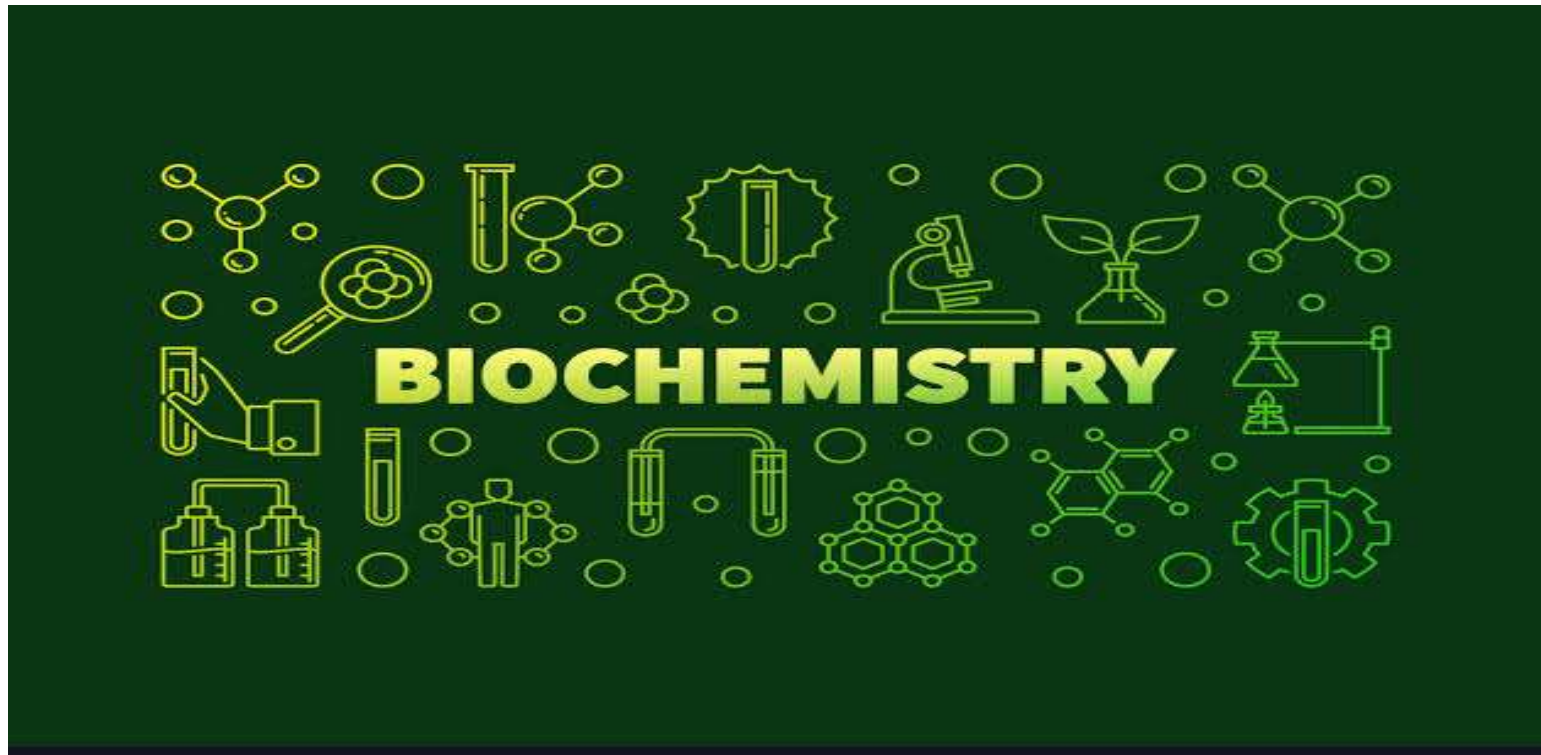




LIPIDS----- BC 4.2

Digestion & absorption of dietary lipids
& it's associated disorders



SLO :Learner will be able to describe digestion & absorption of lipids & its associated disorders

Lipids are a heterogeneous group of **hydrophobic** organic molecules found in cells

- Sparingly soluble in water
- Soluble in organic solvents
(acetone, ether, alcohol, chloroform)

LIPIDS

Simple

- Fats and oils
- Waxes

Compound

- Phospholipids
- Glycolipids
- Proteolipids
(Lipoproteins)

Derived

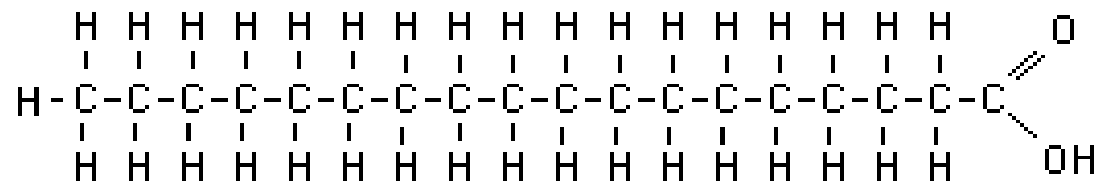
- Fatty acids
- Alcohols
(Glycerol, sterol, etc.)

Fig. 9.1. Classification of lipids.

Fatty Acids

Definition

Fatty acids are carboxylic acids with a long Hydrocarbon chain

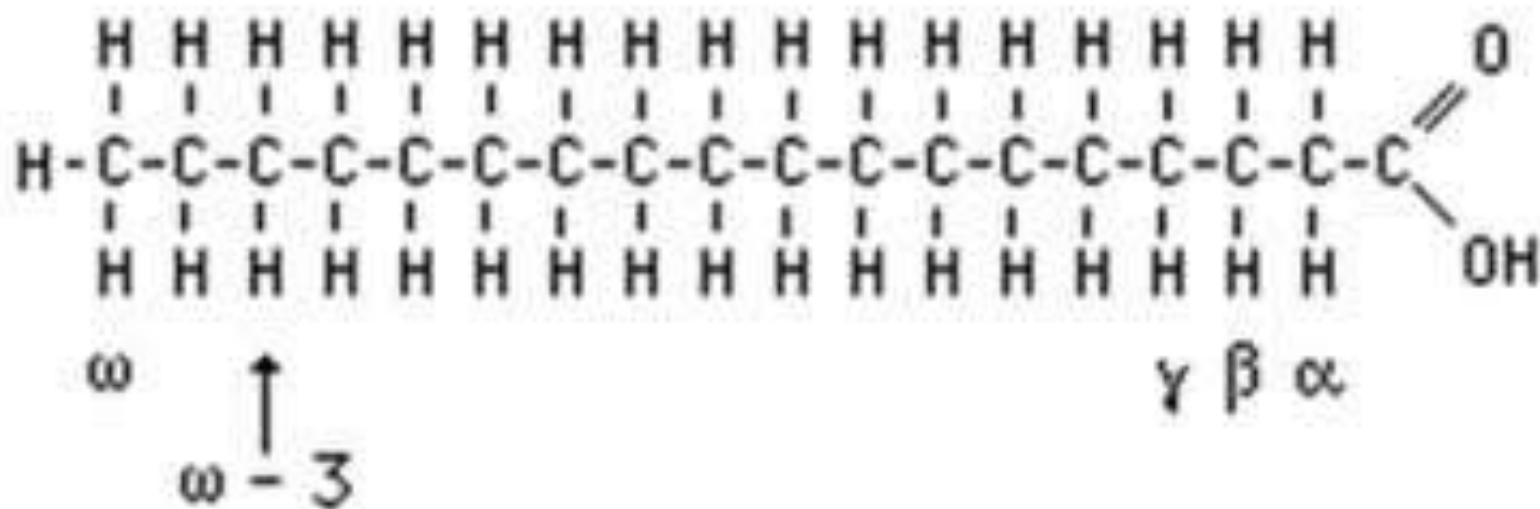


long hydrocarbon chain

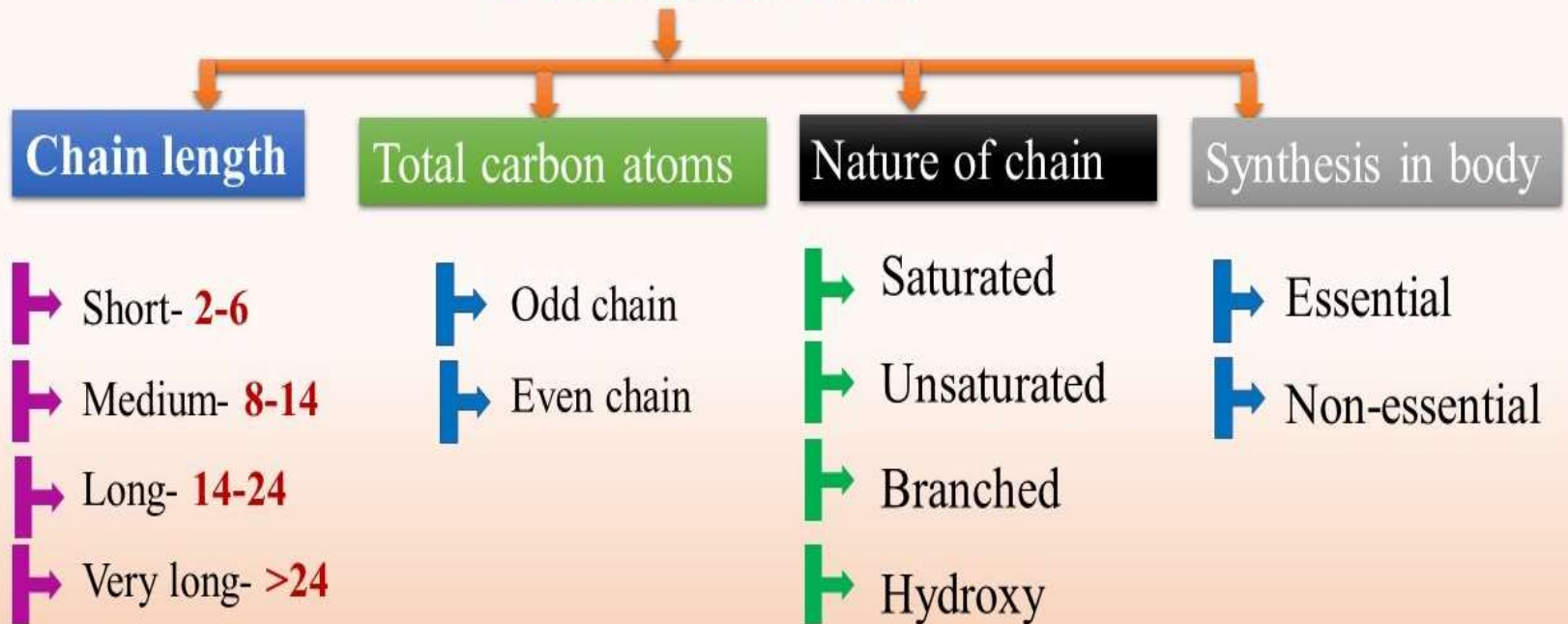
carboxylic
acid group

Essential features of a fatty acid

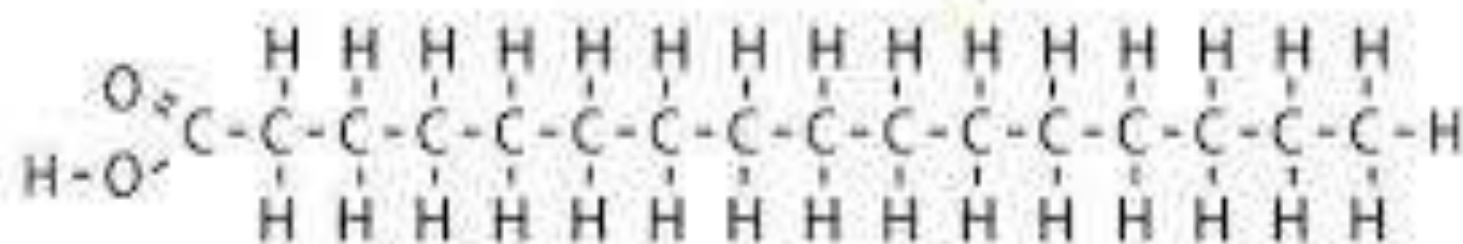
Nomenclature



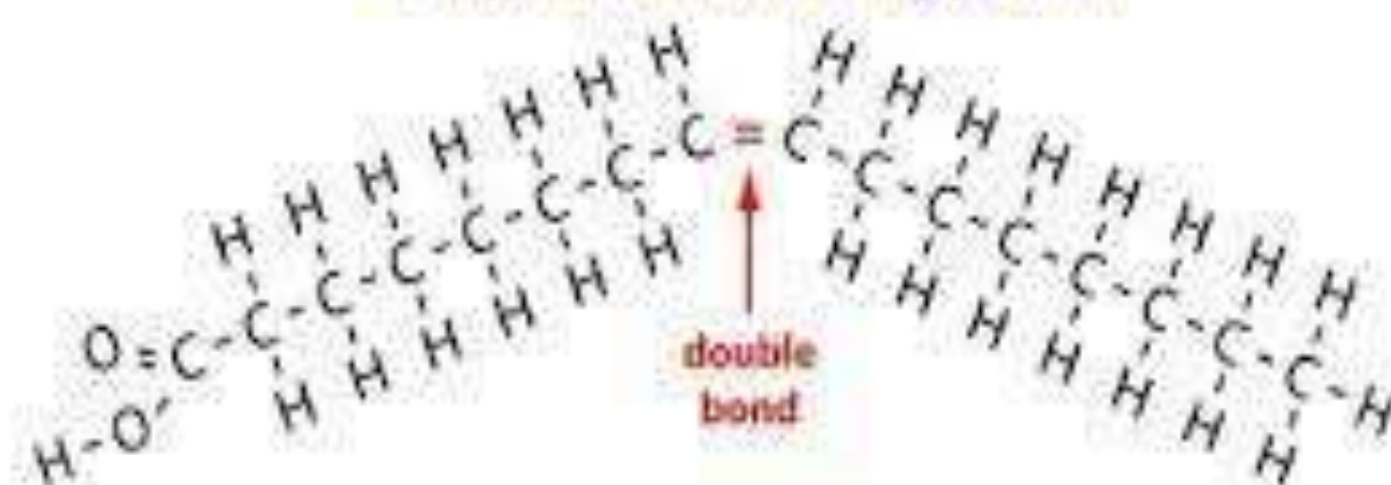
Classification



saturated fatty acid



unsaturated fatty acid



TYPES OF FATTY ACIDS

(according to the number of double bonds)



Saturated (No bond)



Monounsaturated (1 bond)



Polyunsaturated (>1 bond)

Saturated Fatty acids

Systematic Name	Common Name	No. of Carbon Atoms*	Typical Fat Source
Ethanoic	Acetic	2	--
Butanoic	Butyric ★	4	Butterfat
Hexanoic	Caproic	6	Butterfat
Octanoic	Caprylic	8	Coconut oil
Decanoic	Capric	10	Coconut oil
Dodecanoic	Lauric	12	Coconut oil
Tetradecanoic	Myristic	14	Butterfat, coconut oil
Hexadecanoic	Palmitic ★	16	Most fats and oils
Heptadecanoic	Margaric	17	Animal fats
Octadecanoic	Stearic ★	18	Most fats and oils
Eicosanoic	Arachidic	20	Peanut oil
Docosanoic	Behenic	22	Peanut oil



Source: Strayer , 2006

*A number of saturated odd and even chain acids are present in many fats and oils.

Table 9.2. Common saturated fatty acids

Structure	Common name
$\text{CH}_3\text{—COOH}$	Acetic acid
$\text{CH}_3(\text{CH}_2)_2\text{—COOH}$	Butyric acid
$\text{CH}_3\text{—}(\text{CH}_2)_{14}\text{—COOH}$	Palmitic acid
$\text{CH}_3\text{—}(\text{CH}_2)_{16}\text{—COOH}$	Stearic acid

Saturated Fat

meats, butter,
dairy products

solid at room
temperature

increase levels of
“**bad**” cholesterol
(low-density lipoprotein)

low-density lipoprotein
clogs arteries



Unsaturated Fat

vegetable oils

liquid at room
temperature

increase levels of
“**good**” cholesterol
(high-density lipoprotein)

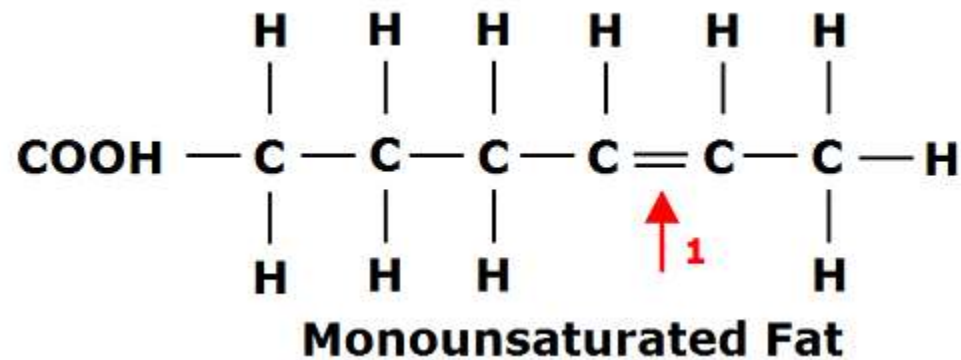
high-density lipoprotein,
or HDL, “grabs” LDL
and escorts it to the liver
where **LDL is broken down**
and eventually removed
from the body



Un saturated Fatty acids

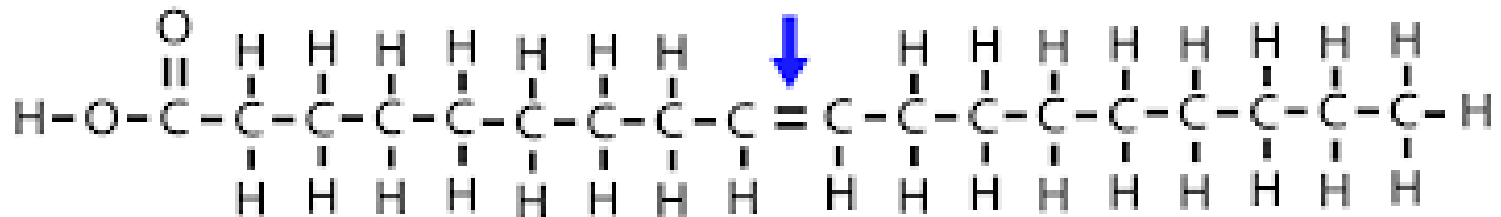
Typical Naturally Occurring Unsaturated Fatty Acids			
Acid	Number of Carbon Atoms	Degree of Unsaturation*	Formula
Palmitoleic	16	16:1— Δ^9	$\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}(\text{CH}_2)_7\text{CO}_2\text{H}$
Oleic	18	18:1— Δ^9	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CO}_2\text{H}$
Linoleic	18	18:2— $\Delta^{9,12}$	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CH}(\text{CH}_2)\text{CH}=\text{CH}(\text{CH}_2)_7\text{CO}_2\text{H}$
Linolenic	18	18:3— $\Delta^{9,12,15}$	$\text{CH}_3(\text{CH}_2\text{CH}=\text{CH})_3(\text{CH}_2)_7\text{CO}_2\text{H}$
Arachidonic	20	20:4— $\Delta^{5,8,11,14}$	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CH}(\text{CH}_2)_4(\text{CH}_2)_2\text{CO}_2\text{H}$

MUFA one double bond

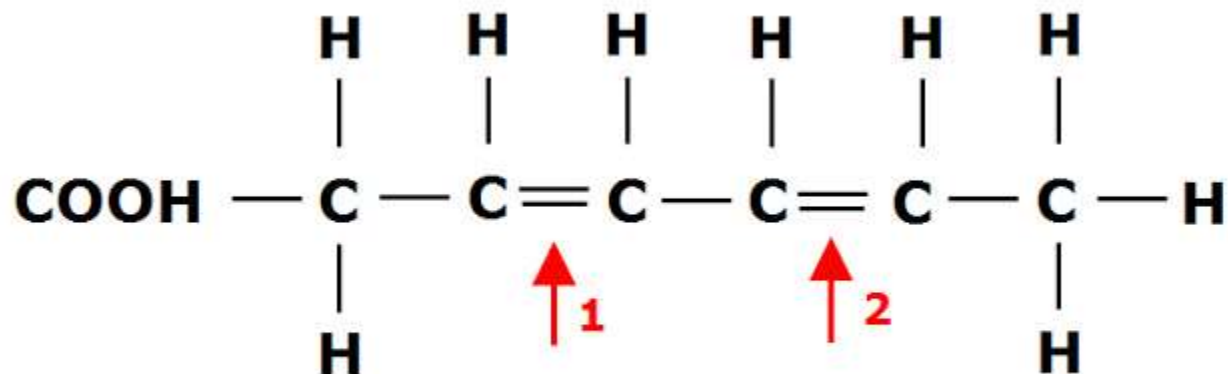


MUFA egs:Oleic acid -18 C

Oleic acid - Monounsaturated fatty acid



PUFA >one double bond



Polyunsaturated Fat

PUFA examples



Linoleic acid (C_{18:2})



α -Linolenic acid (C_{18:3})



Arachidonic acid (C_{20:4})

Sources of PUFA

Plant oils

Soyabean oil, sunflower oil, ground nut oil

Linoleic & Linolenic acid are EFA

(**Essential fatty acids**, since they cannot be synthesised inside body)

If EFA supplied in diet, Arachidonic acid can be synthesised.

Fish oils rich in penta enoic acid

$\omega 3$ family-----Linolenic acid &
Penta enoic acid

$\omega 6$ family---Linoleic & Arachidonic acid

$\omega 9$ family-----Oleic acid

Significance of PUFA

- Linoleic acid, Linolenic acid, & Arachidonic acid (EFA) in diet necessary for growth & normal health.(EFA)
- ω 6 fatty acids in diet help in lowering of Plasma cholesterol by esterification

- Diet rich in ω 3 fatty acids help in reduction of triacyl glycerols (TAG) in plasma
- Arachidonic acid is precursor of Prostaglandins, thromboxanes, leukotrienes.

Trans fatty acids

- Trans-fatty acids are **manufactured fats created during a process called hydrogenation**, which is aimed at **stabilizing polyunsaturated oils** to prevent them from becoming **rancid** and to keep them solid at room temperature. They may be particularly **dangerous for heart** health and may pose a risk for certain **cancers** .

Trans-fatty acids are found in fried foods, commercial baked goods, processed foods and margarine



Trans fatty acids in food items: **Margarine, vanaspati, ghee, bakery and frying fats** and are obtained through industrial hydrogenation and contain significant amounts of TFA.

- Trans fats raise LDL (bad) cholesterol. They lower HDL (good) cholesterol. High LDL along with low HDL levels can cause cholesterol to build up in arteries (blood vessels). This increases risk for heart disease and stroke

- What foods are high in saturated and trans fats?

Saturated fat occurs naturally in **red meat and dairy products**. It's also found in baked foods and fried foods.

Trans fat occurs naturally in small amounts in red meat and dairy products. Trans fat can also be manufactured by adding hydrogen to vegetable oil

- What foods do not contain trans fats?

Whole foods like **fruits, vegetables, whole grains, beans, lean meats, fish, nuts, and lean poultry**

Good fats

- Unsaturated fats — **Monounsaturated and polyunsaturated fats** — lower disease risk.
Foods high in good fats include vegetable oils (such as olive, sunflower, soy, and corn), nuts, seeds, and fish.

Digestion & Absorption of Lipids

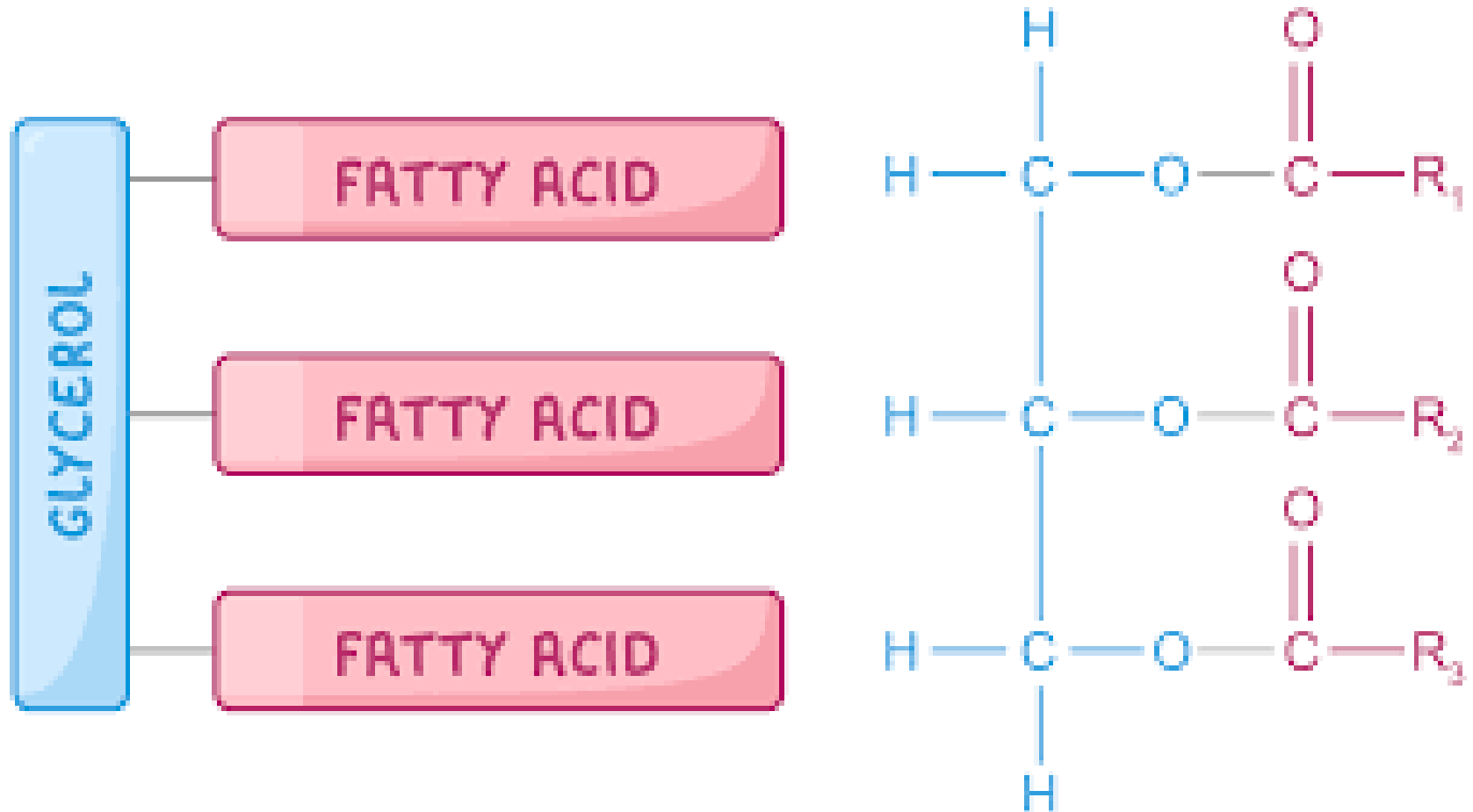
Digestion & Absorption of Lipids

- Digestion in stomach
- Digestion in intestine
- Role of Bile salts in digestion & absorption(Emulsification, Mixed Micelle formation)
- Difference in Absorption of LCFA ,SCFA & MCFA
- Disorders

**Major dietary lipids are TAG,Cholesterol
& phospholipids**

**Average normal indian diet contains
20-30 gm of Lipids**

Tri Acyl Glycerol(TAG) Triglyceride(TG)



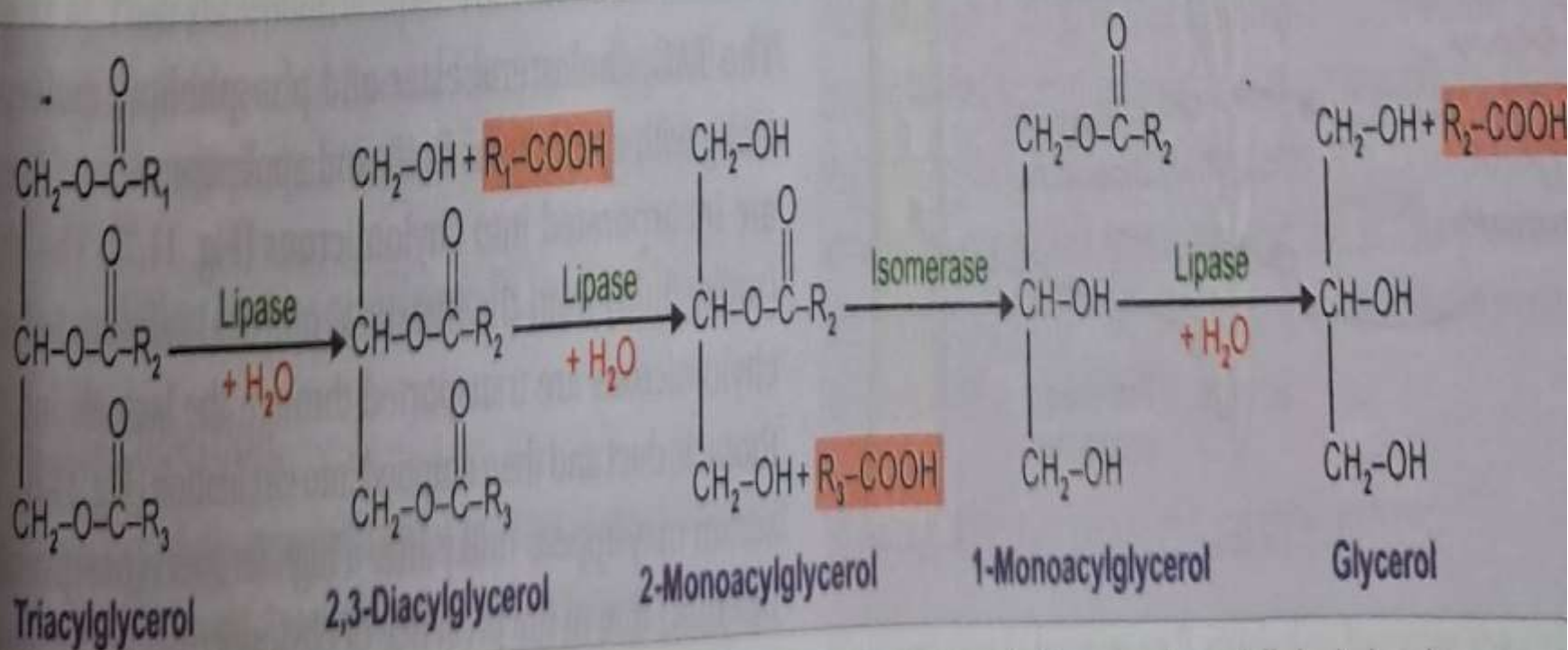


Fig. 11.2: Complete hydrolysis of triglyceride. In the intestines, generally fats are only partially hydrolyzed.

1) Digestion in stomach

- a) Lingual lipase -----act on SCT in milk butter,ghee, coconut oil etc

- b) Gastric lipase---- secreted by chief cells

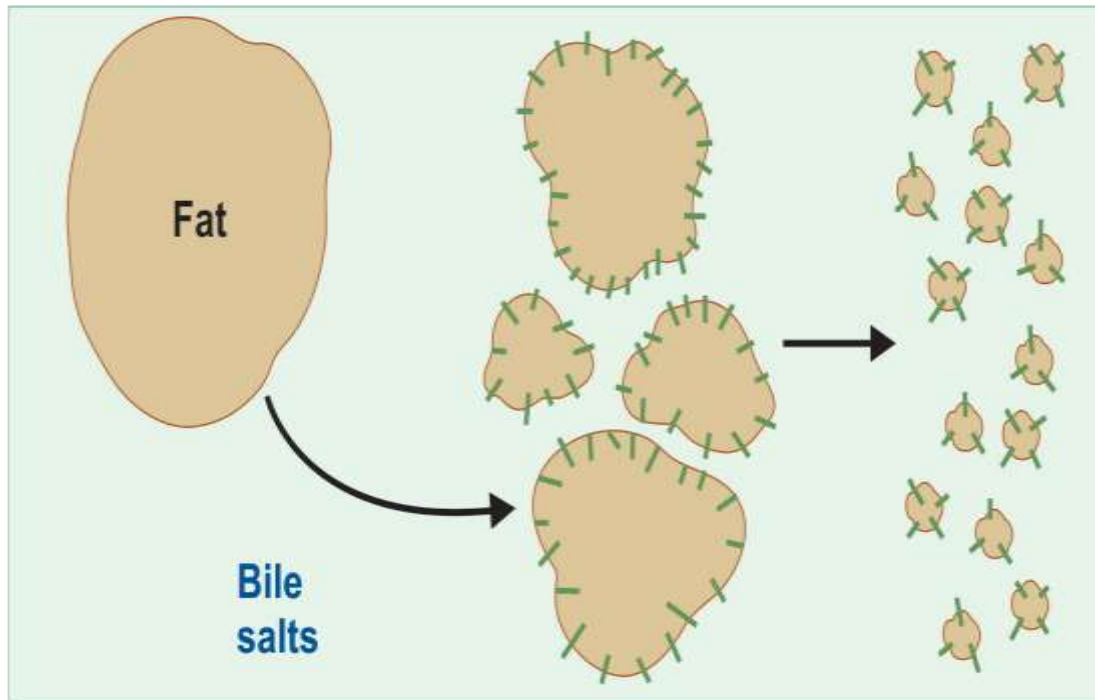
2) Digestion in intestine

1) Emulsification is a prerequisite for digestion of lipids.

By bile salts, peristalsis (mechanical mixing) & phospholipids

Bile salts are important for digestion of lipids

- Bile salts reduce the surface tension & **emulsify** fat droplets, surface area of fat droplets are increased for enhanced activity of enzymes



Action of bile salts. The hydrophobic portions of bile salts intercalate into the large aggregated lipid with the hydrophilic domains remaining at the surface. This leads to breakdown of large aggregates into smaller and smaller droplets. Thus, the surface area for action of lipase is increased.

Lipolytic enzymes in intestine

Pancreatic lipase with co lipase,

Cholesterol esterase

Phospholipase A2

Bile entering the duodenum make the pH
alkaline

Pancreatic lipase with co lipase further
hydrolyse the neutral fats in alkaline pH .

Micellar formation

Bile salts surround the hydrolysed products of fat digestion and form water soluble globules with a fatty core called micelles

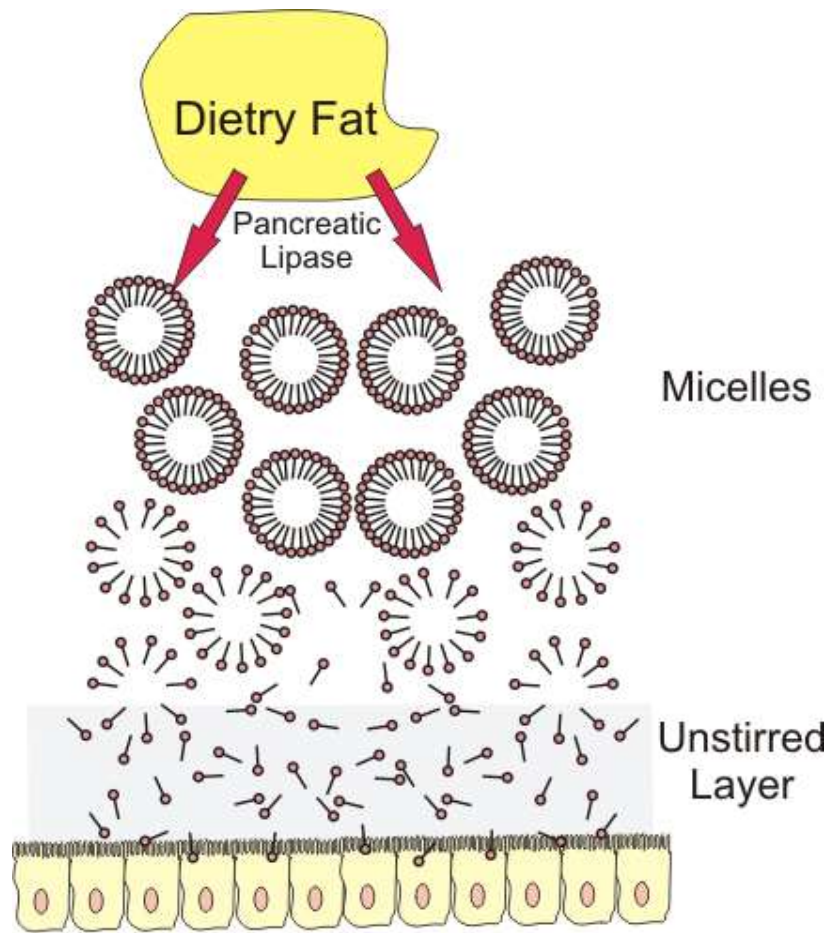
Action of Lipase ,co-lipase,phospholipase on TAG

Major end products of digestion of TAG

(Tri Acyl Glycerol) are

2-MAG, 1-MAG, DAG Glycerol , fatty acids.

Along with cholesterol, lysophospholipids form
molecular aggregates & incorporated into
micelle.



Frank Bounphrey M.D. 2009

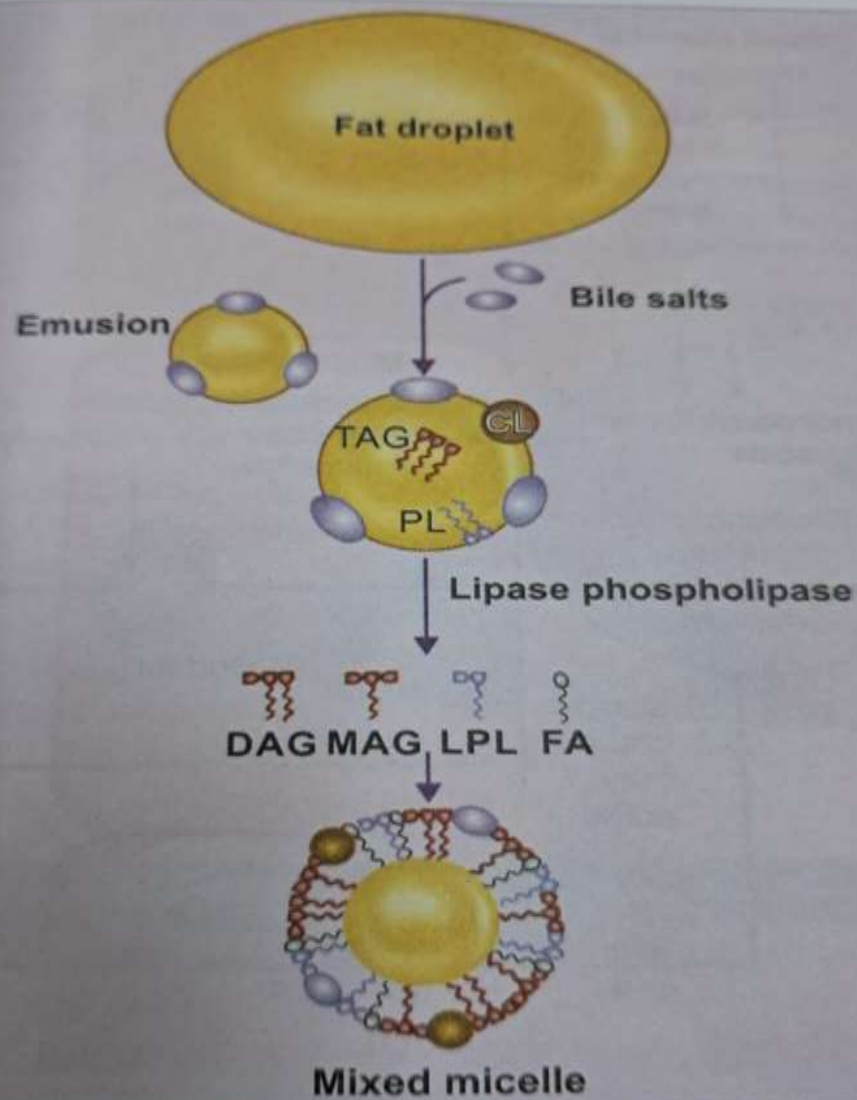


Fig. 11.1: Action of bile salts.

TAG: triacylglycerol, PL: phospholipid, DAG: diacylglycerol, MAG: monoacylglycerol, LPL: lysophospholipid, FA: fatty acid.

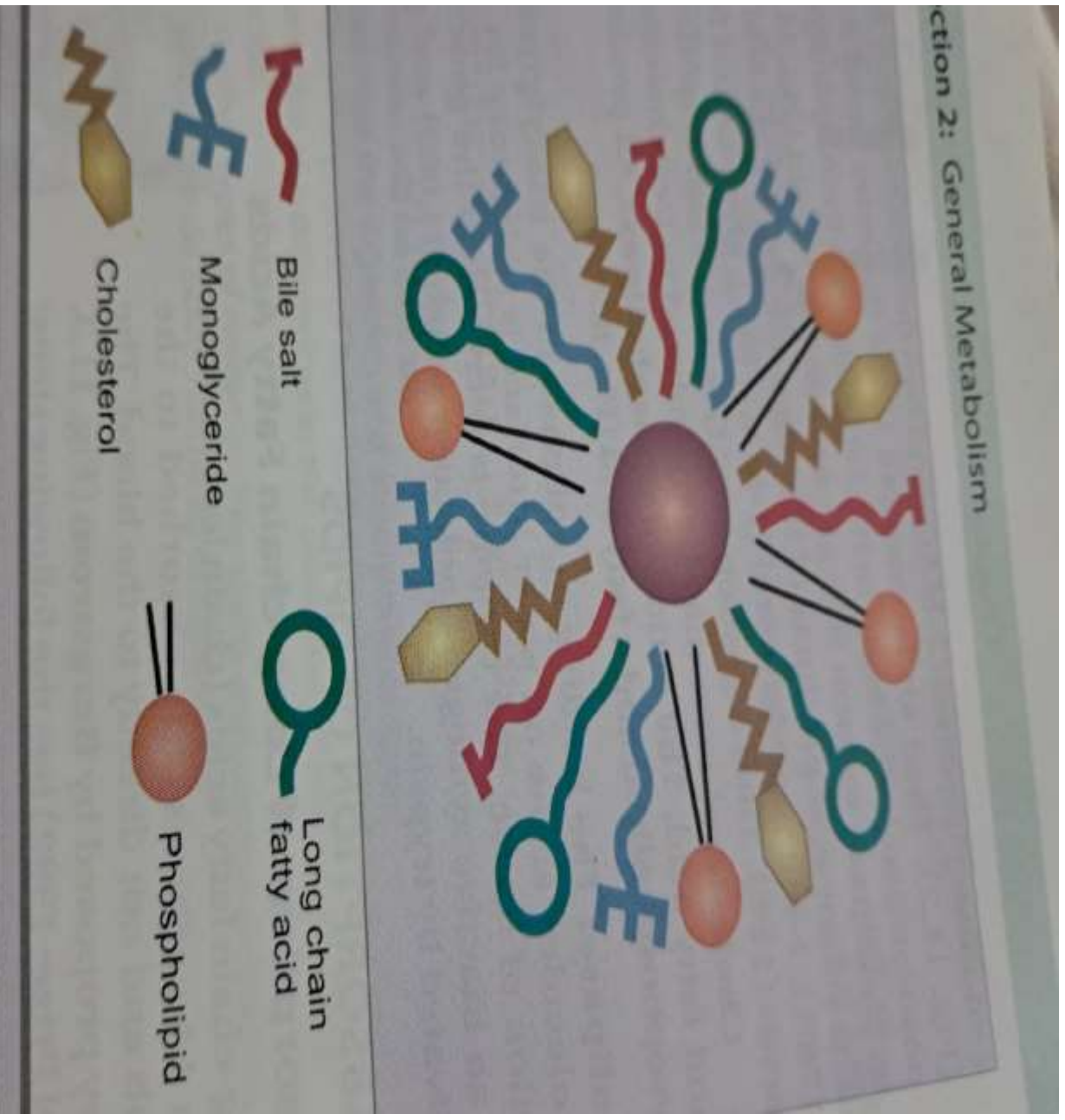


Fig. 11.4: Micellar formation.

11.4). Due to their detergent action, the **bile salts** form micellar aggregates (Fig. 11.1). Micellar formation is essential for the absorption of fat-soluble vitamins.

Micellar formation is essential for the absorption of fat-soluble vitamins such as vitamin A, D and K.

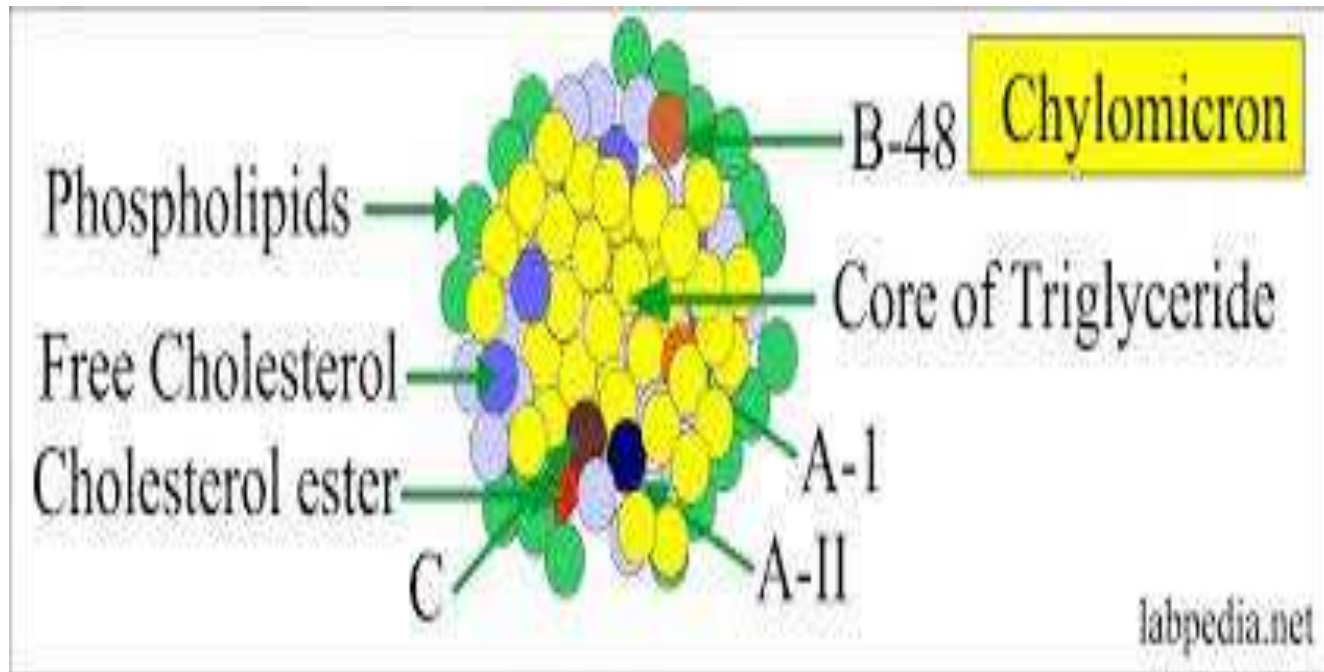
Absorption of lipids

Most fat absorption take place in **duodenum** or **jejunum** of small intestine

A) Absorption of MAG & Long chain Fatty acids

At the surface of microvilli in brush border, MAG & Long chain fatty acids diffuse into intestinal cells,there they form triglycerides,then combine with **apoproteins** to form **chylomicrons**.

Chylomicrons enter lymph system & through thoracic duct, empty into vein of neck.

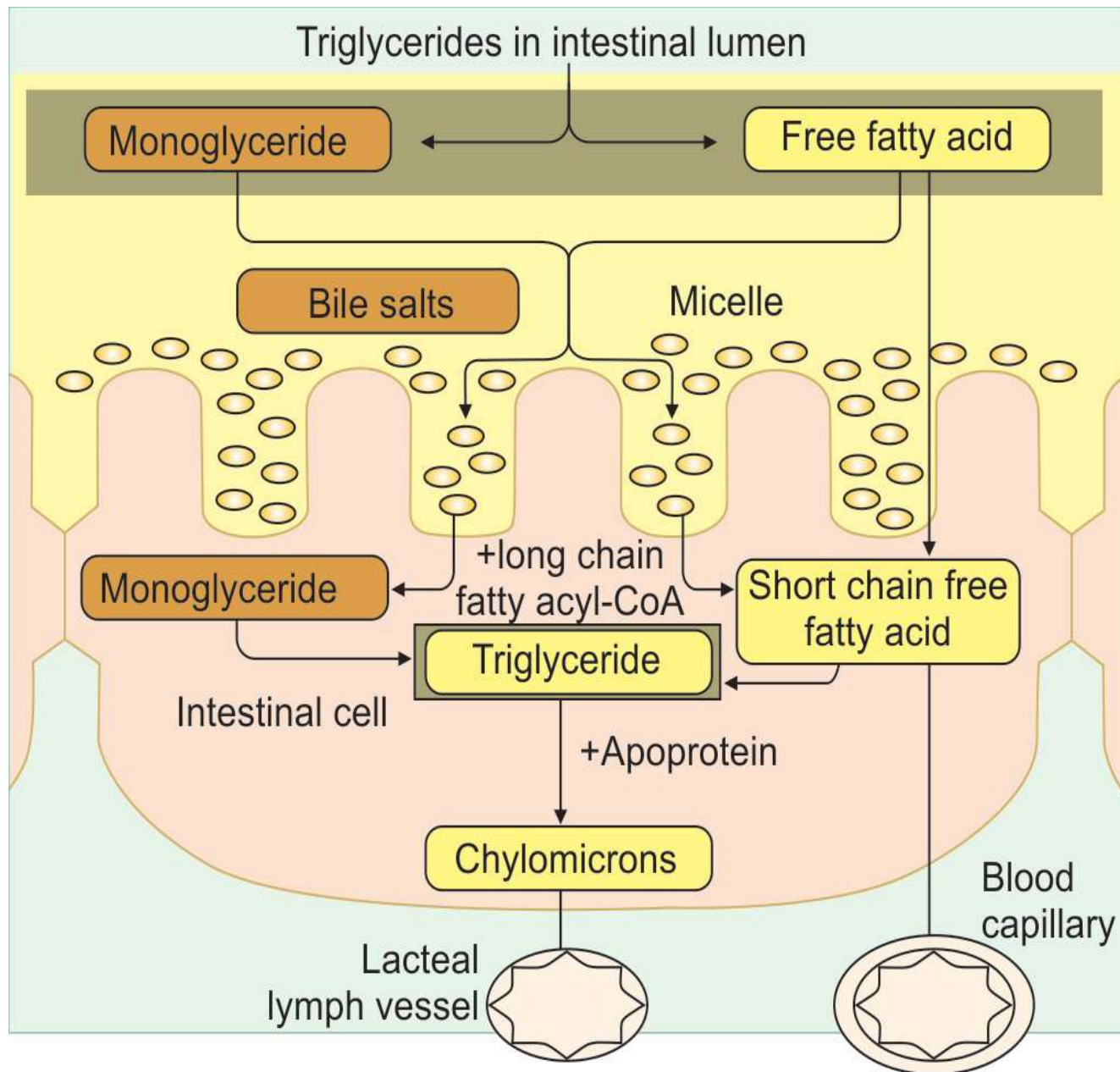


- Absorbed triglycerides are transported in blood as chylomicrons.
- taken up by adipose tissue & liver
- Triglycerides are lysed to produce
free fatty acids
- In blood FA are transported as complexed with albumin .
- Free fatty acids are taken up by cells & oxidised to get energy

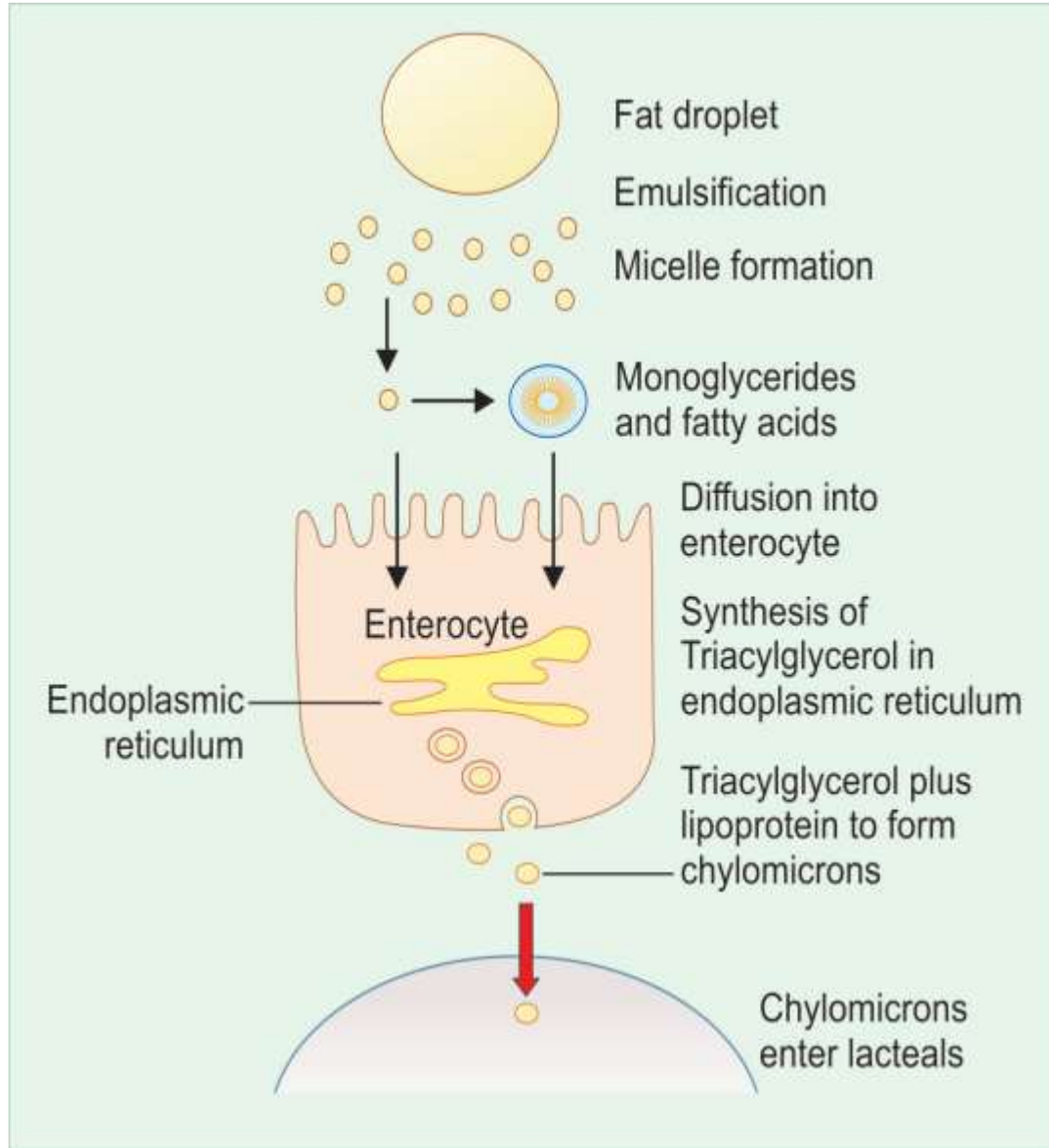
Serum may appear milky after a high fat meal due to presence of chylomicrons in circulation.

Normaly lipemia clears in few hrs by uptake of chylomicrons by tissues.

- **B) Glycerol ,medium chain & small chain fatty acids are absorbed directly into blood stream.**



Digestion & absorption of Fat



Absorption of fat as chylomicrons

This process needs the help of bile salts.

Fatty acid Absorption

	Long-chain fatty acids (Body fat,peanut oil)	Short chain (in milk, butter, ghee) & medium chain fatty acids (coconut oil and mother's milk)
1)	Need Micellerisation	Do not need micellerisation
2)	Absorbed into the intestinal cell wall, where they <u>are re- esterified</u>	do not need re-esterification.
3)	<u>incorporated into chylomicrons and enter into lymphatics.</u>	<u>directly enter into blood vessels, then to portal vein</u>, finally to liver where they are immediately utilized for energy.
3)	absorption is slow	absorption is rapid.

TABLE 13.1: Physiologically important lipases

<i>Lipase</i>	<i>Site of action</i>	<i>Preferred substrate</i>	<i>Product(s)</i>
Lingual/acid-stable lipase	Mouth, stomach	TAGs with short and medium chain FAs	FFA + DAG
Pancreatic lipase + co-lipase	Small intestine	TAGs with long-chain FAs	FFA + 2MAG
Intestinal lipase with bile acids	Small intestine	TAGs with medium chain FAs	3 FFA + glycerol
Lipoprotein lipase	Capillary walls	TAGs in chylomicron or VLDL	FFA + glycerol
Hormone-sensitive lipase	Adipocytes	TAG stored in adipose tissue	FFA + DAG

- **Defective digestion:**

In **steatorrhea**, daily excretion of fat in feces is more than 6 g per day. (Greek word, "steat", means fat).

It is due to **chronic diseases of pancreas.**

In such cases, **unsplit fat** is seen in feces.

Defective absorption:

- On the other hand, if the absorption alone is defective, most of the fat in feces may be **split fat**, i.e. fatty acids and monoglycerides.

Defective absorption may be due to diseases:

A. **Celiac disease, sprue, Crohn's disease.**

B. **Surgical removal** of intestine.

C.Obstruction of bile duct: This may be due to gallstones, tumors of head of pancreas, enlarged lymph glands, etc.

The result is deficiency of bile salts.

In such cases, triacylglycerols with short chain and medium chain fatty acids (SCT and MCT) are digested and absorbed properly, because they do not require micellerization for absorption.

- Since **milk fat and coconut oil** are made up of MCT, they are therapeutically useful in malabsorption syndromes.

- **Chyluria.** There is an abnormal connection between the urinary tract and lymphatic drainage system of the intestine.

Urine appears milky due to lipid droplets.

- **Chylothorax** can result from an abnormal connection between the pleural cavity and thoracic duct.

- Digestion in stomach
- Digestion in intestine
- Role of Bile salts in digestion & absorption(Emulsification, Mixed Micelle formation)
- Difference in Absorption of LCFA ,SCFA & MCFA
- Disorders (unsplit fat(**steatorrhea**), split fat(Crohns disease,sprue,coeliac disease, bile duct obstruction), &Chyluria.

Best wishes

