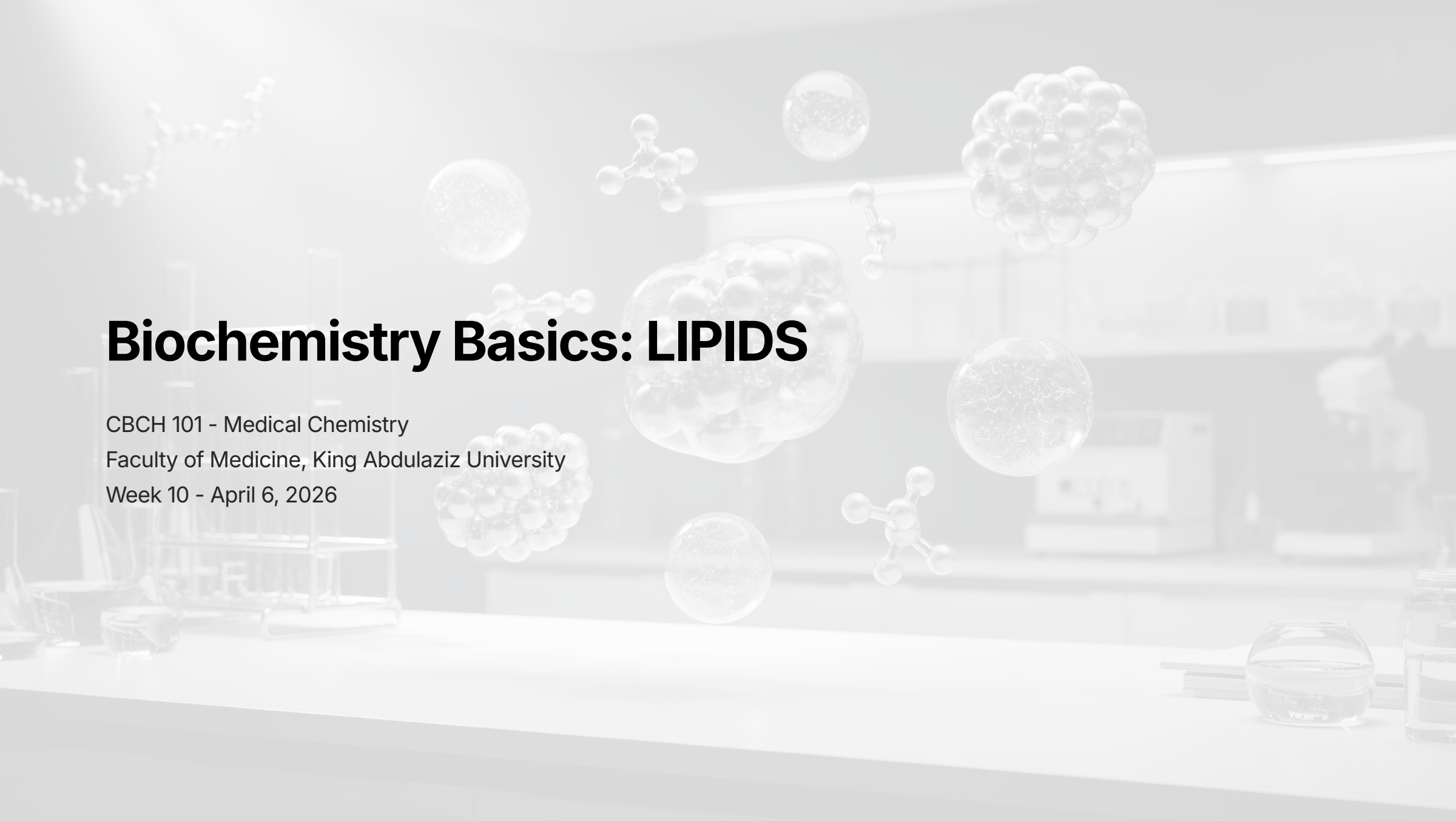




Biochemistry Basics: LIPIDS

CBCH 101 - Medical Chemistry

Faculty of Medicine, King Abdulaziz University

Week 10 - April 6, 2026

Subject Learning Outcomes (SLOs)

By the end of this lecture, you will be able to:

1

SLO 1

Identify and classify the major types of lipids based on their structural characteristics and biological roles

2

SLO 2

Describe the chemical structure of fatty acids and differentiate between saturated and unsaturated fatty acids

3

SLO 3

Recognize essential fatty acids, explain why they are nutritionally essential, and identify their dietary sources

4

SLO 4

Explain the structure of triacylglycerols and describe their primary function as energy storage molecules

5

SLO 5

Describe the amphipathic structure of phospholipids and explain how this enables cell membrane bilayer formation

6

SLO 6

Describe cholesterol structure and explain its physiological functions in membranes, hormones, and bile acids

7

SLO 7

Differentiate between LDL and HDL cholesterol transport and relate lipid profiles to cardiovascular health

8

SLO 8

Identify fat-soluble vitamins, their functions, and recognize clinical consequences of their deficiency

What Are Lipids? Definition & Importance

Definition

Lipids are a diverse group of **hydrophobic or amphipathic** organic molecules that are **largely insoluble in water** but dissolve in nonpolar solvents (chloroform, ether, alcohol).

Basic Properties:

- Made mostly of carbon (C), hydrogen (H), and some oxygen (O)
- Feel greasy or oily to touch
- Examples: oils, butter, fats, waxes

Why Are Lipids Important?

- **Energy Storage:** Store energy for later use (most efficient energy reserve)
- **Cell Structure:** Build cell membranes (protective barriers around cells)
- **Insulation:** Keep body warm (subcutaneous fat layer)
- **Protection:** Cushion vital organs (kidneys, heart)
- **Vitamin Absorption:** Help absorb fat-soluble vitamins (A, D, E, K)
- **Signaling:** Act as hormones and signaling molecules

Classification of Lipids



1. Fatty Acids

Building blocks of other lipids. Long chains of carbon atoms with hydrogen. Contain carboxyl group (COOH)



2. Triacylglycerols (Triglycerides)

Main form of stored fat in body. Made of 3 fatty acids + glycerol backbone. Primary energy storage molecules



3. Phospholipids

Main component of cell membranes. Amphipathic: hydrophilic head + hydrophobic tails



4. Steroids

Include cholesterol and hormones. Special 4-ring fused structure. Important for membranes and signaling



5. Other Lipids

Waxes (protective coatings), Fat-soluble vitamins (A, D, E, K), Eicosanoids (signaling molecules)



Key Feature: All lipids share one property — they are **hydrophobic or amphipathic** (don't mix well with water)

Fatty Acids — Building Blocks of Lipids

Basic Structure

A fatty acid consists of:

- **Carboxyl group (COOH):** Acidic head (one end)
- **Hydrocarbon chain:** Long chain of carbon atoms with hydrogen (middle)
- **Methyl group (CH3):** Terminal end (other end)

General Formula: CH₃-(CH₂)_n-COOH

Understanding the Notation:

18:2 means: **18** = number of carbon atoms in the chain; **2** = number of double bonds (C=C)

Omega number (ω-3, ω-6, ω-9): Position of first double bond counting from the methyl (CH₃) end

Classification by Saturation

Saturated Fatty Acids

- **"Saturated"** = full of hydrogen atoms
- All carbon-carbon bonds are **single bonds (C-C)**
- Chains are **straight** (no kinks)
- **Solid at room temperature**
- Pack tightly together
- **Examples:** butter, animal fats, lard

Unsaturated Fatty Acids

- **"Unsaturated"** = missing some hydrogen
- Have one or more **double bonds (C=C)**
- Chains have **kinks or bends**
- **Liquid at room temperature (oils)**
- Cannot pack tightly (weaker forces)
- **Examples:** olive oil, fish oil, vegetable oils

 **Health Tip:** Unsaturated fats are generally healthier for the heart than saturated fats

Common Fatty Acids — Know These!

Common Name	Carbons:Double Bonds	Type	State
Palmitic acid	16:0	Saturated	Solid
Stearic acid	18:0	Saturated	Solid
Oleic acid	18:1 (omega-9)	Monounsaturated	Liquid
Linoleic acid	18:2 (omega-6)	Polyunsaturated (ESSENTIAL)	Liquid
Alpha-linolenic acid	18:3 (omega-3)	Polyunsaturated (ESSENTIAL)	Liquid

Essential Fatty Acids

Your body CANNOT make these fatty acids — you must get them from food! Humans lack the enzymes needed to insert double bonds at omega-3 and omega-6 positions.

Omega-6 Fatty Acids (ω -6)

Main one: Linoleic Acid (18:2)

Found in:

- Vegetable oils (corn, sunflower, safflower)
- Nuts and seeds
- Soybeans

Functions:

- Healthy skin and cell membranes
- Cell growth and development
- Brain function
- Inflammation regulation

Omega-3 Fatty Acids (ω -3)

Main one: Alpha-linolenic Acid (18:3)

Found in:

- Fatty fish (salmon, mackerel, sardines)
- Flaxseeds and flaxseed oil
- Walnuts
- Chia seeds

Functions:

- Heart and cardiovascular health
- Brain development and function
- Reduce inflammation
- Protect against chronic diseases

📖 **Deficiency Symptoms:** Skin problems (dermatitis), poor wound healing, growth problems in children, neurological issues

Triacylglycerols (Triglycerides) & Phospholipids

Triacylglycerols — Structure & Function

Glycerol backbone (3-carbon alcohol) + **3 Fatty Acids** = Triglyceride

The fatty acids attach to glycerol through **ester bonds**. Think of it like the letter "E" — one backbone with three arms.

Primary Function: Energy Storage

9 kcal/g

Fats provide 9 kilocalories per gram

4 kcal/g

Carbohydrates and proteins only provide 4 kilocalories per gram

Fat stores **MORE THAN TWICE** the energy! Stored in specialized cells called **adipose tissue (fat cells)**

Other Functions:

1. **Thermal Insulation:** Subcutaneous fat layer keeps body warm
2. **Mechanical Protection:** Fat pads cushion vital organs (kidneys, heart)
3. **Metabolic Water Source:** Oxidation of fats produces water

📌 **Remember:** Triglycerides = STORAGE form of fat. When you need energy, triglycerides are broken down to release fatty acids.

Phospholipids — Cell Membrane Builders

Structure: Similar to Triglycerides, BUT Different!

- Glycerol backbone (same as triglycerides)
- Only **2 fatty acids** attached (NOT 3!)
- Third position has a **phosphate group** attached to a polar molecule

Special Property: AMPHIPATHIC

This means phospholipids have TWO different parts:

HYDROPHILIC HEAD

- "Water-loving"
- Contains phosphate group (polar)
- Attracted to water
- Faces aqueous environment

HYDROPHOBIC TAILS

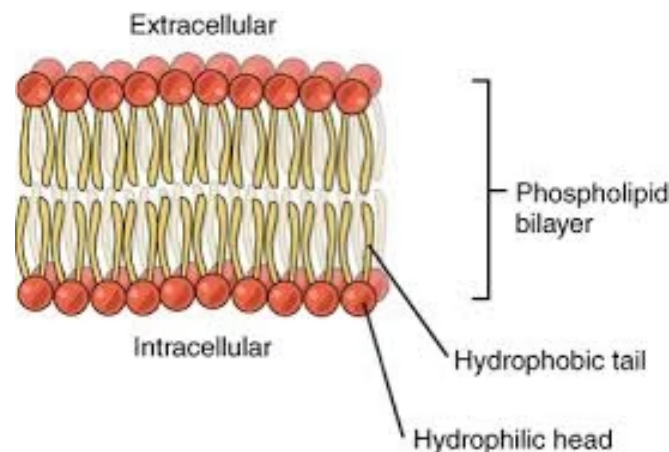
- "Water-fearing"
- Two fatty acid chains (nonpolar)
- Repelled by water
- Faces away from water

Main Function: Cell Membrane Formation

- Phospholipids spontaneously arrange in a **bilayer (double layer)** in water
- **Hydrophilic heads** face OUTWARD toward water (both inside and outside cell)
- **Hydrophobic tails** face INWARD toward each other (away from water)
- This creates a **selective barrier** that controls what enters/exits the cell

The Phospholipid Bilayer — Cell Membrane Structure

In an aqueous (water) environment, phospholipids **automatically** arrange into a bilayer:



The diagram illustrates the cross-section of a cell membrane showing a bilayer of phospholipids. Each phospholipid consists of a **hydrophilic head** (facing the aqueous environments) and two **hydrophobic tails** (oriented toward each other in the interior). The environments are labeled as **EXTRACELLULAR FLUID (Water)** at the top and **CYTOPLASM (Water)** at the bottom.



Creates a barrier

The hydrophobic interior blocks water-soluble molecules



Selective permeability

Controls what can enter or exit the cell



Fluid structure

Allows membrane flexibility and movement



Self-repairing

Phospholipids can move to seal small tears



Key Concept: The amphipathic nature of phospholipids (having both hydrophilic and hydrophobic parts) is what allows them to spontaneously form membranes. This happens automatically — no energy required!

Cholesterol — Essential Steroid

Structure: Unique 4-Ring System

Cholesterol is a **steroid** with a distinctive structure:

- **Four fused carbon rings** (steroid nucleus) — rigid structure
- **Hydroxyl group (-OH)** at one end — slightly polar
- **Hydrocarbon tail** — nonpolar
- Molecular formula: $C_{27}H_{46}O$

Important Biological Functions of Cholesterol:

1 Cell Membrane Component: Intercalates (fits between) phospholipids in membranes. Modulates membrane **fluidity and stability**. Prevents membranes from being too fluid or too rigid. Hydroxyl group near surface; rings interact with fatty acid tails

3 Precursor for Bile Acids: Bile acids help digest and absorb dietary fats. Made in liver, stored in gallbladder

2 Precursor for Steroid Hormones: Sex hormones: Testosterone, estrogen, progesterone. Adrenal hormones: Cortisol (stress), aldosterone (blood pressure)

4 Precursor for Vitamin D: Skin converts cholesterol to vitamin D_3 when exposed to sunlight (UV light). Essential for calcium absorption and bone health

Cholesterol Transport in Blood

The Problem: Cholesterol is a **lipid (fatty substance)** → doesn't dissolve in blood (which is mostly water)

Solution: Cholesterol is packaged with proteins into particles called **LIPOPROTEINS**

Two Main Types of Lipoproteins:

Type	Nickname	What It Does	Health Effect
LDL (Low-Density Lipoprotein)	"BAD" Cholesterol ✗	Transports cholesterol FROM liver TO peripheral tissues (delivery truck)	High LDL → cholesterol deposits in arteries → atherosclerosis → heart attack/stroke
HDL (High-Density Lipoprotein)	"GOOD" Cholesterol ✓	Transports cholesterol FROM tissues BACK TO liver (garbage truck — removes excess)	High HDL → protects against heart disease by removing cholesterol from arteries

Normal Values (Memorize These!):

- **Total Cholesterol:** Less than 200 mg/dL (desirable)
- **LDL Cholesterol:** Less than 100 mg/dL (optimal); Less than 130 mg/dL (near optimal)
- **HDL Cholesterol:** Greater than 40 mg/dL in men; Greater than 50 mg/dL in women (protective)
- **Triglycerides:** Less than 150 mg/dL (normal)

 **Easy Way to Remember:** LDL = "Lousy/Lethal" cholesterol (BAD) | HDL = "Healthy/Happy" cholesterol (GOOD)

Clinical: Lipid Disorders, Fat-Soluble Vitamins & Fat Malabsorption

Lipid Disorders and Health

1. High Cholesterol (Hypercholesterolemia) Problem: Elevated LDL cholesterol in blood (greater than 130–160 mg/dL) Consequences: LDL deposits cholesterol in arterial walls → forms plaques (atherosclerosis) → narrows arteries, restricts blood flow → increases risk of heart attack and stroke Treatment: Diet: Reduce saturated fats, increase fiber and omega-3. Exercise: Regular physical activity. Medications: Statins (if lifestyle changes insufficient)	2. Low HDL Cholesterol Problem: HDL less than 40 mg/dL (men) or less than 50 mg/dL (women) Consequences: Less cholesterol removed from arteries → increased cardiovascular risk Treatment: Exercise, quit smoking, healthy fats (olive oil, fish)	3. High Triglycerides (Hypertriglyceridemia) Problem: Triglycerides greater than 150 mg/dL (often 200–500+ mg/dL)
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Fat Malabsorption Syndromes

Condition where the body **cannot properly absorb dietary fats** from the intestine

Common Causes:

- **Pancreatic insufficiency:** Not enough pancreatic enzymes (lipase) to digest fats
- **Bile deficiency:** Liver disease or gallbladder problems → not enough bile salts
- **Celiac disease:** Damage to small intestine lining
- **Crohn's disease:** Inflammatory bowel disease affecting absorption
- **Cystic fibrosis:** Thick mucus blocks pancreatic ducts
- **Very low-fat diets:** Insufficient dietary fat intake

Consequences of Fat Malabsorption:

1. **Fat-Soluble Vitamin Deficiencies (A, D, E, K):** Vitamin A → Night blindness, dry skin, poor immunity. Vitamin D → Weak bones (rickets in children, osteomalacia in adults). Vitamin E → Nerve damage, muscle weakness. Vitamin K → Bleeding problems (poor blood clotting)
2. **Essential Fatty Acid Deficiency**

Fat-Soluble Vitamins (A, D, E, K)

These vitamins dissolve in **fats and oils** (NOT in water). You need to eat some dietary fat to absorb these vitamins from food! They are stored in **liver and adipose tissue** (unlike water-soluble vitamins).

Vitamin	Main Functions	Deficiency Symptoms	Food Sources
Vitamin A (Retinol)	Vision (especially night vision via rhodopsin); Healthy skin and epithelial cells; Immune function; Growth and development	Night blindness (nyctalopia); Dry eyes (xerophthalmia); Dry, scaly skin; Poor wound healing; Impaired immunity	Carrots, sweet potatoes, liver, dairy, dark leafy greens
Vitamin D (Cholecalciferol)	Calcium absorption in intestine; Strong bones and teeth; Immune system support; Cell growth regulation	Rickets (children) — soft, weak bones; Osteomalacia (adults) — bone pain; Increased fracture risk; Muscle weakness	Sunlight exposure, fatty fish, fortified milk, egg yolks
Vitamin E (Tocopherol)	Antioxidant — protects cells from oxidative damage; Protects cell membranes; Immune function	Hemolytic anemia; Neurological problems; Muscle weakness; Vision problems (rare)	Nuts, seeds, vegetable oils, green leafy vegetables
Vitamin K (Phylloquinone)	Blood clotting (synthesis of clotting factors); Bone metabolism; Prevents excessive bleeding	Prolonged bleeding time; Easy bruising; Hemorrhage; Weak bones	Green leafy vegetables (spinach, kale, broccoli), liver

Summary

1

Lipids

Hydrophobic or amphipathic molecules essential for life, insoluble in water

2

Fatty Acids

Building blocks of complex lipids. **Saturated** (no C=C bonds) = solid fats; **Unsaturated** (one or more C=C) = liquid oils. **Essential fatty acids** (linoleic acid 18:2 omega-6; alpha-linolenic 18:3 omega-3) cannot be synthesized by body. Know: Palmitic (16:0), Stearic (18:0), Oleic (18:1), Linoleic (18:2), Linolenic (18:3)

3

Triglycerides

Main energy storage (3 fatty acids + glycerol); provide 9 kcal/g

4

Phospholipids

Amphipathic (hydrophilic head + hydrophobic tails). Form bilayer membranes with heads facing water, tails facing each other. Essential for all cell membranes

5

Cholesterol

Steroid with 4-ring structure. Functions: membrane stability, precursor for hormones/bile acids/vitamin D. **LDL** ("bad") delivers cholesterol to tissues → high LDL causes atherosclerosis. **HDL** ("good") removes cholesterol from tissues → high HDL is protective. Normal values: Total less than 200 mg/dL; LDL less than 100 mg/dL; HDL greater than 40 mg/dL

6

Fat-Soluble Vitamins (A, D, E, K)

Require dietary fat for absorption. Vitamin A → night vision (deficiency causes night blindness). Vitamin D → calcium absorption, bone health. Vitamin E → antioxidant. Vitamin K → blood clotting. Fat malabsorption syndromes cause deficiencies

Practice Question — Case Scenario

A 48-year-old patient presents for routine health screening. Blood lipid panel results:

- Total Cholesterol: 260 mg/dL
- LDL: 180 mg/dL
- HDL: 32 mg/dL
- Triglycerides: 320 mg/dL

Questions to Think About:

1. Are these values normal or abnormal? Compare to normal ranges.
2. What is the primary cardiovascular risk concern?
3. Which value is most concerning: high LDL or low HDL?
4. What dietary and lifestyle modifications would you recommend?

Answers:

1 All values are **ABNORMAL** (Total greater than 200; LDL greater than 130; HDL less than 40; TG greater than 150)

2 **Very high risk** for atherosclerosis and cardiovascular disease (heart attack/stroke)

3 **BOTH are concerning** — high LDL deposits cholesterol in arteries; low HDL means less cholesterol removal

4 Reduce saturated fats, increase omega-3 (fish), exercise regularly, weight loss, possibly statin medication

References: Ferrier, D.R. (2022). *Lippincott's Illustrated Reviews: Biochemistry* (8th ed.)

Thank You! Questions?

CBCH 101 - Medical Chemistry | Department of Clinical Biochemistry, Faculty of Medicine, King Abdulaziz University