Chapter 5: Lipids: Fats, Phospholipids, and Sterols
Student learning outcomes: At the end of this chapter, you should be able to:

- Discuss benefits and risks of dietary fats
- Compare and contrast types of fats
- Select foods containing healthy fats and limit unhealthy fats
THINK about this – then share within a PAIR – then SHARE with the class

- Which foods in your diet provide fat?

- Why do you need fat in your diet?

- What are the benefits and consequences of a low-fat diet?
Sources of dietary fats

- Animal sources:
  - meat, cheese, dairy

- Plant sources:
  - vegetable oils, nuts, avocados

- “Hidden” dietary fat:
  - French fries, pizza, pasta dishes, baked goods, salad dressings
Benefits of dietary fats

- Provide texture, flavor, aroma to foods
Low-fat diets

![Bar chart showing fat intake in 1971 and today.](chart)

- Men and women are compared.
- Fat intake is measured in grams/day and as a percentage of calories.

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Lipids: a class of large biological molecules

- **Lipids**
  - Called “fats” in the diet
  - Saturated fats
    - Triglycerides
      - 3 fatty acids + 1 glycerol
      - In cell membranes
      - Starting material
  - Unsaturated fats
  - Phospholipids
    - In cell membranes
  - Sterols
    - In cell membranes
  - Cholesterol
    - Starting material

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Lipid types / Triglyceride

- Glycerol, fatty acids: chains of carbon atoms, acid at end
Lipid types / Phospholipid

- Phosphate, chains of carbon atoms
Lipid types / Sterols

- Multiple chemical rings

![Sterol molecule diagram](image-url)
Carbon bonding

- Carbon can form four bonds

Diagram showing carbon atoms forming single and double bonds.
Saturated vs. unsaturated fatty acids

- **Saturated fats**: carbons are saturated by hydrogens

- **Unsaturated fats**: carbons not saturated
Saturated vs. unsaturated fats in foods

The fat on the outside of a steak is solid at room temperature because it is high in saturated fatty acids, which pack tightly together.

Vegetable oils are a liquid at room temperature because they are high in unsaturated fatty acids. The bent chains of these fatty acids prevent tight packing, allowing the oil to flow.
Monounsaturated vs. polyunsaturated fats

- **Monounsaturated fats:** one double bond

- **Polyunsaturated fats:** more than one double bond
Types of fatty acids

Palmitic acid

The fat on the outside of a steak is solid at room temperature because it is high in saturated fatty acids, which pack tightly together.
Types of fatty acids

Oleic acid

Carbon–carbon double bond

Vegetable oils are a liquid at room temperature because they are high in unsaturated fatty acids. The bent chains of these fatty acids prevent tight packing, allowing the oil to flow.
Types of Fatty Acids

Linoleic acid

Alpha-linolenic acid
Omega-3 vs. Omega-6 polyunsaturated fats

- **Omega-3**: first double bond at 3rd bond from omega end
- **Omega-6**: first double bond at 6th bond from omega end
Essential vs. non-essential fatty acids

- **Essential** fatty acids cannot be made in the body, so they are essential in the diet. Example: omega-3 fatty acids (e.g. alpha-omega-6-fatty acids) and omega-6 (e.g. linoleic acid)

  - Sources:

    - omega-3 = flaxseed, walnuts, soy (decreases inflammation-blood clotting-blood pressure)

    - omega-6 = vegetable oils and meats (increases inflammation-blood clotting-blood pressure)

- **Non-essential** fatty acids can be made by the body, so they are not essential in the diet
Cis vs. trans-fats

- **Cis fat:** hydrogens on same side (like sisters)

- **Trans fat:** hydrogens are across (like a transcontinental flight goes across the US)
**Cis vs. trans-fats**

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

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

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Types of fatty acids

- Saturated fats
- Polyunsaturated fats
  - Omega-3
  - Omega-6
- Monounsaturated fats
- Unsaturated fats
  - Naturally = cis
  - Industrialized = trans
**Trans-fat (trans-fatty acids)**

- Found naturally in small amounts (e.g. dairy products)
- Large amounts created when unsaturated fatty acids are partially converted to saturated fatty acids by the industrialized process of hydrogenation
  - Decreases the reactivity of lipids / used to decrease rancidity and increase shelf life
  - *Most dangerous dietary fat*
  - Look for “hydrogenated oils” in ingredients list // avoid this type of fat!!!
Trans-fat vs. palm oil

- Trans-fat food labeling led food producers to replace hydrogenated oil with palm oil
- Palm oil is a tropical oil high in saturated fat
- Increased palm oil production led to rainforest destruction
**Trans-fat (trans-fatty acids)**

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

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

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

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

If the product has less than 0.5 gram of trans fat per serving, the nutrition facts panel will list the amount of trans fat as 0, even if partially hydrogenated oil is an ingredient.
Calculate the \textit{trans}-fat

- Food industry able to “mislead the consumer // in trans-fat labeling zero actually means 0.4 grams

- A bag of chips has 8 servings and \textit{has a \textit{trans}-fat free label}

- Each serving actually has 0.4 g of \textit{trans} fat (label lists as 0 g of fat)

- If you eat \(\frac{1}{2}\) of the bag of chips, how many grams of \textit{trans}-fat have you consumed?
Types of fatty acids

- Saturated fats
  - Animal fats
  - Tropical fats
- Unsataturated fats
  - Omega-3
    - Cold-water, fatty fish
  - Omega-6
    - Vegetable oils
    - Nuts
    - Flax seed
    - Walnuts
- Monounsaturated fats
- Polyunsaturated fats
- Industrialized = trans
- Baked goods
- Processed foods
- Olive oil
- Canola oil
Less healthy to healthier dietary fats

- Healthiest
  - Polyunsaturated omega-3 fats
  - Monounsaturated fats
  - Polyunsaturated omega-6 fats
- Least healthy
  - Saturated fats
  - Industrialized = trans fat
Phospholipids

[Diagram of a phospholipid molecule with labels for fatty acid, glycerol, phosphate group, fat-soluble tails, and water-soluble head.]
Phospholipids: in cell membranes and used to make other molecules
Cholesterol: in cell membranes and used to make other molecules
Phospholipids
Phospholipids

Cell interior (aqueous environment)

Cholesterol

Phospholipid

Lipid bilayer

Membrane protein

Lipid environment

Cell exterior (aqueous environment)
Cholesterol: an animal sterol

- Non-essential nutrient /// made by the liver
- In cell membranes of animal cells
  - Dietary sources: animal products
  - Plant sterols can reduce human cholesterol
- Used to make vitamin D and steroid hormones (for example: estrogen, testosterone, cortisol)
Cholesterol transport in blood

- Lipids are hydrophobic = water fearing // (Oil and water don’t mix)

- Blood is mostly water

- In order to transport lipids you need to surrounded lipids by hydrophilic transporters // (= water loving) molecules for transport in blood
Lipoproteins (examples: LDL & HDL)
Lipoproteins in blood
Chylomicrons

- **Chylomicrons** transport triglycerides, cholesterol, and fat-soluble vitamins from the small intestines to the liver.

- Triglycerides in **chylomicrons** are broken down into glycerol and fatty acids by **lipoprotein lipase** (in blood vessels) to cross membranes then are reassembled into triglycerides in somatic cells and adipocytes.

  - Note: empty chylomicron remnants are returned to the liver for recycling.
Very low density lipoproteins (VLDL)

- **VLDL** particles are made in the liver

- **VLDL** particles function similar to chylomicrons (transport triglycerides which are broken down by lipoprotein lipase)

  - Remainder of **VLDL** particles are returned to the liver or made into **LDL** particles
Low density lipoproteins (LDL)

- LDL particles deliver cholesterol to cells
- LDL particles bind to LDL receptors on cells to help cholesterol move from the blood into cells
Low density lipoproteins (LDL)

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

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

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

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

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

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

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

Chylomicrons are the largest lipoproteins and contain the greatest proportion of triglycerides.

VLDLs are smaller than chylomicrons but still contain a high proportion of triglycerides.

LDLs contain a higher proportion of cholesterol than do other lipoproteins.

HDLs are high in cholesterol and are the densest lipoproteins due to their high protein content.
High density lipoproteins (HDL)

- **HDL** particles transport cholesterol from cells to the liver

- The liver uses cholesterol to make bile acids
Bile

- **Bile** is stored in the gall bladder before entering the small intestines.

- **Bile** emulsifies (breaks up larger particles) dietary fat so it is more accessible to lipases (lipid-digesting enzymes).

- **Dietary fiber** binds cholesterol to keep it from being reabsorbed into the body from the small intestines (so more is excreted from the body).
How to Decrease your LDL and Increase HDL

- Decrease dietary *trans*-fat, saturated fat, and cholesterol
- Increase dietary polyunsaturated fats and monounsaturated fats
- Quit smoking // Exercise
- Improve social relationships
LDL vs. HDL

- **LDL** particles transport cholesterol from the liver to body cells
  - Work to decrease your blood levels of LDL // (“you want your low to be low”)

- **HDL** particles transport cholesterol from body cells to the liver so they can be excreted
  - Work to increase your blood levels of HDL // (“you want your high to be high”)
Lipoproteins are blood transport particles

- We do not eat LDL and HDL / produced by liver

- Dietary lipids (such as cholesterol and triglycerides) are packaged into lipoprotein particles (such as LDL and HDL) for transport in blood
LDL is “lethal”

- Blood vessel injury, inflammation and LDL oxidization generates plaques blood vessel walls in atherosclerosis

- Antioxidants (found in fruits and vegetables) can limit oxidation of LDL

- Atherosclerosis can narrow blood vessels and limit blood flow to tissues so that fewer nutrients and oxygen molecules are delivered
Atherosclerosis development

1. Normal Artery
2. Damage to the Artery Wall
3. Plaque Formation
4. Plaque Enlargement
5. Plaque Rupture
6. Heart Attack

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Atherosclerosis can lead to heart attacks and strokes

- Atherosclerosis plaques can break through the blood vessel walls and stimulate clot formation to completely block blood flow.

- In the heart, this causes heart attacks (also called myocardial infarctions, or MIs).

- In the brain, this causes strokes (also called cerebral vascular accidents, or CVAs).
Risk factors for atherosclerosis and cardiovascular disease

- Poor diet
- Smoking
- Diabetes
- High blood pressure (hypertension)
- Obesity
- Sedentary
- Blood lipids (high LDL, triglycerides; low HDL)
- Family history, age, gender, race
Benefits of lipids/fats

- Provide texture, flavor, aroma to foods
- Phospholipids and cholesterol are in membranes and are starting materials for other molecules
- Help absorb fat-soluble vitamins
- Light-weight, long-term storage of energy
- Insulation, cushion, lubricant
Conversion of fatty acids to energy

1. Fatty acids → Acetyl-CoA
2. Acetyl-CoA → Citric acid cycle → ATP
3. ATP → High-energy electrons → O₂ → H₂O
Feasting vs. fasting

Feasting: When excess energy is consumed, it is stored as triglycerides in adipose tissue.

Fasting: When no food has been eaten for a while, triglycerides from adipose tissue are broken down, releasing fatty acids as an energy source.

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Storage of excess fatty acids
Dietary fat and obesity

- Fat has 9 calories per gram
- Carbohydrates & proteins have 4 calories per gram
- Fat is efficiently stored
- A little to much “fatty food” provides a great many calories!
Dietary recommendations

- **Total fat:** 20%–35% of total calories
  - 30–40% for ages 1–3 & 25–35% for ages 3–18

- **Saturated fat:** less than 7% of total calories

- **Cholesterol:** less than 300 mg per day

- **Trans-fat:** limit
Mediterranean and Asian diets may decrease cardiovascular disease
MyPlate Choices

- **Grains**: Whole grains such as whole-wheat bread, oatmeal, brown rice, flax, quinoa, barley, bulgur, and popcorn, which are low in saturated fat and provide poly- and monounsaturated fat along with fiber and B vitamins.

- **Vegetables**: Leafy, green, and orange vegetables such as spinach, kale, broccoli, green beans, carrots, and sweet potatoes. These have little or no fat unless it is added in cooking or processing.

- **Fruits**: Fresh and dried fruit, most of which is very low in fat. Avocados are a high-fat fruit that provide heart-healthy monounsaturated fats.

- **Dairy**: Nonfat or low-fat milk products such as low-fat milk, yogurt, and cottage cheese. These provide all the protein and calcium found in full-fat dairy products, but with little or no saturated fat or cholesterol. Legumes, which are low in fat and high in fiber, and nuts and seeds, which add omega-3 and monounsaturated fat, and fish, which provides EPA and DHA.

- **Protein**: Processed grains such as frozen pizzas, macaroni and cheese, flavored rice dishes, crackers, and baked goods, which can be hidden sources of total fat, saturated fat, and trans fat. French fries and breaded fried vegetables, such as onion rings, zucchini, and mushrooms, which are high in added fat and calories and can be a source of saturated fat or trans fat. Fruit pies and tarts, which are high in refined sugar and can add saturated fat, and trans fat to the diet. Whole-fat dairy products such as whole milk, ice cream, cheese, and cream, which are high in total fat, saturated fat, and cholesterol. Fatty and fried meats such as sausages, fried chicken, and steaks, which are high in saturated fat, and cholesterol.


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Food labels

Chocolate Chip Cookies

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Food labels

- Reduced fat: Contains at least 25% less fat per serving than the regular or reference product.
- Fat free: Contains < 0.5 g fat per serving.
- Low fat: Contains ≤ 3 g fat per serving.

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Fat replacers

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

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

The sugar sucrose is usually added to low-fat and nonfat baked goods to improve flavor and add volume. Sucrose adds 4 Calories per gram.

Protein-based fat replacers are made from milk and egg proteins processed to form millions of microscopic balls that slide over each other, mimicking the creamy texture of fat. They are used in frozen desserts, cheese foods, and other products but cannot be used for frying because they break down at high temperatures.

Andy Washnik

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Review Questions

- Use these slides to access your knowledge and prepare for the unit exam.
Concept check

What are similarities and differences between:

- saturated and unsaturated fats?
- monounsaturated and polyunsaturated fats?
- omega-3 and omega-6 fats?
- cis-fats and trans-fats?
Which of the following is a saturated fatty acid?

1) 

2) 

3)
Which of the following is a polyunsaturated fatty acid?

1) 

2) 

3)
Which of the following is an omega-6 fat?

1)  

2)  

3)
Which of the following is a *trans* fat?

1)

2)

3)
Trans-fat in the news

- Margarine vs. butter

- Trans-fat added to nutrition facts panel (2006)

- Trans-fat bans (for example, New York City)
Debate the issues

- Should the government pass additional trans-fat bans?

- Should unhealthy foods such as soda and potato chips have an additional tax?
Concept check

- Americans consume too much saturated fat and too few omega-3 fats.

- What dietary recommendations could be made to help them improve their diets?
Which fat sources can you increase and limit to improve your fat intake?

- Polyunsaturated omega-3 fats
- Monounsaturated fats
- Polyunsaturated omega-6 fats
- Saturated fats
- Industrialized = trans fat

Healthiest to Least healthy
Concept check

To improve health, consume:

1. more animal fat  
2. more monounsaturated fat  
3. less omega-3 fat  
4. less plant fat
Concept check

- How are phospholipids and cholesterol similar and different?

- What is an example of a non-essential nutrient?
Concept check

- If a person does not have LDL receptors, what would you expect to happen to blood levels of LDL?

- What are examples of foods you can limit and increase to lower your LDL and raise your HDL?
Checking student learning outcomes

- What are the benefits and risks of dietary fats?

- How are fats classified? What are the similarities and differences between types of fat?

- Which foods should be consumed and avoided to improve health?
Concept check

Which of the following is true?

1. Cholesterol is made in the small intestines.
2. Bile is packaged into HDL particles.
3. HDL is oxidized during atherosclerosis.
4. LDL delivers cholesterol to cells.
Concept check

- What are some benefits of lipids/fats discussed so far?
Concept check

- What are benefits and dangers of limiting fat intake?

- What are the dangers of consuming too much fat?
Concept check

Which dietary and lifestyle changes can you make to decrease your risk of atherosclerosis and cardiovascular disease?
Concept check

- What are some benefits of diets rich in fruits and vegetables?

- What are some consequences of diets high in animal fats?