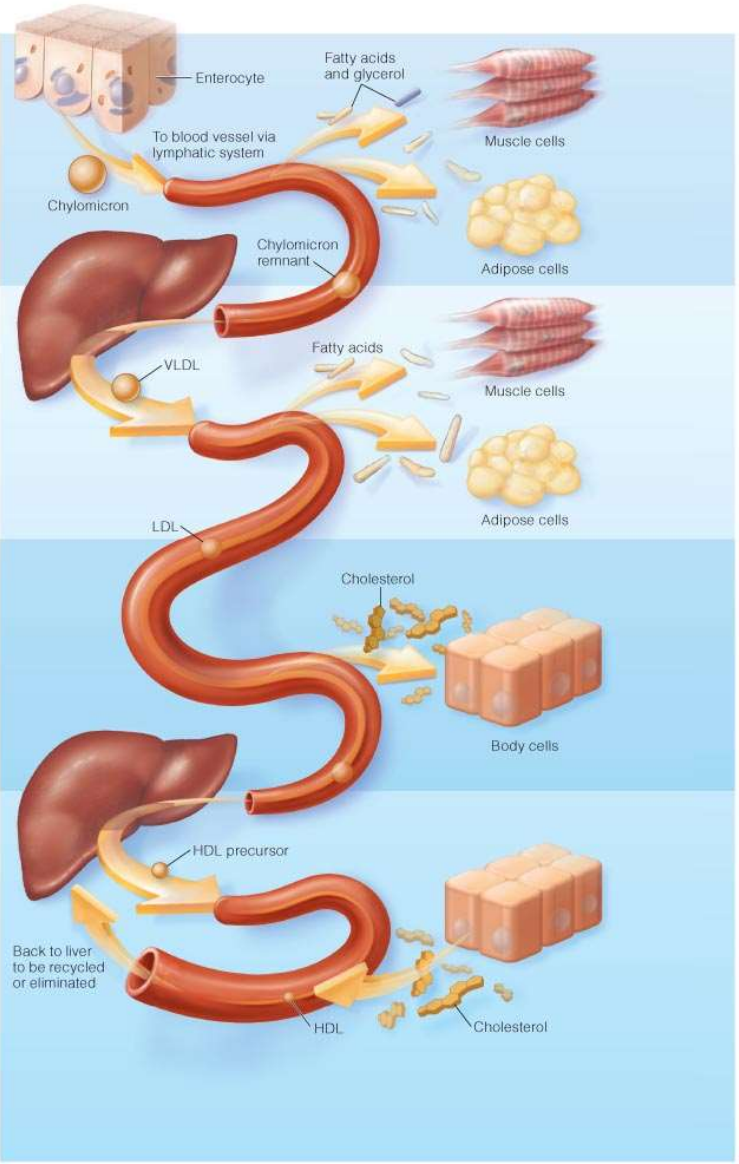
Lipids are transported in the body via several different lipoprotein compounds, such as chylomicrons, VLDLs, LDLs, and HDLs.

CHYLOMICRONS
Chylomicrons are produced in the enterocytes to transport dietary lipids. The enzyme lipoprotein lipase (LPL), found on the endothelial cells in the capillaries, hydrolyzes the triglycerides in the chylomicrons into fatty acids and glycerol, which enter body cells (such as muscle and adipose cells), leaving a chylomicron remnant. Chylomicron remnants are dismantled in the liver.

VLDLS
VLDLs (very-low-density lipoproteins) are produced primarily in the liver to transport endogenous fat in the form of triglycerides into the bloodstream. The enzyme lipoprotein lipase (LPL) found on the endothelial cells in the capillaries, breaks apart the triglycerides in the chylomicrons. The fatty acids can then enter the body cells, especially the muscle and adipose cells, leaving a chylomicron remnant. Glycerol is also released and is transported back to the liver.

LDLS
LDLs (low-density lipoproteins) are created with the removal of most of the VLDLs' triglyceride load. LDLs are rich in cholesterol, which they deliver to body cells with LDL receptors. LDLs not taken up by the cells are primarily taken up by the liver for degradation.

HDLS
HDLs (high-density lipoproteins) are produced in the liver and circulate in the blood, picking up cholesterol from dying cells, other lipoproteins, and arterial plaques. They return this cholesterol to the liver, where it can be recycled or eliminated from the body through bile.



In Depth: Cardiovascular Disease

- Recommendations to improve blood lipid levels
  - Keep total fat intake level to within 20–35% of your daily energy intake
  - Decrease your dietary saturated fat to less than 7% of total energy intake
  - Increase your consumption of dietary omega-3 fatty acids from foods (e.g., green vegetables, fish)
  - Consume 400 µg/day of folate
  - Increase dietary intakes of whole grains, fruits, and vegetables

In Depth: Cardiovascular Disease (cont.)

- Recommendations to improve blood lipid levels, *cont*.
  - Maintain blood glucose within normal ranges
  - Eat meals throughout the day rather than eating most of your Calories in the evening before bed
  - Limit alcohol consumption
  - Don’t smoke
  - Maintain an active lifestyle
  - Maintain a healthful body weight

Understanding Lipid Profiles

TABLE 1 Interpreting Blood Cholesterol Levels

Total Cholesterol Level	Category
Less than 200 mg/dL	Desirable
200–239 mg/dL	Borderline high
240 mg/dL and above	High

LDL (Bad) Cholesterol Level	LDL Cholesterol Category
Less than 100 mg/dL	Optimal
100–129 mg/dL	Near optimal/above optimal
130–159 mg/dL	Borderline high
160–189 mg/dL	High
190 mg/dL and above	Very High

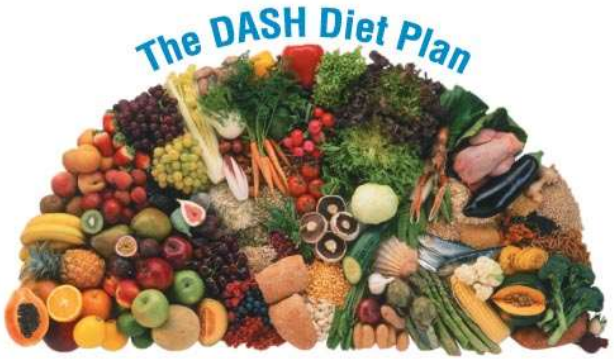
HDL (Good) Cholesterol level	HDL Cholesterol Category
Less than 40 mg/dL	A major risk factor for heart disease
40–59 mg/dL	The higher, the better
60 mg/dL and higher	Considered protective against heart disease

Source: National Institutes of Health. 2012, Summer. Cholesterol levels: What you need to know. *NIH Medline Plus Magazine* 7(2):6–7. www.nlm.nih.gov/medlineplus

In Depth: Cardiovascular Disease

- Recommendations to reduce blood pressure
  - Limit dietary sodium
  - Follow the DASH diet
    - Dietary Approaches to Stop Hypertension
  - If needed, use doctor-prescribed medications

The DASH Diet Plan



Food Group	Daily Servings	Serving Size
Grains and grain products	7–8	1 slice bread 1 cup ready-to-eat cereal* ½ cup cooked rice, pasta, or cereal
Vegetables	4–5	1 cup raw leafy vegetables ½ cup cooked vegetable 6 fl. oz vegetable juice
Fruits	4–5	1 medium fruit ¼ cup dried fruit ½ cup fresh, frozen, or canned fruit 6 fl. oz fruit juice
Low-fat or fat-free dairy foods	2–3	8 fl. oz milk 1 cup yogurt 1½ oz cheese
Lean meats, poultry, and fish	2 or less	3 oz cooked lean meats, skinless poultry, or fish
Nuts, seeds, and dry beans	4–5 per week	⅓ cup or 1½ oz nuts 1 tbsp. or ½ oz seeds ½ cup cooked dry beans
Fats and oils†	2–3	1 tsp. soft margarine 1 tbsp. low-fat mayonnaise 2 tbsp. light salad dressing 1 tsp. vegetable oil
Sweets	5 per week	1 tbsp. sugar 1 tbsp. jelly or jam ½ oz jelly beans 8 fl. oz lemonade

*Serving sizes vary between ½ and 1¼ cups. Check the product's nutrition label.

†Fat content changes serving counts for fats and oils: for example, 1 tablespoon of regular salad dressing equals 1 serving; 1 tablespoon of a low-fat dressing equals ½ serving; 1 tablespoon of a fat-free dressing equals 0 servings.