



الأيض (١)

**Metabolism (1)**

**BCH 340**

**Lecture 9: Lipid metabolism**

# Intended learning outcomes (ILOs)

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

- Define lipids and explain their diverse biological functions.
- Classify lipids based on their chemical structure.
- Explain the process of lipid digestion in the gastrointestinal tract.
- Discuss the absorption of lipids in the small intestine.

# Introduction

- Lipids are a diverse group of organic molecules that are insoluble in water but **soluble in nonpolar solvents** such as chloroform, ether, and benzene.
- They play essential roles in living organisms, serving as structural components of cell membranes, energy storage molecules, and signaling molecules.
- Lipids are characterized by their **hydrophobic nature**, which arises from their long hydrocarbon chains and nonpolar chemical structures.

# Classification of lipids

Lipids

Simple lipids

Esters of fatty acids with alcohol

- Fats and oils
- Waxes

Conjugated lipids

Esters of fatty acids with alcohol and additional functional group

- Phospholipids
- Glycolipids
- Lipoproteins

Derived lipids

Hydrolysis of simple or complex lipids

- Fatty acids
- Cholesterol
- Ketone bodies

# Functions of lipids

- Lipids (**particularly triglycerides**) serve as a major source of energy in the body.
  - They **store energy** in adipose tissue for later use during times of fasting or increased energy demands.
  - Lipids provide more than twice as much energy (**9 Kcal/1 gm** of lipids) as carbohydrates.
- Some lipids serve as **structural component** of cell membranes (e.g., phospholipids and cholesterol).
- Cholesterol is the **sole precursor** of steroid hormones (such as cortisol, aldosterone, estrogen, and testosterone).
  - These hormones play crucial roles in regulating various physiological processes, including metabolism, growth, reproduction, and stress response.

# Functions of lipids (cont.)

- Adipose tissue (primarily composed of triglycerides) acts as an insulating layer beneath the skin.
  - It helps to maintain **body temperature** by reducing heat loss from the body and protecting internal organs from temperature fluctuations.
- Lipids serve as protective coatings around vital organs (such as the kidneys and heart), providing them with a layer of **protection** and **shock absorption**.
- Lipids facilitate the absorption of **fat-soluble vitamins** (A, D, E, and K) in the intestine.

# Dietary lipids

- The average daily intake of lipids for an adult man can vary depending on factors such as dietary habits, lifestyle, and energy requirements.
  - However, a common recommendation is that fats should contribute around 20% to 35% of total daily caloric intake.
- The main lipids found in diet are:
  - Triglycerides (also known as triacylglycerols)
  - Phospholipids
  - Sterols (e.g. cholesterol)

# Digestion of lipids

## In the mouth:

- Digestion of lipids begins in the mouth, where **lingual lipase** (secreted by the salivary glands) starts breaking down triglycerides into smaller molecules (diglycerides and free fatty acids).
  - However, lingual lipase plays a minor role in overall lipid digestion compared to other digestive enzymes. **Why??**

## In the stomach:

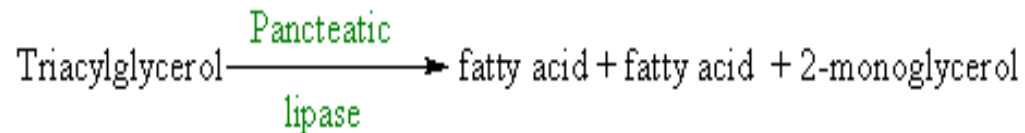
- Once food reaches the stomach, **gastric lipase** (secreted by the gastric glands) continues the digestion of lipids.
- Gastric lipase works optimally in the **acidic environment of the stomach** and further breaks down triglycerides into diglycerides and free fatty acids.

# Digestion of lipids (cont.)

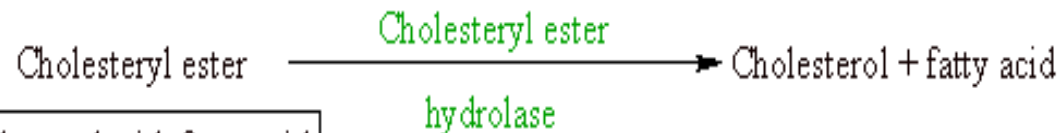
## In the small intestine:

- The majority of lipid digestion occurs in the small intestine.
- When partially digested food (chyme) enters the duodenum, it triggers the release of hormones such as **cholecystokinin** and **secretin**, which stimulate the release of bile and pancreatic enzymes.
- Bile **emulsifies** large lipid droplets into smaller droplets, increasing the surface area for enzyme action.
- Pancreatic lipase (along with co-lipase), then hydrolyzes emulsified triglycerides into **2-monoglycerides** and **free fatty acids**.

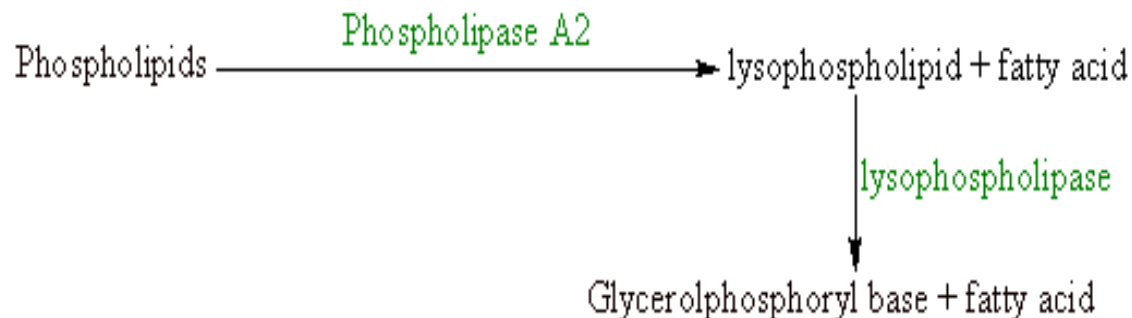
## Enzymatic digestion of lipids in small intestine



i.e. two fatty acids from carbons 1 and 3 are removed leaving 1 fatty acid attached to carbon 2 of the glycerol.



Cholesterol with fatty acid  
attached by ester linkage

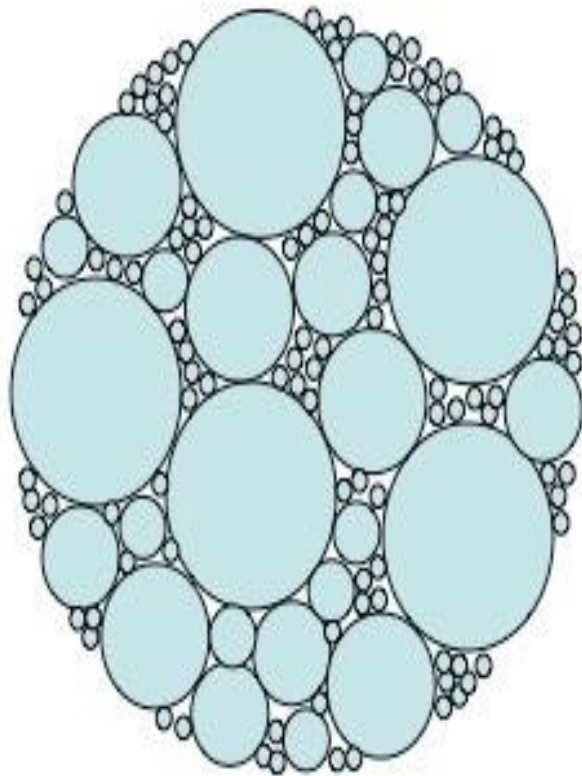


# Digestion of lipids (cont.)

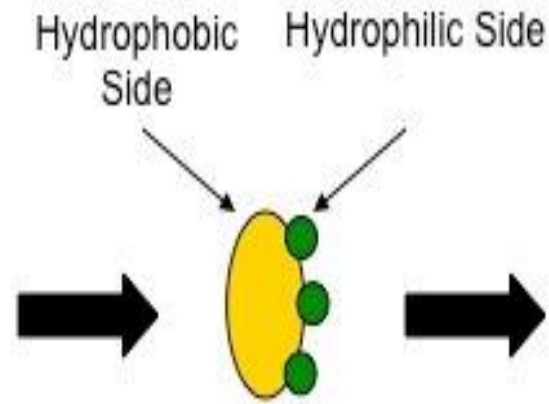
## Micelle formation:

- Monoglycerides, fatty acids, and other lipid-digestion products associate with bile salts and other lipophilic molecules to form **micelles** (small water-soluble complexes).
- Micelle formation is the process by which lipids are **solubilized** and **emulsified** in the aqueous environment of the intestinal lumen, allowing for efficient enzymatic digestion and absorption.
- Micelles transport lipid digestion products to the brush border membrane of enterocytes (absorptive cells) lining the small intestine.

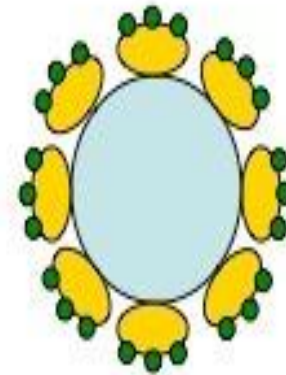
# Formation of emulsified droplets



**Fat Globule**



**Bile Salt**



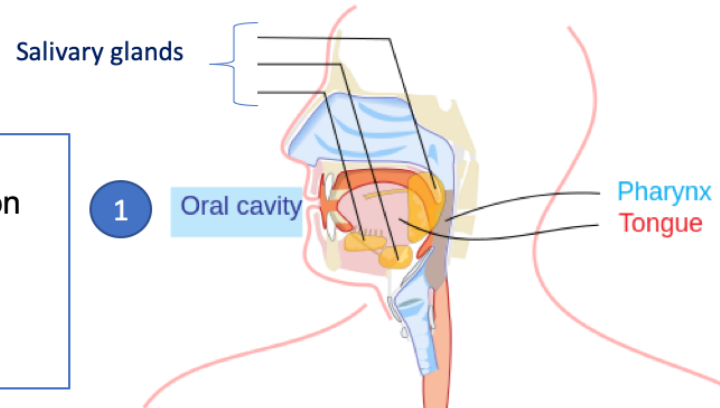
**Emulsified Droplets**



# Lipid digestion in the human gastrointestinal tract

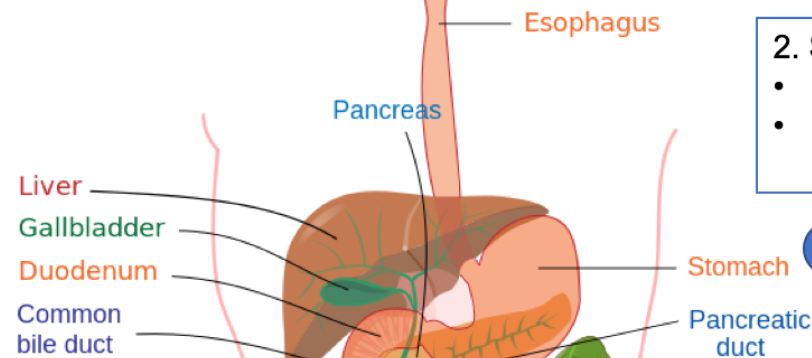
## 1. MOUTH

- mechanical digestion
- mixing with saliva
- limited enzymatic digestion (*lingual lipase*)



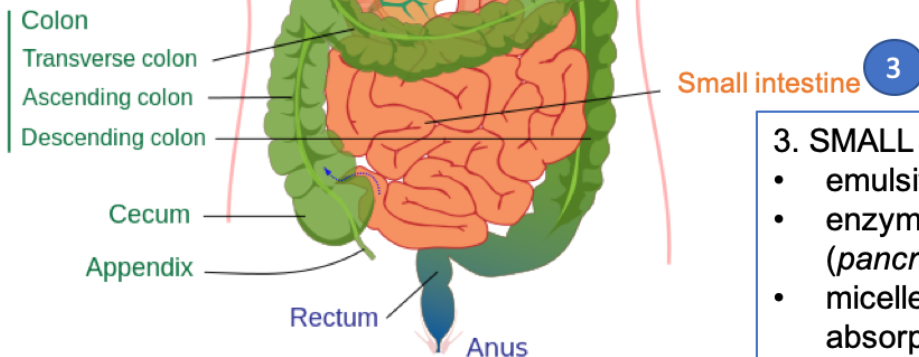
## 2. STOMACH

- mixing/churning
- limited enzymatic digestion (*gastric lipase*)



## 3. SMALL INTESTINE

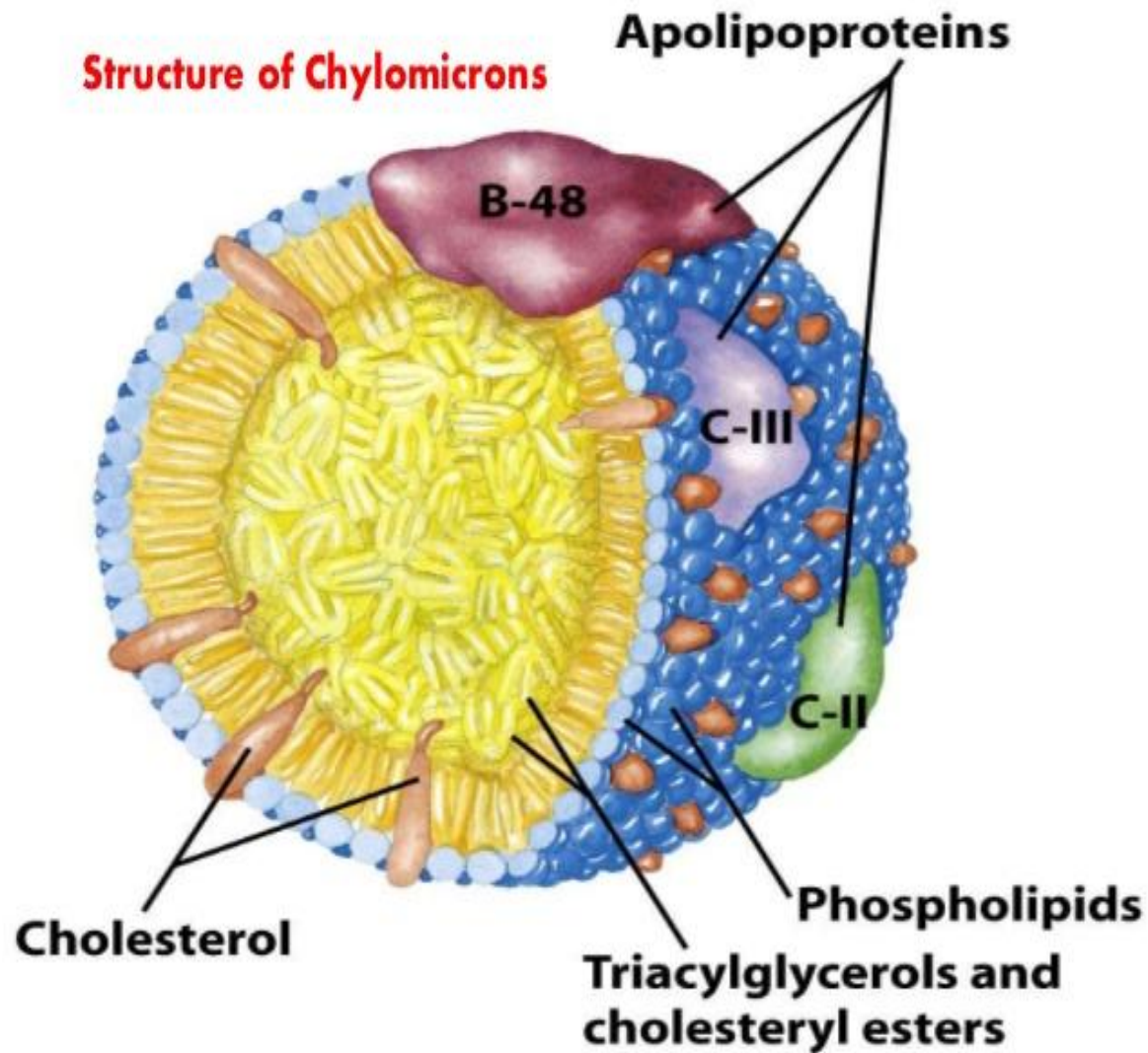
- emulsification (bile)
- enzymatic digestion (*pancreatic lipases*)
- micelles help with absorption

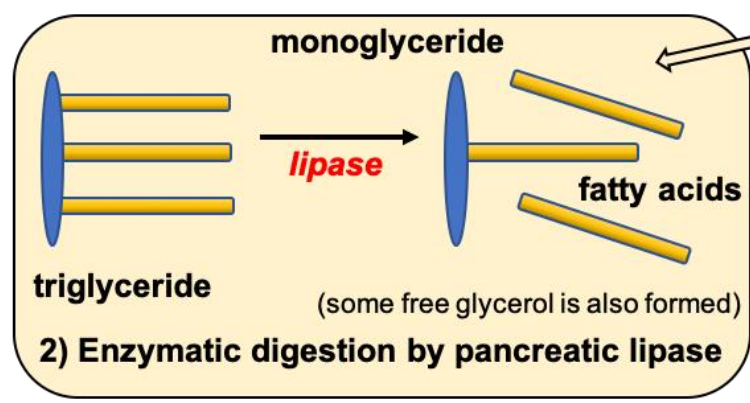
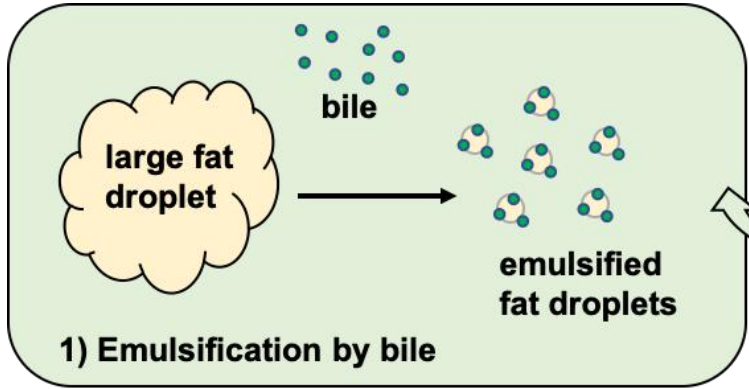


# Lipid absorption from the small intestine

- The formation of micelles **increases the solubility** of lipids in the aqueous environment, allowing them to come into close contact with the absorptive epithelial cells lining the small intestine (enterocytes).
- The hydrophobic core of the micelles facilitates the **passive diffusion of lipids** across the plasma membrane of the enterocytes.
- Once inside the enterocytes, the monoglycerides and fatty acids are **re-esterified into triglycerides** and packaged into chylomicrons.
- Chylomicrons are then released into the lymphatic system and transported to various tissues throughout the body for utilization or storage.

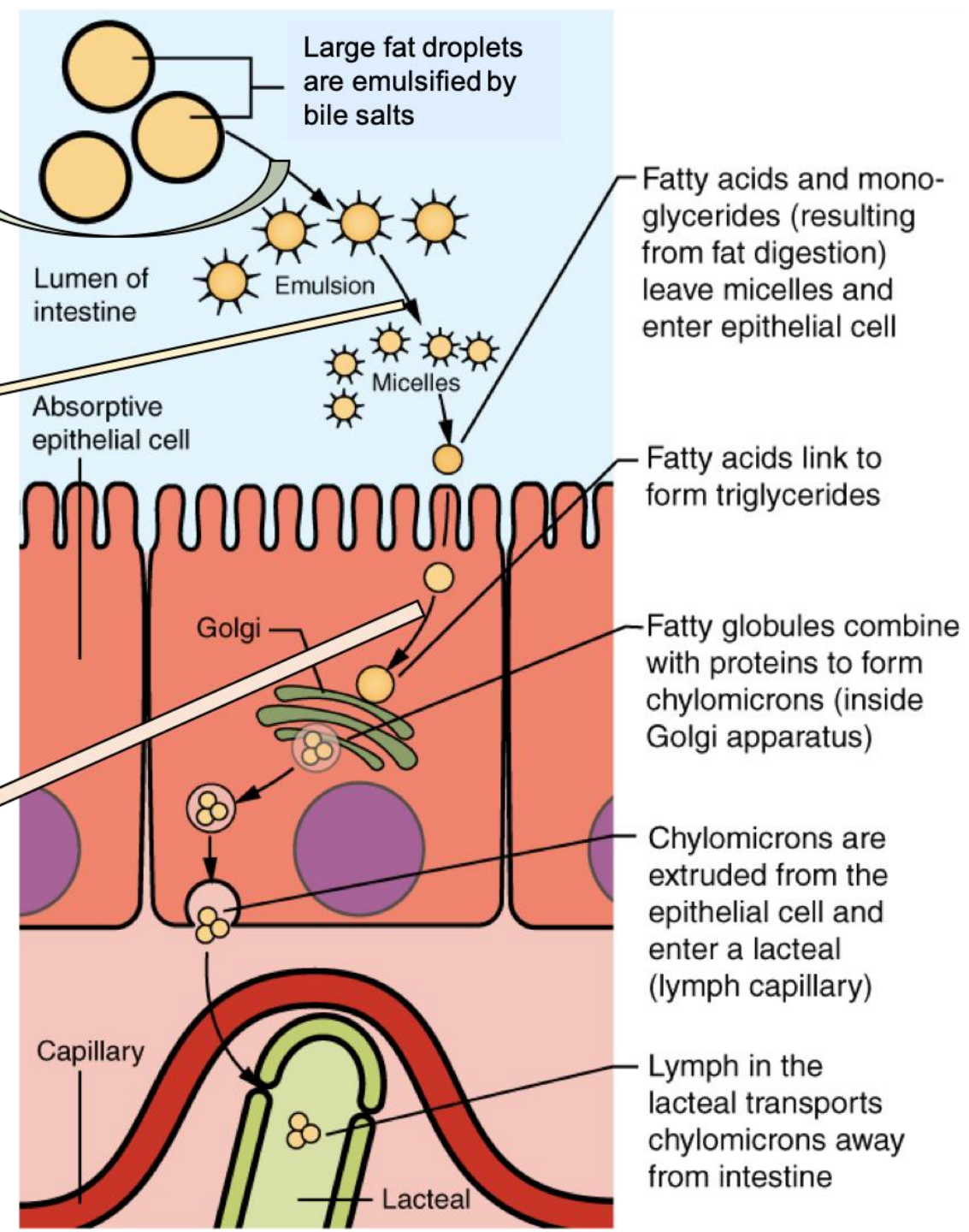
# Structure of chylomicrons





**3) Absorption of products of fat digestion depends on size**

- Short and medium-chain fatty acids and glycerol (small products) → absorbed into blood via capillary (not shown in figure)
- Long-chain fatty acids and monoglycerides (large products) → form into triglycerides and are transported in chylomicrons into lymph vessels



# Summary

- Lipids are classified based on their chemical structure to three major categories; simple, conjugated and derived lipids.
- Dietary lipids (such as triglycerides, phospholipids, and cholesterol) undergo digestion in the gastrointestinal tract, primarily through pancreatic lipases in the small intestine.
- The digested lipids are absorbed as free fatty acids and monoglycerides into intestinal cells before being transported via chylomicrons into the lymphatic system to various tissues throughout the body.