The Lipids: Triglycerides, Phospholipids, and Sterols

Chapter 5

Types of Lipids

- Triglycerides
  - Saturated Fatty Acids
  - Unsaturated Fatty Acids
    - Monounsaturted Fatty Acids
    - Polyunsaturated Fatty Acids
      - Essential Fatty Acids
      - Omega 3 Fatty Acids
- Phospholipids
- Sterols
- All are found in the body and in foods

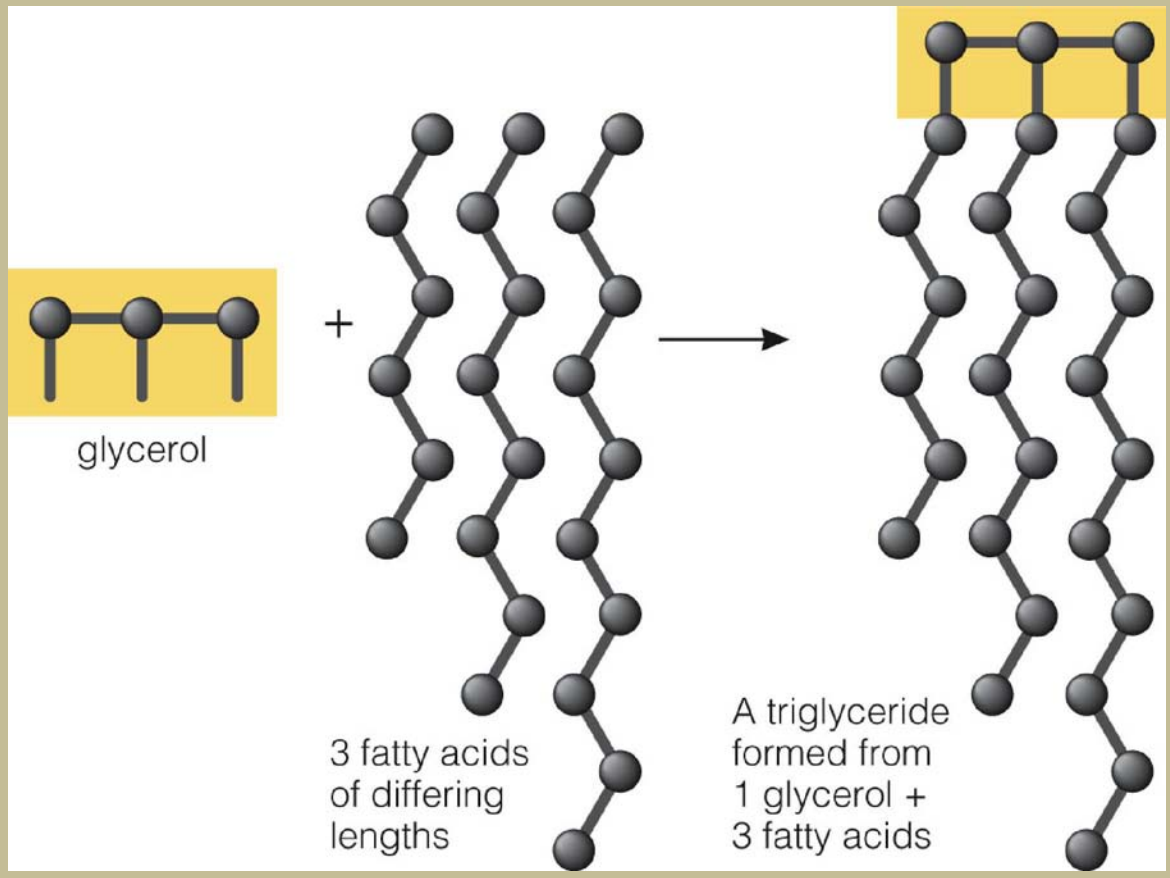
Fatty Acids and Triglycerides

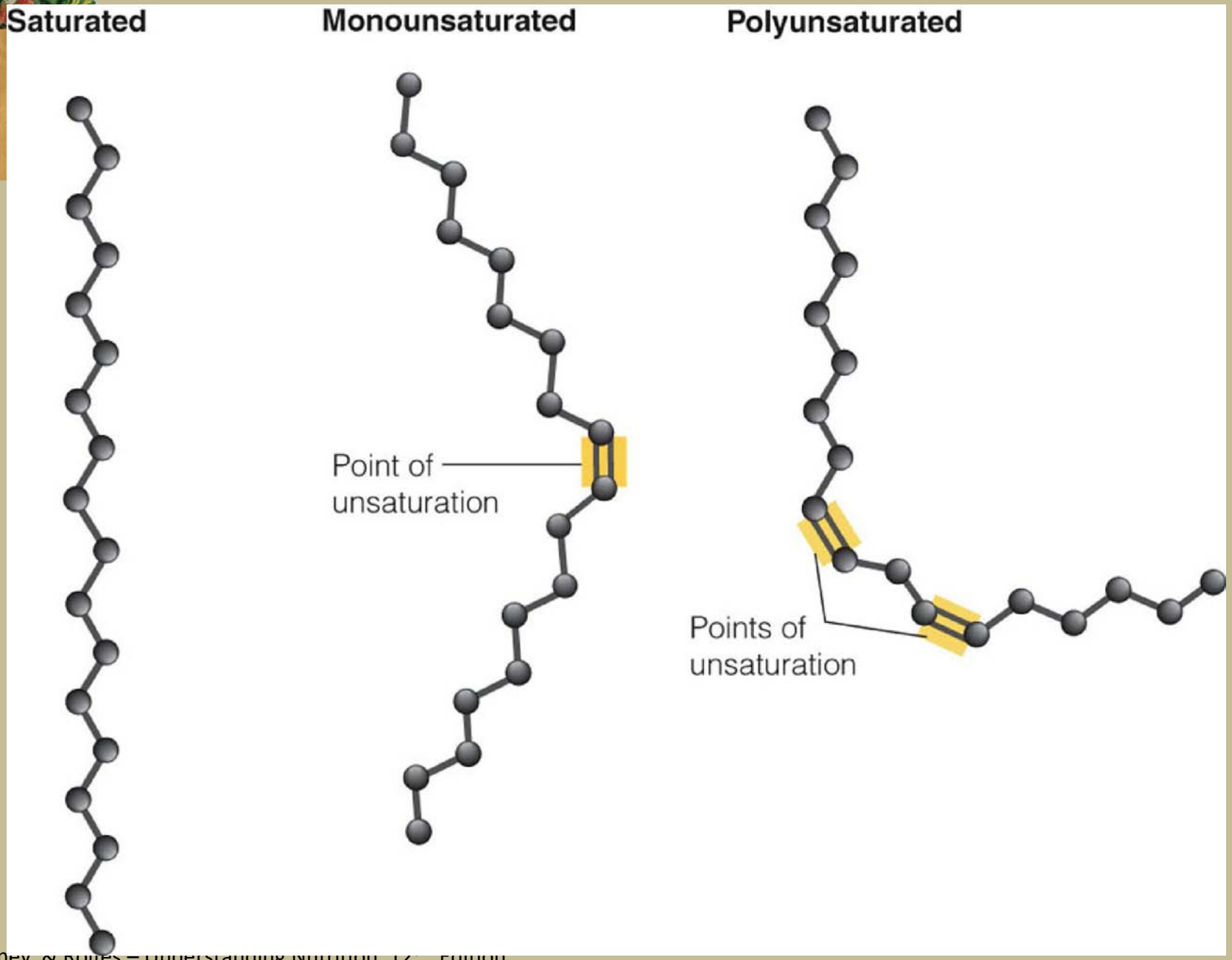
- Chemical makeup: Carbons, Hydrogen, Oxygen
- Energy provided per gram (9 kcal/gm)
  - More carbons and hydrogens
- Preview of lipids
  - Triglycerides: glycerol and 3 fatty acids
  - Fatty acids: even number of carbons
  - Fatty acids: saturated or unsaturated
  - Omega-3 and omega-6 fatty acids – location of the double bond from the methyl end

Chemist's View of Fatty Acids and Triglycerides

- Triglycerides
  - Glycerol backbone
  - Three fatty acids
  - Formed via series of condensation reactions
  - Usually contain mixture of fatty acids
  - Saturated Fats
  - Monounsaturated Fats
  - Polyunsaturated Fats

Triglyceride Structure




Saturated
Monounsaturated
Polyunsaturated
Point of unsaturation
Points of unsaturation

Saturated Fatty Acids

- Solid at room temperature
- Triglyceride with all fatty acids saturated with hydrogen bonds
- Food examples include:

  butter, lard, solid shortening, sour cream, cream cheese, whole fat dairy products, coconut, and palm and palm kernel oils

Monounsaturated Fats

- Liquid at room temperature
- Triglyceride with one double bond
- Food sources include:
  olives, peanuts, avocadoes, canola oil

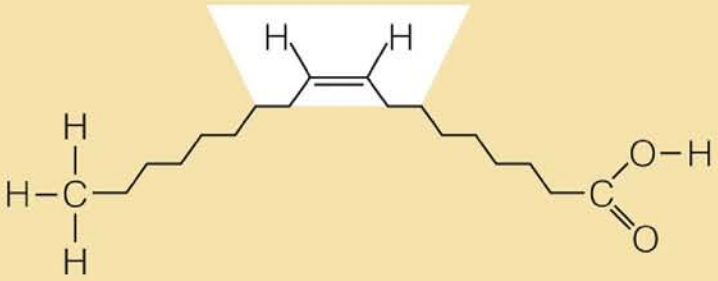
Polyunsaturated Fatty Acids

- Triglycerides with more than one double bond
  - Provide essential fatty acids: Omega 3 and 6
  - Omega 3 – double bond is 3 molecules away from the end of the chain
  - Omega 6 – double bond is 6 molecules away from the end of the chain
- Food sources include many oils:
  - Corn, soybean, safflower, cottonseed, flaxseed, walnut

Influences of Saturation in Foods and in the Body

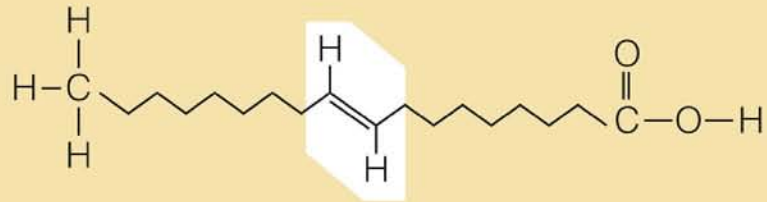
- Degree of unsaturation
  - Firmness
    - Polyunsaturated fats < Saturated
    - Shorter chain fatty acids softer
  - Stability:
    - Unsaturated less stable than saturated
  - Hydrogenation
  - Trans Fats

Chemist's View of Fatty Acids and Triglycerides



cis-fatty acid

A *cis*-fatty acid has its hydrogens on the same side of the double bond; *cis* molecules bend into a U-like formation. Most naturally occuring unsaturated fatty acids in foods are *cis*.



trans-fatty acid

A *trans*-fatty acid has its hydrogens on the opposite sides of the double bond; *trans* molecules are more linear. The *trans* form typically occurs in partially hydrogenated foods when hydrogen atoms shift around some double bonds and change the configuration from *cis* to *trans*.

Phospholipids and Sterols

- Phospholipids
  - Solubility in fat and water
  - Emulsifiers in food industry
  - Lecithin
  - Food sources
  - Roles
    - Part of cell membranes
    - Emulsifiers

Phospholipids and Sterols

- Sterols
  - Food sources
    - Cholesterol
    - Plant sterols
  - Roles of sterols
    - Body compounds made from cholesterol

Essential Fatty Acids

- Body can make all but 2 fatty acids
  - Linoleic (omega 6)
  - Linolenic (omega 3)
- Functions of Essential Fatty Acids
  - Provide materials for eicosanoids
  - Structural and functional pars of cell membranes
  - Provide lipids to the brain and nerves
  - Promote growth and vision
  - Support immune cell functions
- US diets are higher in omega 6

Omega 3 Fatty Acids

- Essential for growth and development especially eyes and brain
- May protect against heart disease, stroke, cancers, arthritis
- Food sources
  - EPA and DHA: Fatty fish and fish oil supplements
  - ALA:
    - Canola oil, flaxseed, walnuts, dark green leafy vegetables, enriched food products

Omega 6 Fatty Acids

- Plentiful in the US diet
- Food sources include:
  - Linoleic acid: Vegetable oils, dark green leafy vegetables, seeds, nuts, grains,
  - Arachidonic acid: Meats, poultry, eggs
    - Can be made from linoleic acid

Lipid Digestion

- Fats are hydrophobic
  - Digestive enzymes are hydrophilic
- Goal of fat digestion
  - Dismantle triglycerides
    - Monoglycerides, fatty acids, and glycerol

Lipid Digestion

FAT

Mouth and salivary glands
Some hard fats begin to melt as they reach body temperature. The sublingual salivary gland in the base of the tongue secretes lingual lipase.

Stomach
The acid-stable lingual lipase initiates lipid digestion by hydrolyzing one bond of triglycerides to produce diglycerides and fatty acids. The degree of hydrolysis by lingual lipase is slight for most fats but may be appreciable for milk fats. The stomach's churning action mixes fat with water and acid. A gastric lipase accesses and hydrolyzes (only a very small amount of) fat.

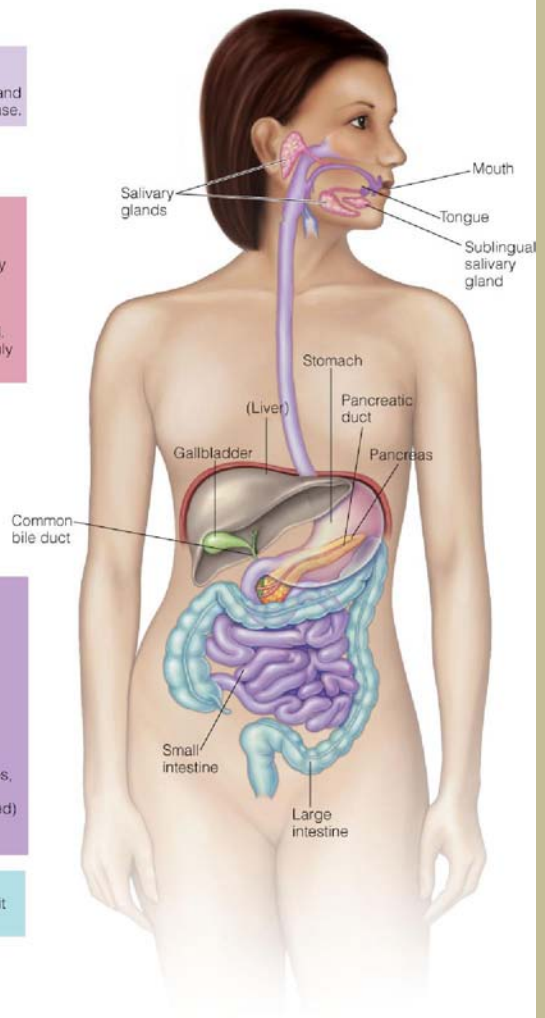
Small intestine
Bile flows in from the gallbladder (via the common bile duct):

Fat —(Bile)→ Emulsified fat

Pancreatic lipase flows in from the pancreas (via the pancreatic duct):

Emulsified fat (triglycerides) —(Pancreatic (and intestinal) lipase)→ Monoglycerides, glycerol, fatty acids (absorbed)

Large intestine
Some fat and cholesterol, trapped in fiber, exit in feces.



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Digestion and Absorption of Lipids

Dietary Sources:

Mouth: ⟶ (Lingual Lipase)Minor role in fat digestion

Stomach:(gastric lipase) ⟶ Triglycerides ⟶Diglycerides + Fatty Acids

Small Intestine:

CCK (hm) releases Bile (emulsifies fat)

Pancreatic Lipase: Monoglycerides, Glycerol, Fatty Acids

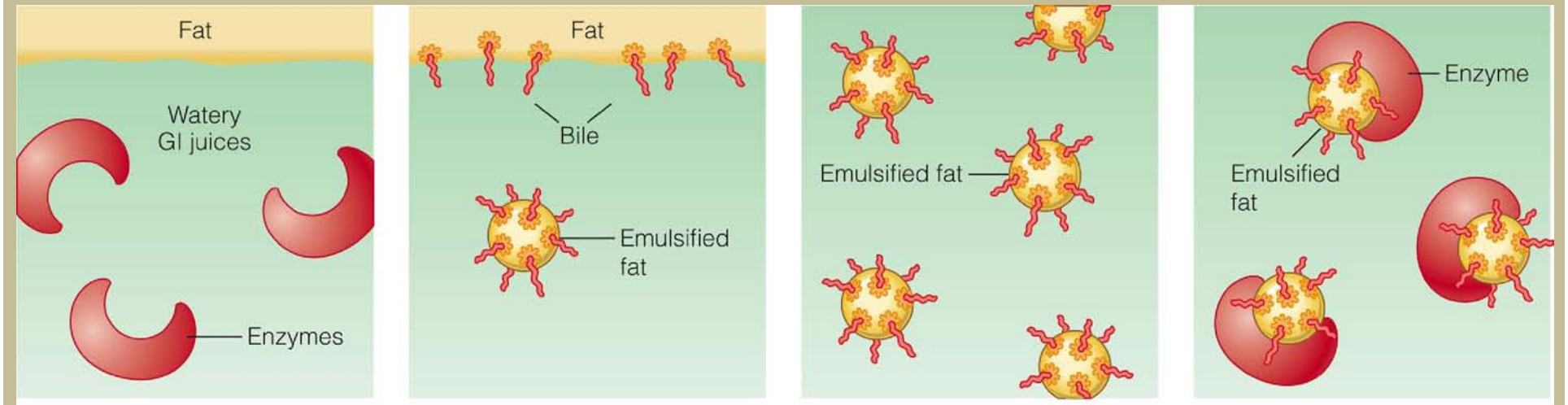
Glycerol and Fatty Acids (<12 C – bloodstream)

Monoglycerides and larger F/A – make chylomicrons
Bile: reabsorbed and recycled or trapped by dietary fibers lower cholesterol

Large Intestine:

Some fat and cholesterol trapped in fiber – excreted

Emulsification of Fat by Bile



In the stomach, the fat and watery GI juices tend to separate. The enzymes in the GI juices can't get at the fat.

When fat enters the small intestine, the gallbladder secretes bile. Bile has an affinity for both fat and water, so it can bring the fat into the water.

Bile's emulsifying action converts large fat globules into small droplets that repel one another.

After emulsification, more fat is exposed to the enzymes, making fat digestion more efficient.

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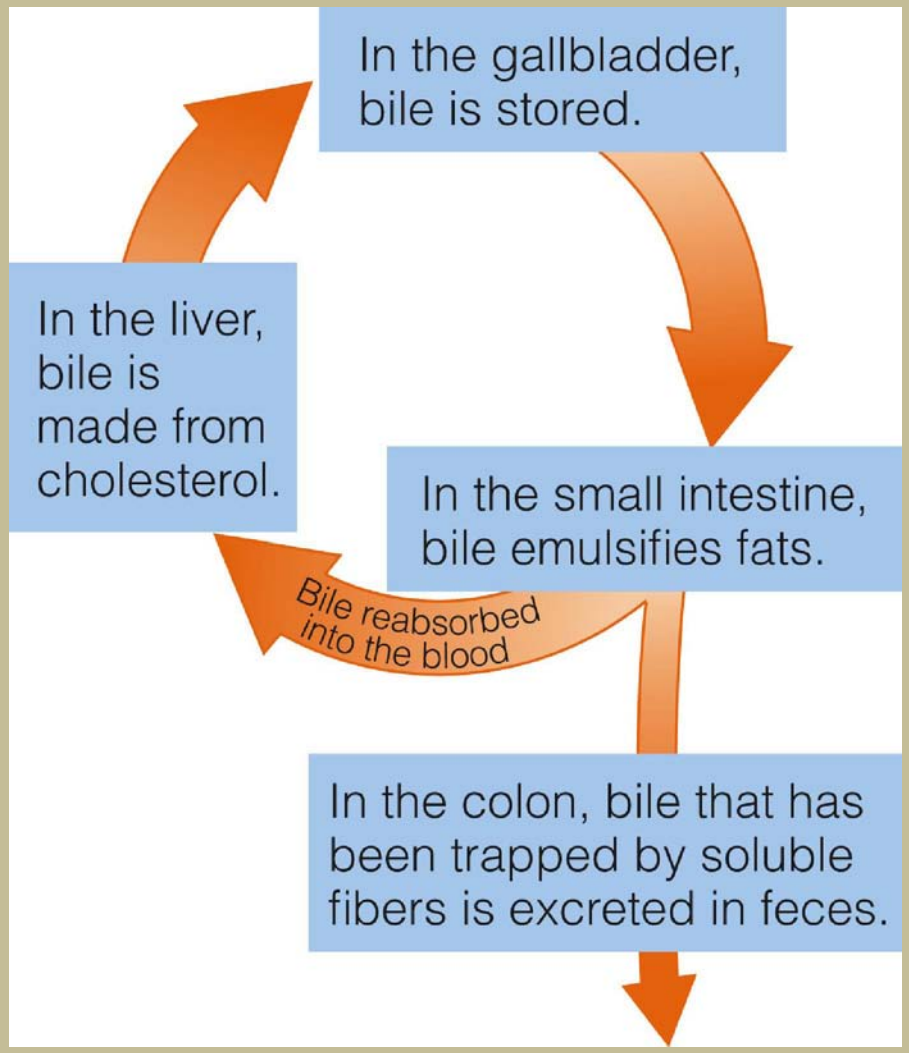
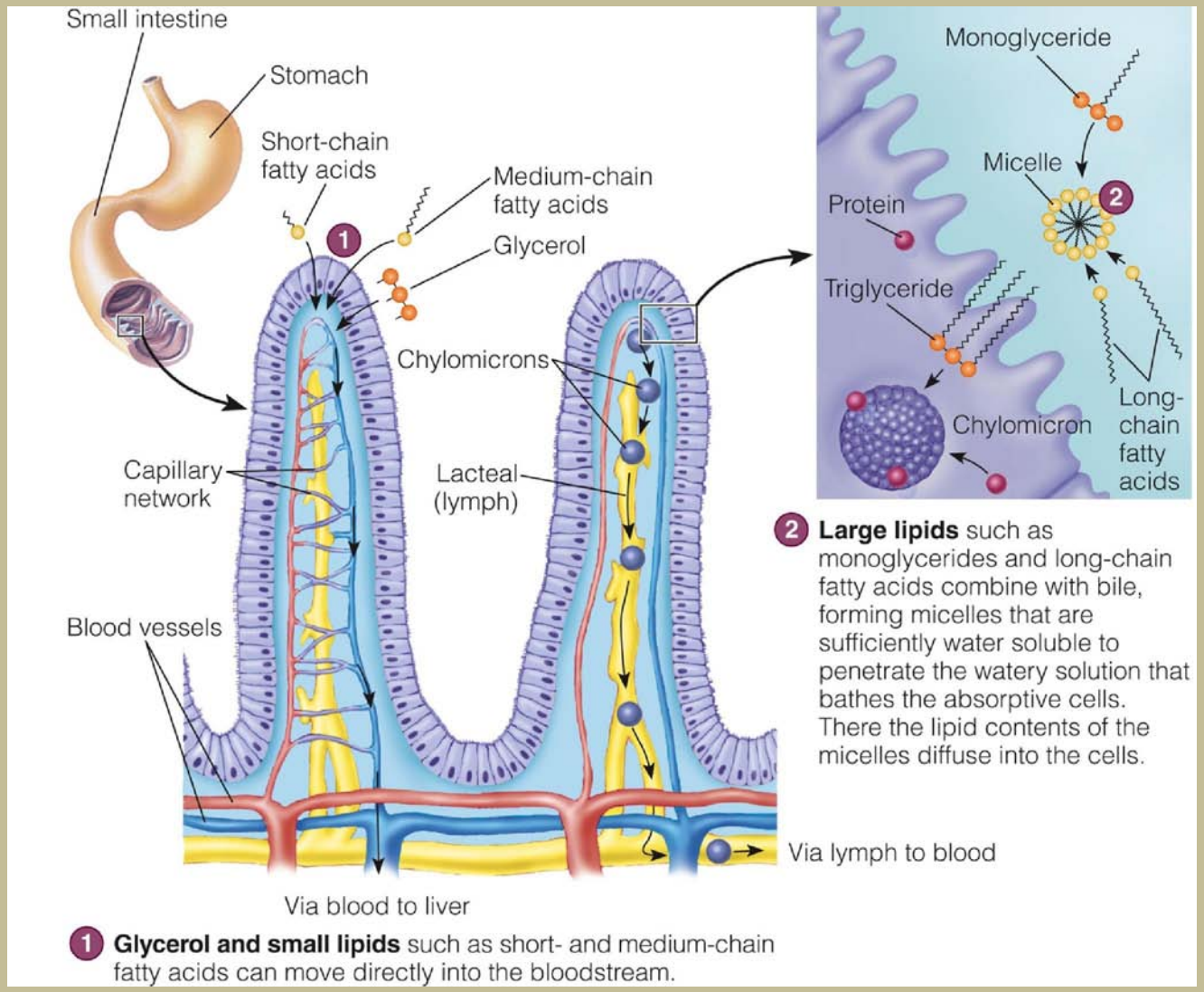
Enterohepatic Circulation of Bile



Lipid Absorption

- Circulatory System
  - Glycerol and short- & medium-chain fatty acids
- Lymphatic system
  - Monoglycerides and longer chain fatty acids emulsified into ***Micelles***
  - Micelles diffuse into intestinal cells – reassembled intoTG
  - Packed with proteins – ***chylomicrons***
  - Bypass liver at first

Absorption of Fat



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Lipid Transport

- Four main types of lipoproteins
  - Chylomicrons
  - Very Low Density Lipoproteins
  - Low Density Lipoproteins
  - High Density Lipoproteins
- Vary in the kinds and amount of lipids and protein
- High lipid content = lower density
- High protein content = high density

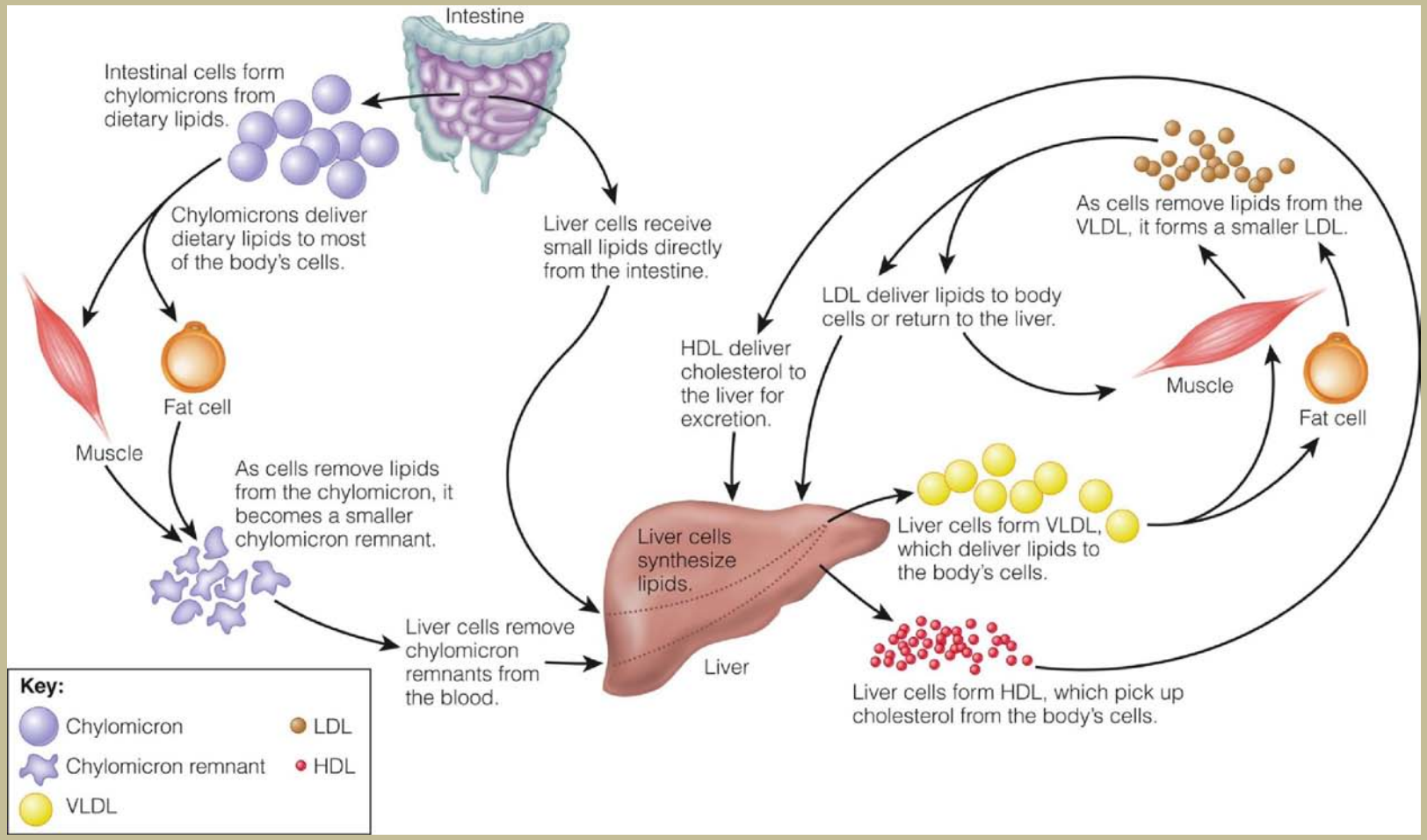
Lipid Transporters

- Chylomicrons (from the diet)
  - Largest and least dense
  - Transport diet-derived lipids in lymph to body
  - Cells remove TG as they move by
  - Liver removes remnants from blood
- Very-low-density lipoproteins (VLDL)
  - Made in the liver
  - Proportion of lipid shift – cells remove TG

Lipid Transport

- Four main types of lipoproteins
  - Low-density lipoproteins (LDL)
    - Cell needs
    - Liver regulation – special receptors remove LDL
  - High-density lipoproteins (HDL)
    - Remove cholesterol from cells
    - Carry cholesterol to liver for recycling
    - Anti-inflammatory properties
- Health implications

Lipid Transport



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Review Questions

- Name the types of lipids
- Describe the structure of a triglyceride
- What are the difference between saturated, monounsaturated, and polyunsaturated fats
- What are trans fats?
- What is a micelle
- How are fats transported in the body?
- What are the differences between LDL and HDL and why are they important in relationship to heart health?

Lipids in the Body: Triglycerides

- Function
  - Provide the cells with energy
    - Immediate use or stored
  - Insulate against temperature extremes
  - Protect against shock
  - Help body use carbs and protein efficiently

Lipids in the Body: Essential Fatty Acids

- Linoleic acid – Omega-6 fatty acid
  - Sources
- Linolenic acid – Omega-3 fatty acid
  - Sources
  - DHA
  - EPA
    - Eicosanoids
- Fatty acid deficiencies

Lipid Metabolism

- Adipose cells store fat after meals
- Using fat for energy:
  - Protein sparing
  - 60% of energy needs supplied by fat during rest
- Energy deprivation
    - Fat breakdown occurs
    - Even with excess fat available only small amount can provide glucose to brain, RBC, nerve cell
    - Without adequate carbs, ketone bodies are formed

Lipids and Health

Heart Health:
Dietary Fat and Serum Cholesterol Levels

- Saturated Fat and Trans Fats
  - ↑Total Cholesterol & LDL
- Polyunsaturated Fat
  - ↓ Total Cholesterol
  - ↓ LDL
  - ↓ HDL
- Monounsaturated Fat
  - ↓ Total Cholesterol
  - ↓ LDL
  - No effect on HDL

High-Fat Foods and Heart Disease

1% increase in dietary saturated fatty acids[a]	→	2% increase in LDL cholesterol[b] → 2% increase in heart disease risk[c]
1% decrease in dietary saturated fatty acids[a]	→	2% decrease in LDL cholesterol[b] → 2% decrease in heart disease risk[c]

Lowering Cholesterol and LDL with Diet

- Reduce Saturated Fat
- Try to eliminate all trans fats
- Limit dietary cholesterol intake
- Substitute mono and polyunsaturated fats in place of saturated and trans fats
- Increase dietary fiber and plants sterols/stanols

Reducing Saturated Fats

- Avoid butter, lard, solid shortening, stick margarine, cream cheese, sour cream
- Use lean cuts of meat; limit to 4-6 oz/day
- Consume nonfat or lowfat dairy products
- Reduce intake of cakes, cookies, pastries, ice cream
- Limit oils, margarines, mayonnaise, salad dressings
- Try to avoid tropical oils (coconut, palm)

Increase Mono and Polyunsaturated Fats

- Monounsaturated
  - Olive, canola, peanut
  - Almonds and walnuts
- Polyunsaturated
  - Corn, safflower, soybean, cottonseed

Remember portion size is key!!!

Reducing Trans fats

- Trans fats are unsaturated fats hardened in the food manufacturing process
- Trans fats act like saturated fats and can raise LDL levels
- Reduce “hydrogenated” fat intake as much as possible

Increase Plant Sterols/Stanols

- Essential components of plant cell membranes and structurally resemble cholesterol
- Reduces LDL by interfering with cholesterol absorption in the digestive tract
- 2-3 grams/day can lower LDL by 6-15%
- Food sources include:
  - Benecol and Take Control Spreads
  - Minute Maid Heartwise Orange Juice
  - Nature Valley Heart Healthy Granola Bars

Increase Dietary Fiber

- Fiber is an undigested component of plant foods
- Insoluble fiber:
  - Add bulk to diet and helps with regularity
  - Found in fruits, vegetables, grains
- Soluble fiber:
  - Forms a gel in liquids, can help control cholesterol and blood sugar levels
  - Oats, beans, lentils, barley, some fruits/vegs
  - Ground flax seed and Metamucil (psyllium)
- Consume 25-35 grams dietary fiber/day

Other Health Effects of Lipids

- Cancer
  - Promotion rather than initiation of cancer
  - Dietary fat and cancer risk
    - Differs for various types of cancer
- Obesity
  - Cutting fat from diet reduces kcalories
  - Dietary recommendations

Recommended Intakes of Fat

- DRI and Dietary Guidelines
  - Diet low in saturated and trans fat
  - Diet low in cholesterol
  - 20 to 35 percent of daily energy from fat
- AI set for linoleic and linolenic acids
- Daily Values (DV) on food labels
  - Saturated fat and cholesterol
- Risk of insufficient fat intake

From Guidelines to Groceries Healthier Fat Selections

- Functions of fat in foods
  - Fat-soluble vitamins: A, D, E, and K
  - Flavor, texture, and palatability
- Review the Food Pyramid
  - Meats and meat alternatives
  - Milk and milk products
  - Fruits, Vegetables, Grains
  - Added and Invisible Fats
- Check Food Labels

Butter Wars

Butter

Nutrition Facts
Serving Size 1 Tbsp (14g)
Servings per container about 32

Amount per serving	
Calories 100 Calories from Fat 100	
	%Daily Value*
Total Fat 11g	17%
Saturated Fat 7g	37%
Trans Fat 0g	
Cholesterol 30mg	10%
Sodium 95mg	4%
Total Carbohydrate 0g	0%
Protein 0g	
Vitamin A 8%	

Not a significant source of dietary fiber, sugars, vitamin C, calcium, and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: Cream, salt.

Margarine (stick)

Nutrition Facts
Serving Size 1 Tbsp (14g)
Servings per container about 32

Amount per serving	
Calories 100 Calories from Fat 100	
	%Daily Value*
Total Fat 11g	17%
Saturated Fat 2g	11%
Trans Fat 2.5g	
Polyunsaturated Fat 3.5g	
Monounsaturated Fat 2.5g	
Cholesterol 0mg	0%
Sodium 105mg	4%
Total Carbohydrate 0g	0%
Protein 0g	
Vitamin A 10%	

Not a significant source of dietary fiber, sugars, vitamin C, calcium, and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: Liquid soybean oil, partially hydrogenated soybean oil, water, buttermilk, salt, soy lecithin, sodium benzoate (as a preservative), vegetable mono and diglycerides, artificial flavor, vitamin A palmitate, colored with beta carotene (provitamin A).

Margarine (tub)

Nutrition Facts
Serving size 1 Tbsp (14g)
Servings per container about 32

Amount per serving	
Calories 100 Calories from Fat 100	
	%Daily Value*
Total Fat 11g	17%
Saturated Fat 2.5g	13%
Trans Fat 2g	
Polyunsaturated Fat 4g	
Monounsaturated Fat 2.5g	
Cholesterol 0mg	0%
Sodium 80mg	3%
Total Carbohydrate 0g	0%
Protein 0g	
Vitamin A 10%	

Not a significant source of dietary fiber, sugars, vitamin C, calcium, and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: Liquid soybean oil, partially hydrogenated soybean oil, buttermilk, water, butter (cream, salt), salt, soy lecithin, vegetable mono and diglycerides, sodium benzoate added as a preservative, artificial flavor, vitamin A palmitate, colored with beta carotene.

Margarine (liquid)

Nutrition Facts
Serving size 1 Tbsp (14g)
Servings per container about 24

Amount per serving	
Calories 70 Calories from Fat 70	
	%Daily Value*
Total Fat 8g	13%
Saturated Fat 1.5g	7%
Trans Fat 0g	
Polyunsaturated Fat 4.5g	
Monounsaturated Fat 2g	
Cholesterol 0mg	0%
Sodium 110mg	8%
Total Carbohydrate 0g	0%
Protein 0g	
Vitamin A 10%	

Not a significant source of dietary fiber, sugars, vitamin C, calcium, and iron.

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: Liquid soybean oil, water, salt, hydrogenated cottonseed oil, vegetable monoglycerides and soy lecithin (emulsifiers), potassium sorbate and sodium benzoate (to preserve freshness), artificial flavor, phosphoric acid (acidulant), colored with beta carotene (source of vitamin A), vitamin A palmitate.

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Case Study: Diet and Heart Disease

Activity: Chocolate and Heart Health