LIPID METABOLISM

In Health and Diseases

7 Main Human Body Lipid (Forms)

1. Free Fatty acids
2. Cholesterol
3. Triacylglycerol
4. Phospholipid
5. Glycolipids
6. Lipoproteins
7. Eicosanoids

Metabolism of Lipid Forms

Generation, Operation, Destruction

- Sources/Biosynthetic Pathways (Anabolism)
- Functions/Associated Metabolic Pathways
- Breakdown/Degradation Pathways (Catabolism)

- **Health=** Biomolecules in body present in regulated, balanced and in ordered mechanisms.

- **Disorders=** Biomolecules of body get dysregulated, imbalanced and interferences in mechanisms.

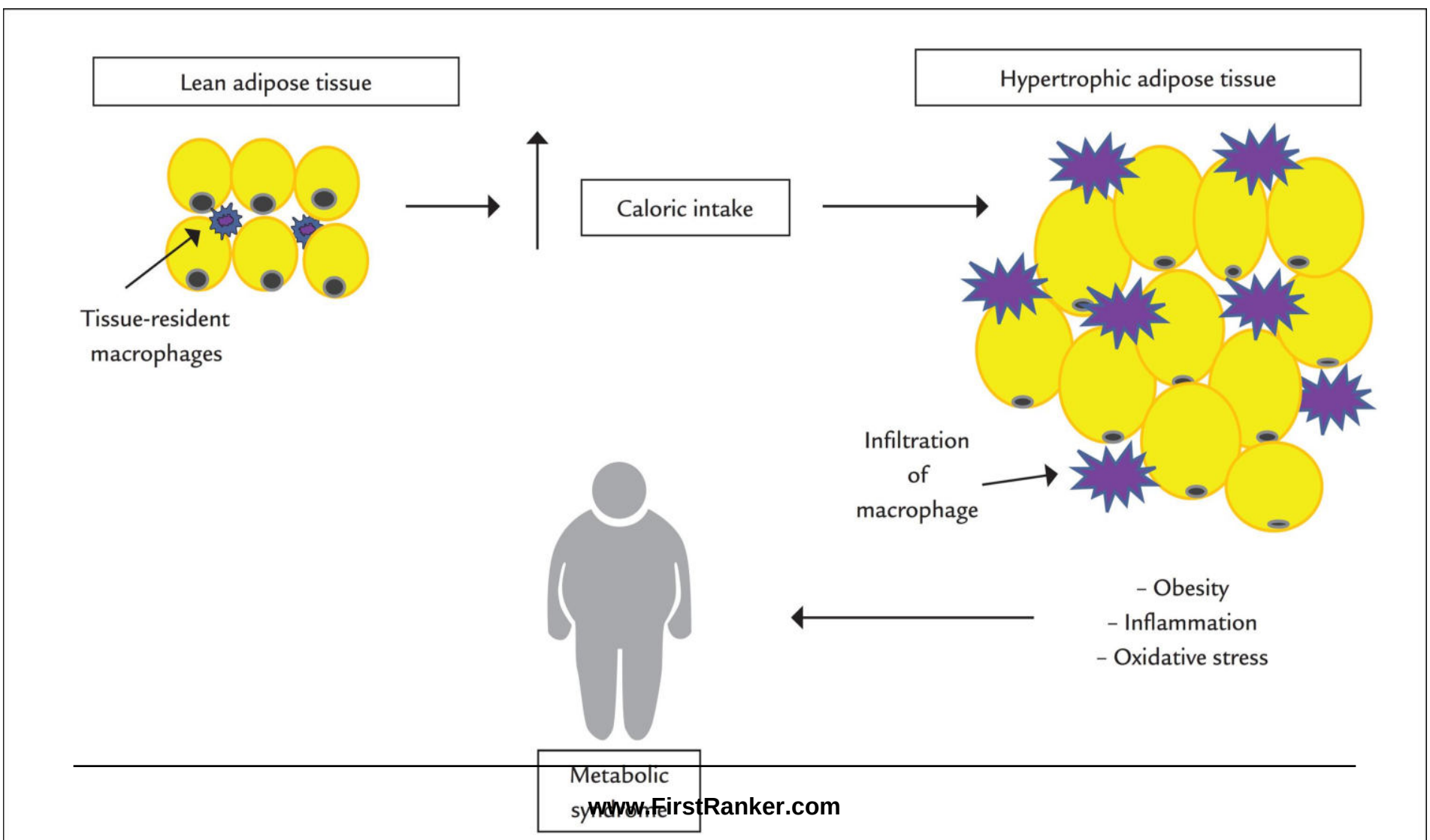
Lipid Metabolism Derangement Is Associated with

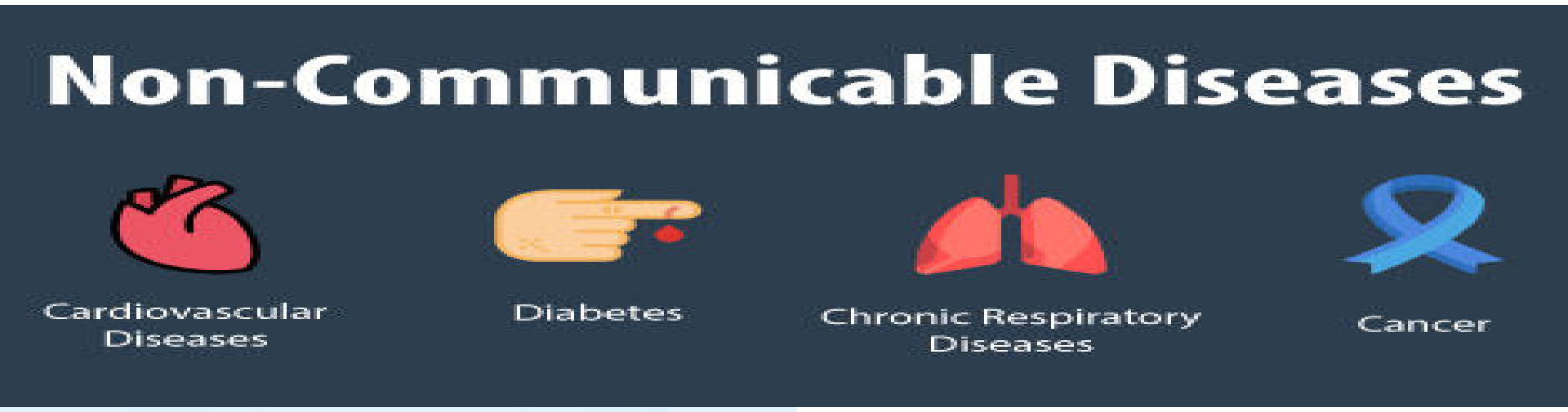
Obesity

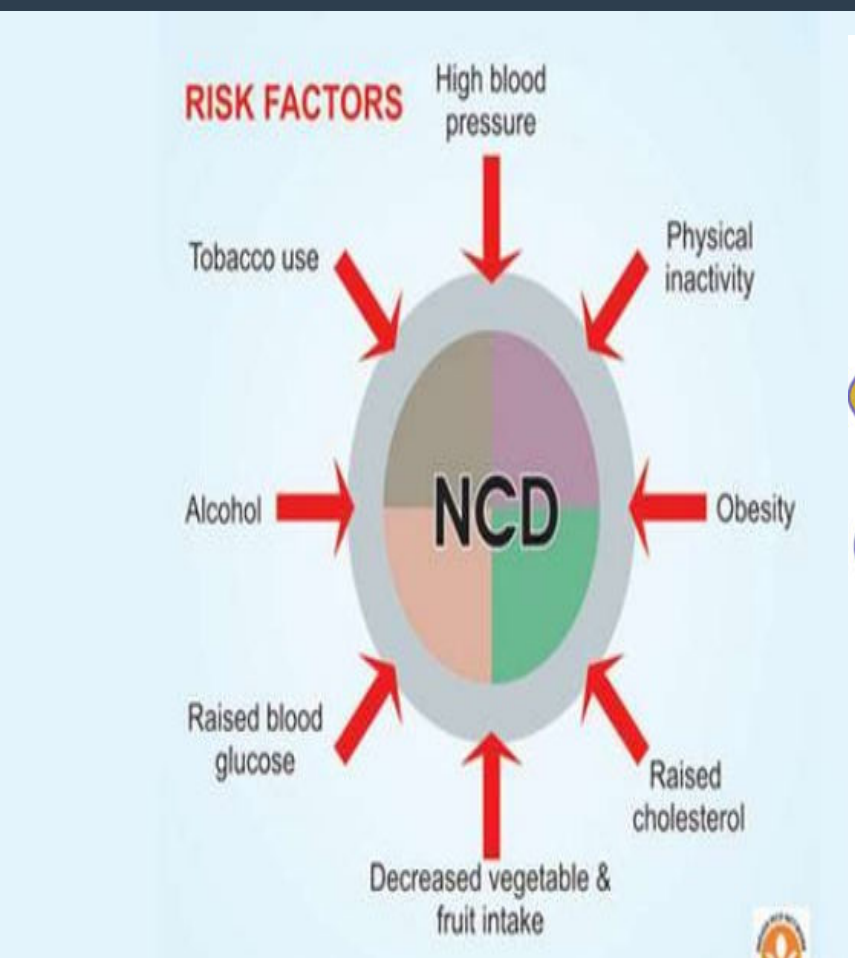
Metabolic Syndrome

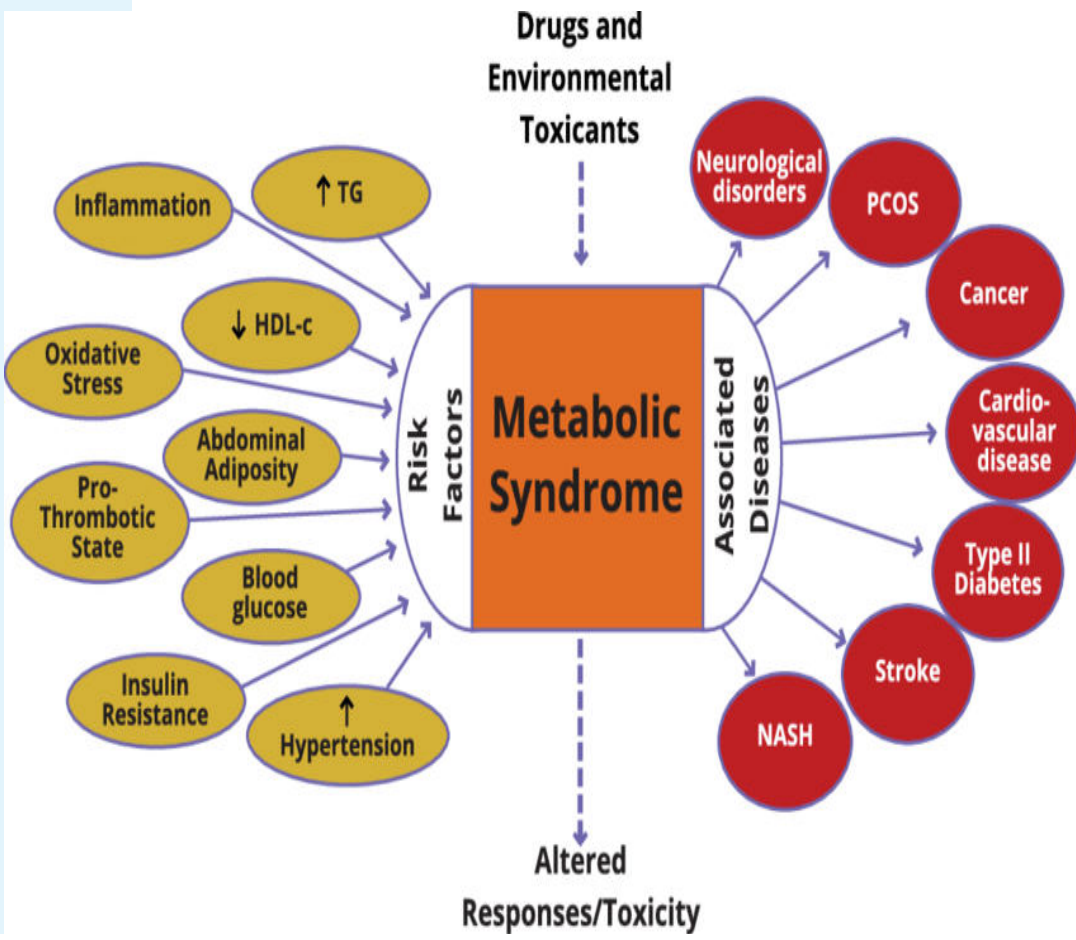
Non Communicable Diseases

Obesity And Metabolic Syndrome









SYNOPSIS

1. DIETARY LIPIDS

–INGESTION

–DIGESTION

–ABSORPTION

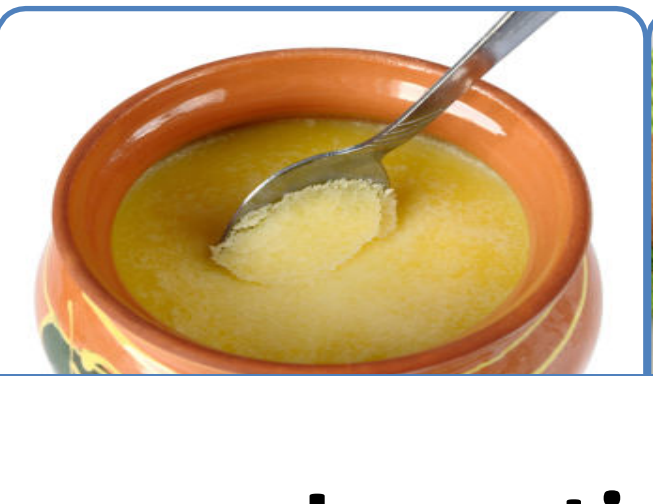
–TRANSPORTATION

–UPTAKE BY TISSUES

2. LIPOLYSIS: LIPID CATABOLISM / Utilization Of Stored TAG
   - ❑ FATTY ACID OXIDATION
   - ❑ KETONE BODY METABOLISM
3. LIPOGENESIS:
   - ❑ LIPID BIOSYNTHESIS
   - ❑ DE NOVO BIOSYNTHESIS OF FATTY ACIDS
4. LIPOPROTEIN METABOLIM/ TRANSPORTATION OF LIPID FORMS
5. DISORDERS ASSOCIATED TO LIPID METABOLISM

INGESTION OF DIETARY LIPIDS/ EATING OF DIETARY LIPIDS

- **Lipids** are **chief constituents** of human food.

Ingestion Of Dietary Lipids

- **What quantity** and **quality** of Lipid forms to be ingested per day?
- **Which forms** of dietary Lipids ingested from **rich sources ?**
- **Why** to eat dietary Lipids?

What quantity and quality of Lipids to be ingested per day?

In What Amount (Quantity) Dietary Lipids to be Eaten?

- **Daily consumption** of **dietary Lipids by human beings varies** and depends upon:

  - **Dietary habits of an individual**
  - **Economic status of a family**

RDA OF DIETARY LIPIDS

- **Per day quantity** of dietary Lipids **for an adult individual** is:

  - **20-35% of Calorie need**
  - **50-80 grams/day** of **dietary Lipids**

In What Form (Quality) Dietary Lipids are ingested?

FORMS AND SOURCES OF INGESTED DIETARY LIPIDS

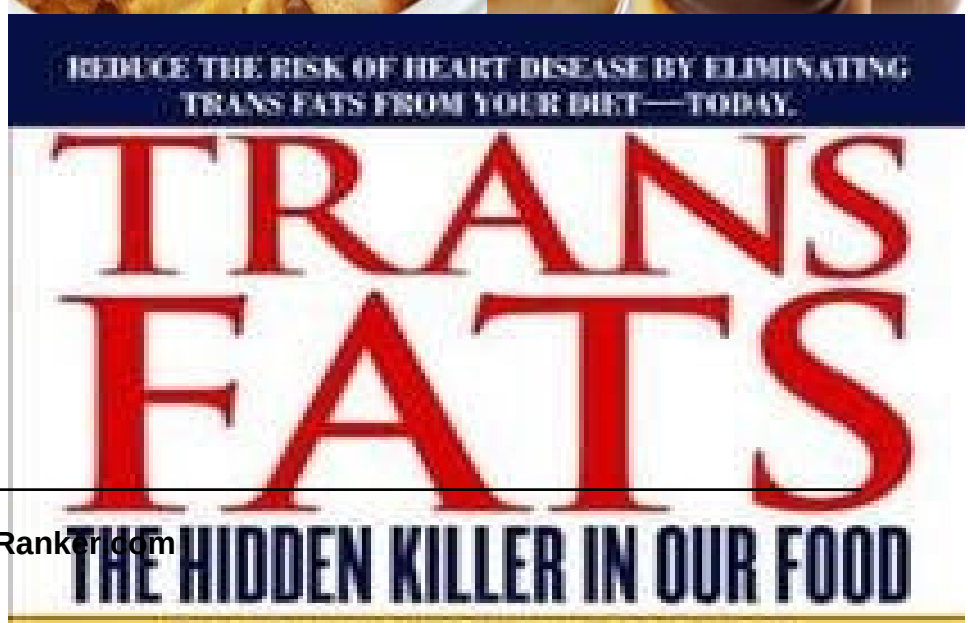
- **Dietary ingested Lipids contain following forms of Lipids:**
  - **Triacylglycerol** (TAG):**Principal dietary Lipid form ingested - 98%.**
  - **Phospholipid**
  - **Cholesterol Ester**
  - **Fat soluble Vitamins:** are soluble in Fat hence associated with fatty foods.

Quality Of Dietary Lipids To be ingested

- **Natural**
- **PUFA of Cis Form**
- **Omega 3 and Omega 6**
- **PUFA:MUFA:SFA 1:1:1 ratio**

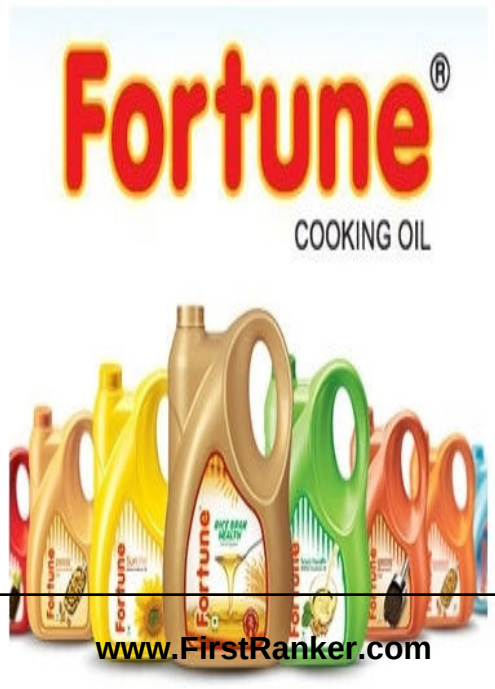
Avoid Trans Fats
As they are detrimental to Health

- Sources of dietary Lipids **should be free from Trans Fatty acids/less than 1%.**
- Trans Fatty acids are **not readily metabolized by human body.**
- Trans Fats **increases the risk of Atherosclerosis.**



Dietary Rich Sources Of Lipids

- Obtained from both foods **of Plant and Animal origin.**



Forms Of Fat in Food Sources

Visible Fat

Butter, Margarine, Salad oils and dressing, Shortening Fat Meat

Invisible Fat

Cheese, Cream portion of homogenized milk, Egg yolk, Nuts, Seeds, Olives.

Sources Of Plant Lipids

- **Plant Oils:** Peanut ,Safflower ,Sunflower, Olive, Mustard Oils, Margarine etc.

- **Nuts:** Peanuts , Walnuts , Cashew ,Almonds, Sesame ,Pine etc

Sources Of Animal Lipids

- Milk and Milk products
- Egg Yolk
- Sea foods –Fish, Shell fish
- Animal-Fat ,Meat , Liver and Brain

MUFA (MONOUNSATURATED FATTY ACIDS) FOOD SOURCES


Milk Products


Corn


Cashew Nut


Whole Grain wheat


Olives


Walnut


Avocado Oil


Peanut


Flaxseeds

PUFA (POLYUNSATURATED FATTY ACID) FOOD SOURCES


Sunflower seed

Rich Dietary Sources of PUFAs

High in omega-3

DHA
- salmon
- herring
- sardines
- eggs

ALA*
- flaxseed
- olive oil
- avocados
- almonds
- walnuts
- seeds

High in omega-6
- vegetable oil
- canola oil
- safflower oil
- eggs
- meat
- dairy products

* alpha-linolenic acid, from which the body can make DHA

Omega-6

Linoleic Acid
(LA)

Arachidonic Acid
(AA)

Omega-3

α–Linolenic Acid
(ALA)

Desaturases
Elongases

Eicosapentaenoic acid
(EPA)

Desaturases
Elongases

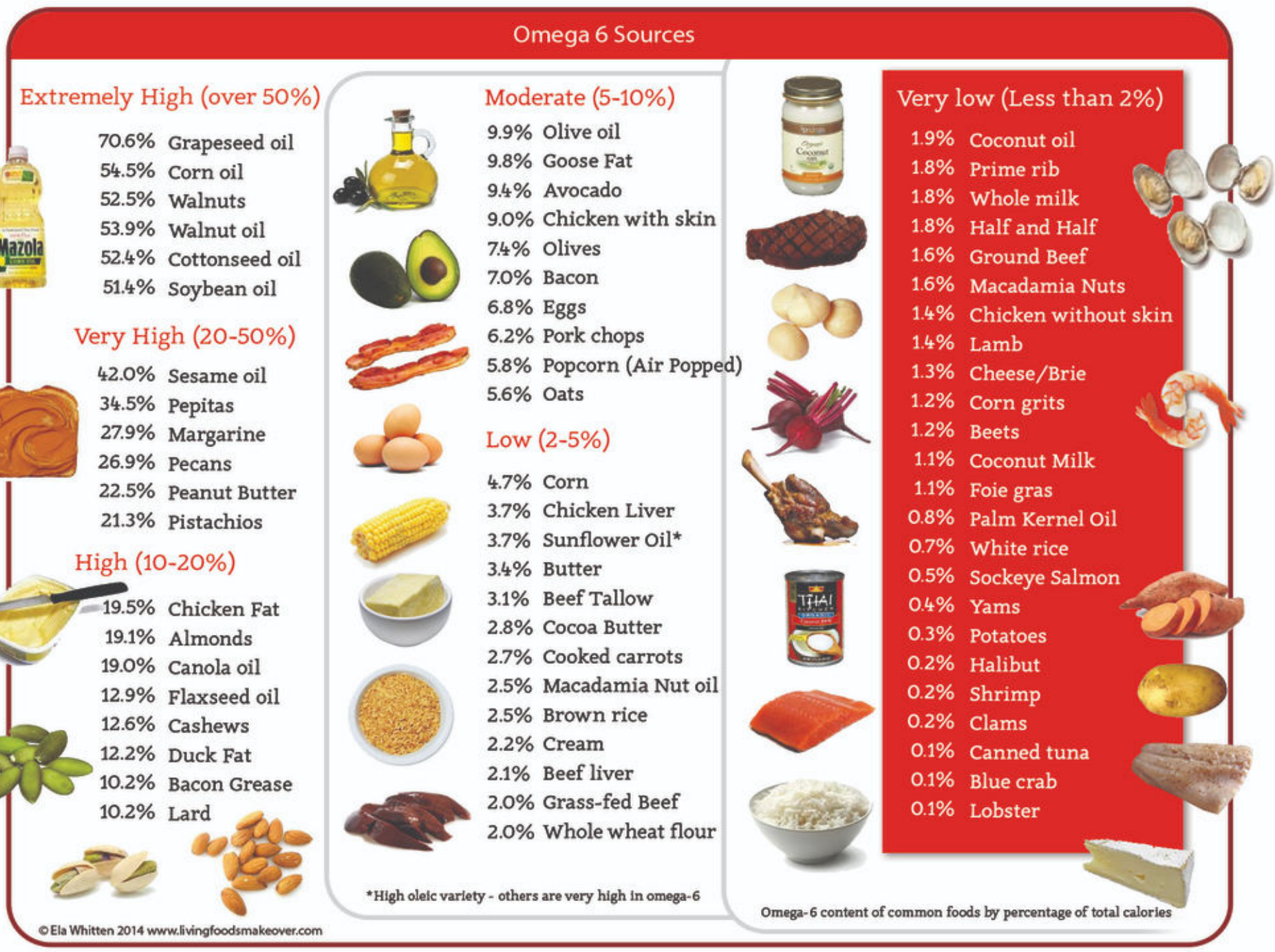
Docosahexaenoic acid
(DHA)

Cyclooxygenases
Lipoxygenases

Pro-Inflammatory:
Eicosanoids
Prostaglandins,
Leukotrienes,
Thromboxanes

Minimally Inflammatory:
Eicosanoids
Inflammation Resolving:
Resolvins, Protectins

Oil	Omega-6 Content	Omega-3 Content
Safflower	75%	0%
Sunflower	65%	0%
Corn	54%	0%
Cottonseed	50%	0%
Sesame	42%	0%
Peanut	32%	0%
Soybean	51%	7%
Canola	20%	9%
Walnut	52%	10%
Flaxseed	14%	57%
Fish*	0%	100%



Why To Eat Dietary Lipids?

OR

Importance Of Ingesting Dietary Lipids

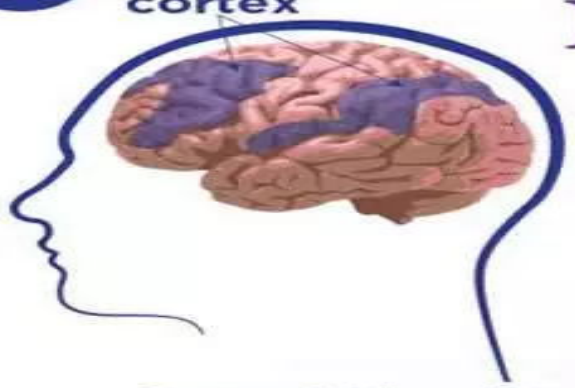
Importance Of Ingesting Dietary Lipids:

- **TAG (predominantly ingested)** - **secondary source of energy for body tissues.**
- **Source of Essential Fatty acids/PUFAs-structural components of tissues.**
- **Source of Fat Soluble Vitamins- Vitamin A,D,E and K associated with Fatty foods.**
- **Improve taste of recipes.**
- **Increase palatability and satiety value.**

- **Thus daily consumption of dietary lipids** is essential for

- **Maintenance of normal**
  - **Health**
  - **Growth**
  - **Reproduction**

study 1 frontoparietal cortex



Nutrition and Brain Health

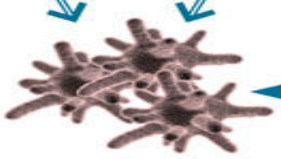
study 2 fornix

Omega-3 fatty acids:
Alpha-linoleic acid; stearidonic acid; eicostatrienoic acid

Balance of **Omega-3** and **Omega-6 fatty acids**

LA (n6) → DGLA → AA

(–) (+)



Inflammation

(–)

LNA (n3) → EPA → DHA

LA, linoleic acid; DGLA, dihomogamma-linolenic acid; LNA, alpha-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Omega-3 Fatty Acids

Sources of omega-3 are flaxseed, walnuts, hemp seed, chia seeds, brown algae, and cod-liver oil. It helps to lower cholesterol levels.

Brain function

Improves Macro/Microvascular function

Eyesight

Nervous system

Minimize/Heals Inflammation

Immune system

Lower Blood Pressure

Joint health

Improves Cholesterol level

Reduce Coronary Calcium

Healthy skin

Reduce Cardiovascular Risk

Cut down Plaque Formation

Digestion Of Dietary Lipids In GIT

Digestion of Dietary Lipids

Is

Cleavage Of Ester Bonds

Present In Various

Complex /Unabsorbable Lipid Forms

By

Lipases/Lipolytic Enzymes

In

Different Parts Of GIT

Digestion of lipids

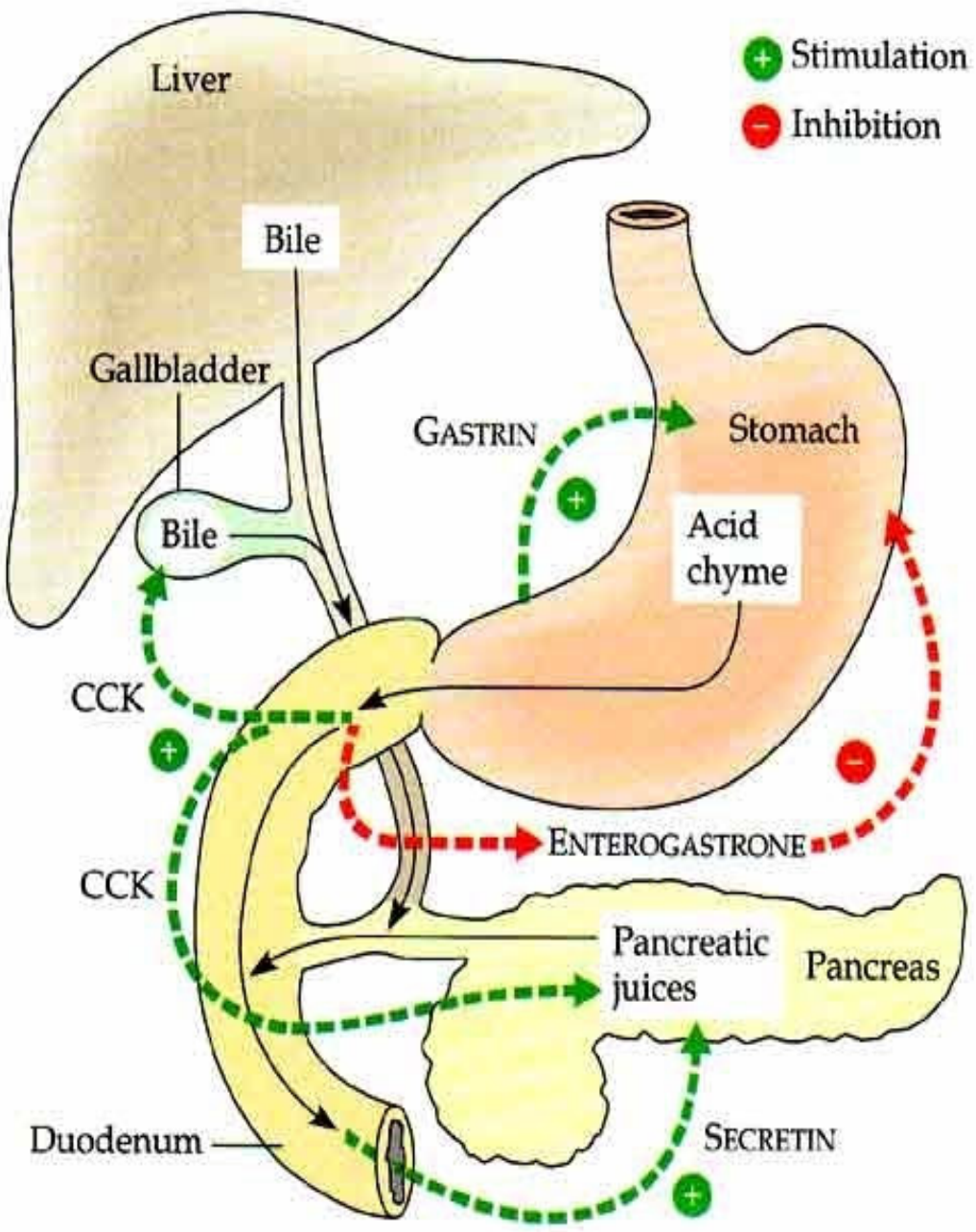
1- Triglycerides

2- Phospholipids

3- Cholesterol esters

Prerequisites for Lipid Digestion

- GIT Hormones
- Optimum pH
- Emulsifiers
- Emulsification
- Lipid Digesting Enzymes- Lipases



Gastrin

Chyme stimulates

Cholecystokinin (CCK)

Secretin

to release **bile** from gallbladder and Pancreas for Pancreatic juice.

Enterogastrone

- **Cholecystokinin** (CCK) and **Secretin**

- **Stimulates** the: **Gallbladder to contract and release bile**.

B- Lipase enzymes

Types:

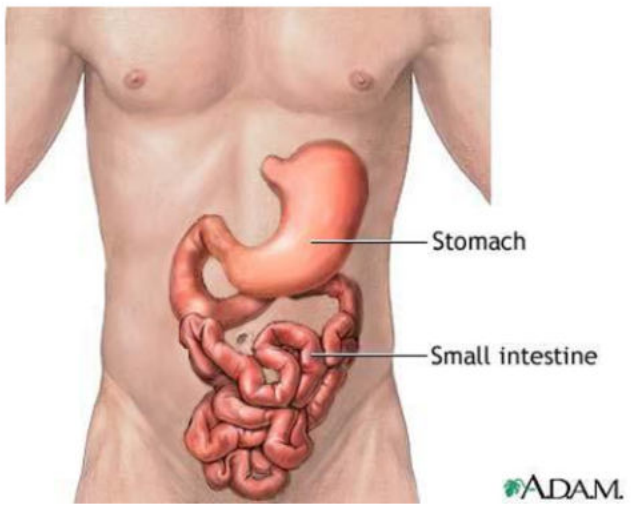
1- lingual lipase

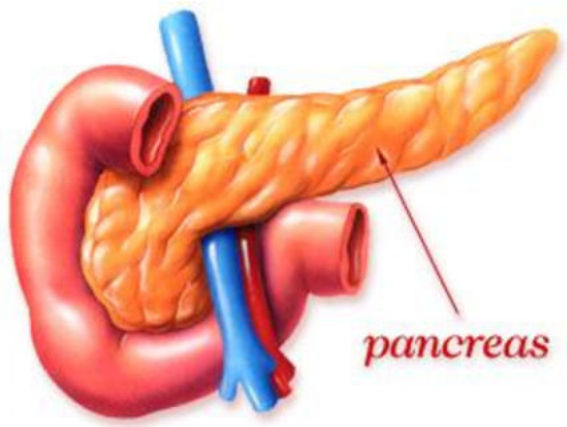
2- gastric lipase

3- pancreatic lipase

4- intestinal lipase

the most active is pancreatic lipase.



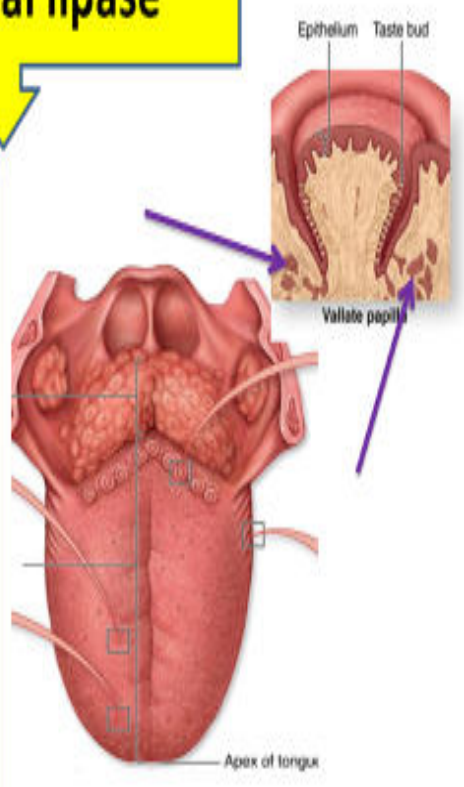


Mechanism Of Lipid Digestion in Different Parts of GIT

Insignificant Lipid Digestion Occurs in Mouth and Stomach

1- Lingual lipase

- secreted by the dorsal surface of the tongue (Von-Ebner's glands)
- Is not of much significance in humans



2- Gastric lipase (pH 3-6)

Triacylglycerols		
Short & mediuim chain unsaturated fatty acids	Gastric lipase (infants)	Short & mediuim free fatty acids & 1,2 diacylglycerols

- Though **Salivary juice contains Lingual Lipase** and **Gastric juice contains Gastric Lipase** .

- **Digestion of dietary Lipids** in **mouth is negligible and stomach is**~10% of TAGs are hydrolyzed

Insignificant Digestion Of Lipids In Mouth and Stomach Due to:

- **No optimal pH** of salivary and gastric juices
- **No optimal activity** of **Enzyme Lipases (Optimal pH range 6-8)**
- **No Emulsification Process in Mouth and Stomach**

- **Dietary Lipids (insoluble form) when not emulsified**
- **Do not have contact with polar and soluble forms of Lipases present in the aqueous phase of salivary and gastric juices.**

- **There is no cleavage of Ester bonds** of Lipid structures in **salivary and gastric juices**
- Insignificant digestion of Lipids in **mouth and stomach.**

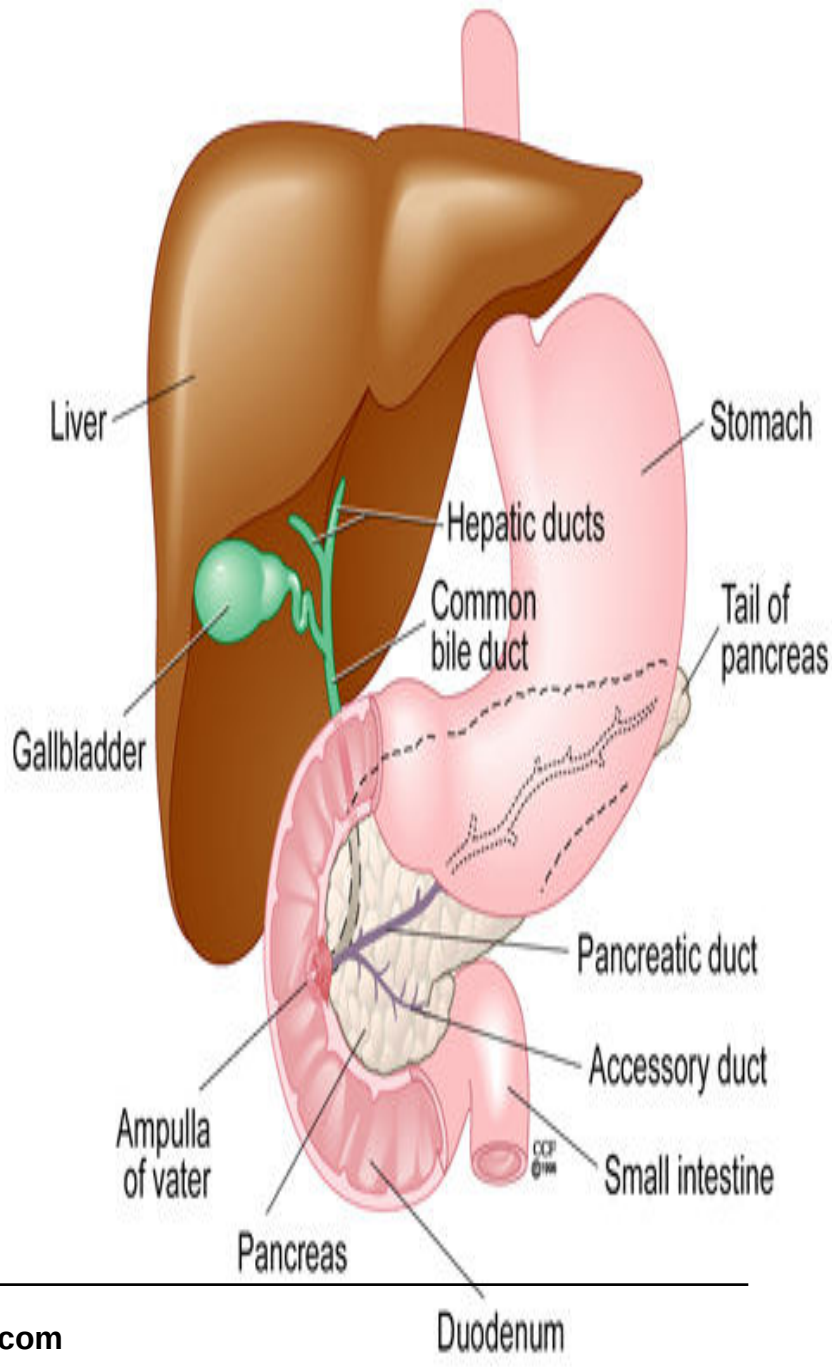
Significant and Complete Digestion Of Dietary Lipids Occurs In Small Intestine In presence of Bile after Emulsification

Requirements for Emulsification To Form Emulsions

Essentially Requires Presence Of Bile

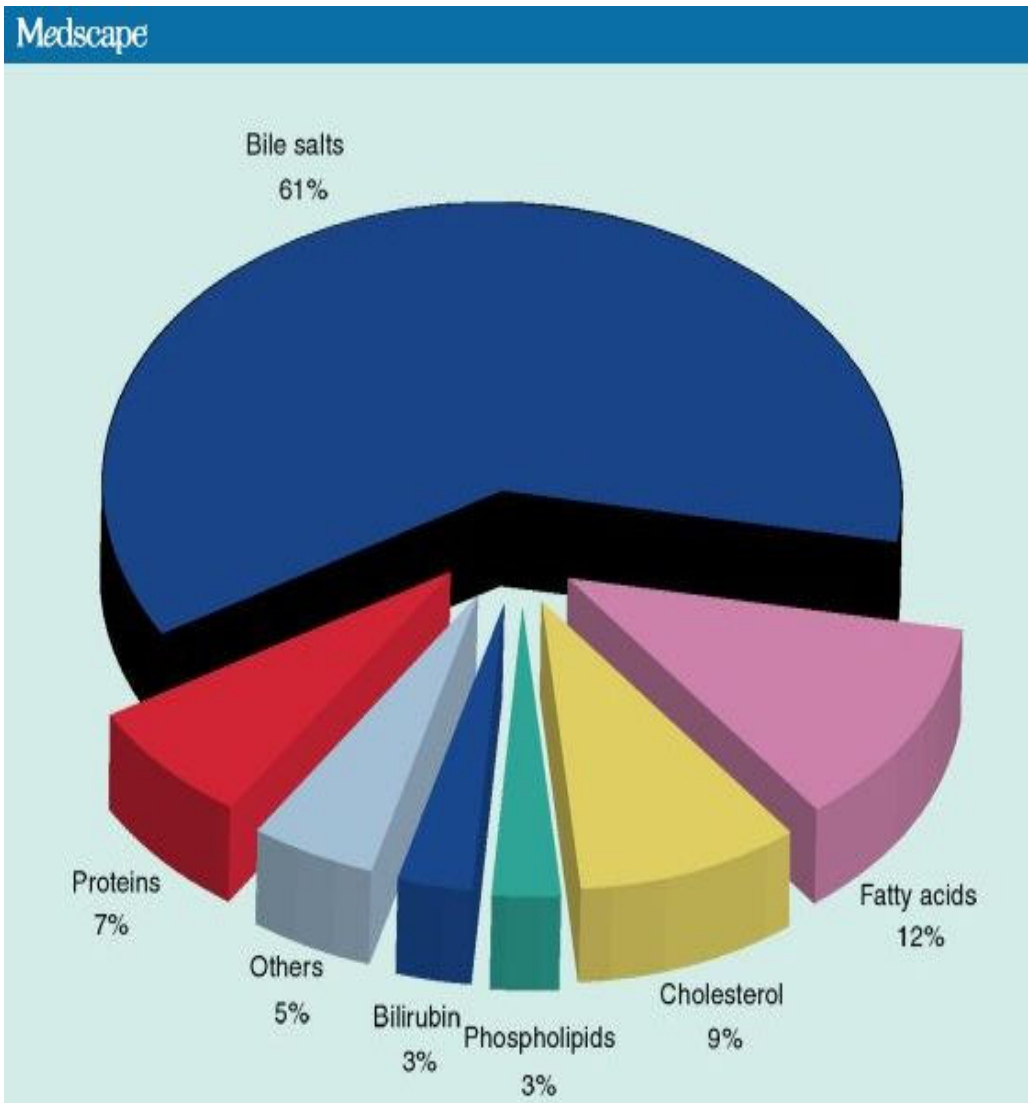
In Small Intestine For Lipid Digestion and Absorption

- **Bile** is a **greenish fluid produced in Liver.**
- **Concentrated and stored in Gall bladder**.
- Carried through bile duct
- Later **secreted in Small intestine via Common Bile Duct (CBD)**



Composition Of Bile

- Bile is an **Alkaline solution**
- Composed of:
  - –Bile Salts **(Surfactant)**
  - –Bilirubin **(Bile Pigment)**
  - –Bile acids
  - –Cholesterol
  - –Lecithin



Composition of human bile

	Liver Bile	Gallbladder Bile
Water	96-98%	88-90%
Bile salts	11 mg/ml	60 mg/ml
Bilirubin	0.4 mg/ml	3 mg/ml
Total Lipid	~3 mg/ml	~24 mg/ml
	Basic (pH 7.50 to 8.05)	Acidic (pH 6.80 to 7.65)
	Dilute (lipids)	Concentrated (lipids)
	Lighter color	Darker color
	Indefinitely metastable	Limited metastability

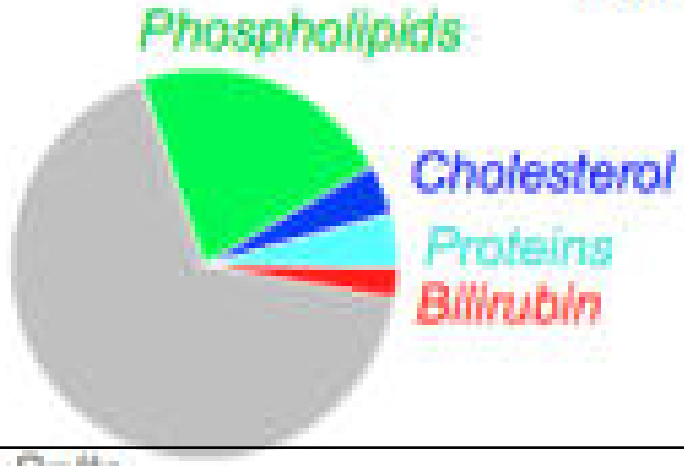
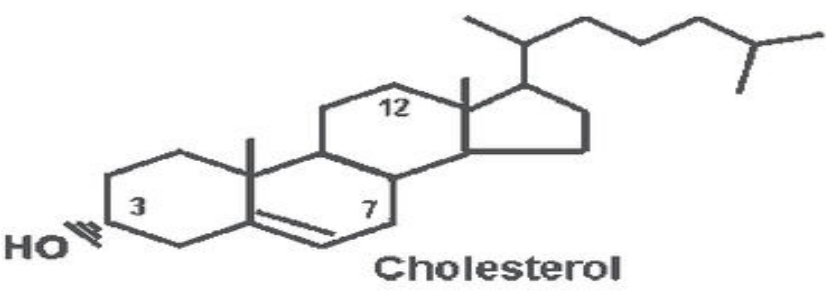


Table 5.1: Composition of bile

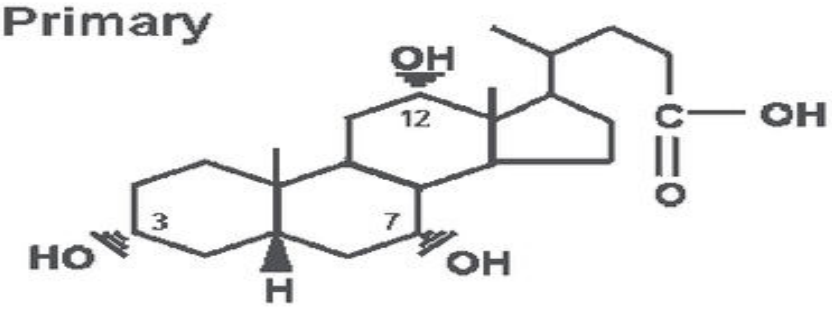
	Liver bile	*Gallbladder bile*
Water	97.5 g/dl	92 g/dl
Bile salts	1.1 g/dl	6 g/dl
Bilirubin	0.04 g/dl	0.3 g/dl
Cholesterol	0.1 g/dl	0.3 to 0.9 g/dl
Fatty acids	0.12 g/dl	0.3 to 1.2 g/dl
Lecithin	0.04 g/dl	0.3 g/dl
Na^+	145.04 mEq/L	130 mEq/L
K^+	5 mEq/h	12 mEq/L
Ca^{++}	5 mEq/L	23 mEq/L
Cl^-	100 mEq/L	25 mEq/L
HCO_3^-	28 mEq/L	10 mEq/L

Bile Acids Derived From Cholesterol

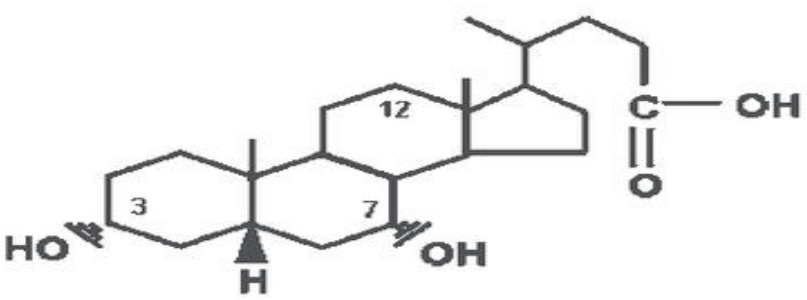


Cholesterol

Primary

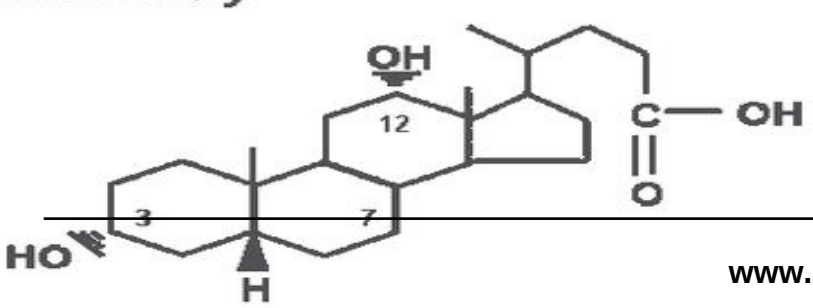


Cholic acid (CA)

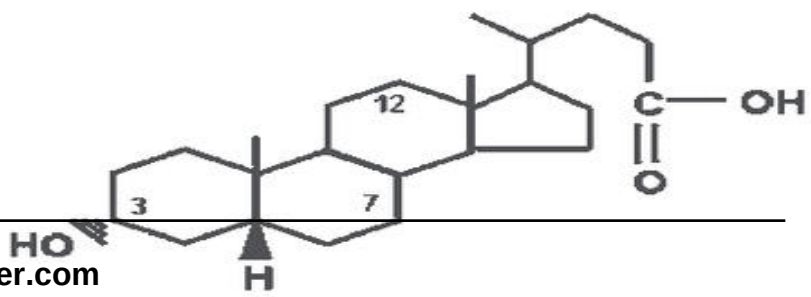


Chenodeoxycholic acid (CDCA)

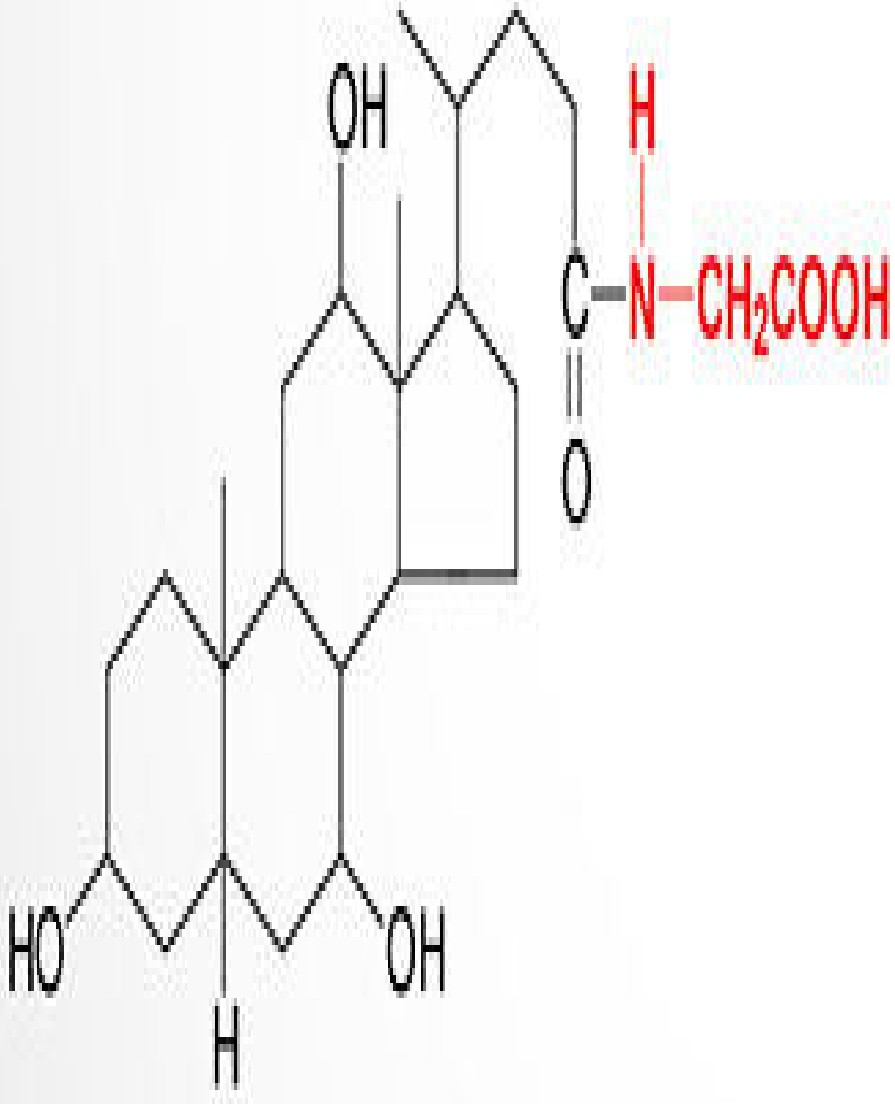
Secondary



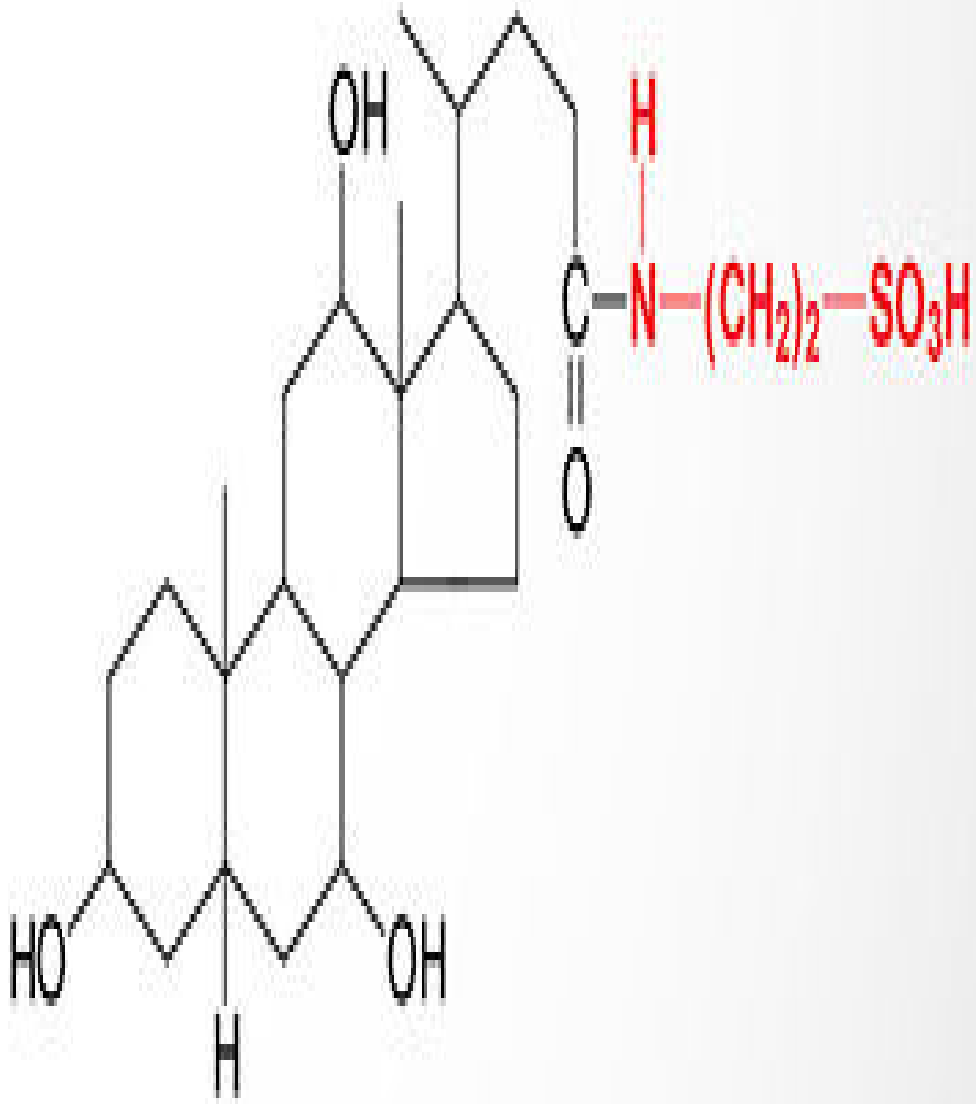
Deoxycholic acid (DCA)



Lithocholic acid (LCA)



Glycocholic acid

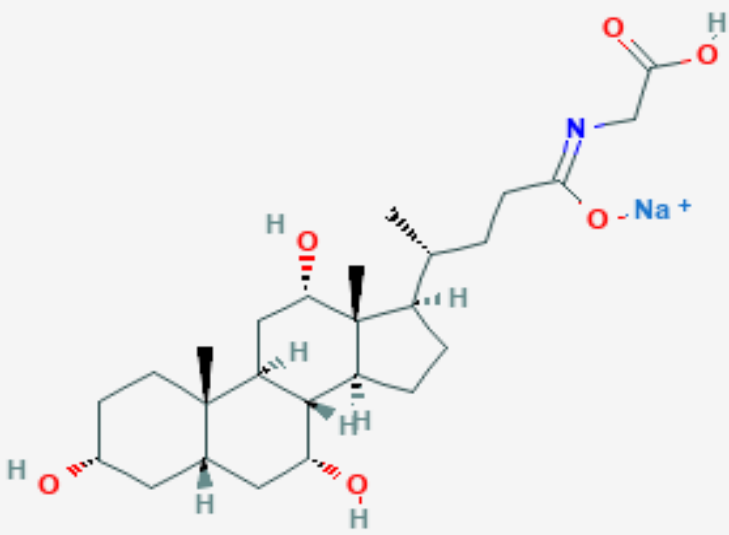


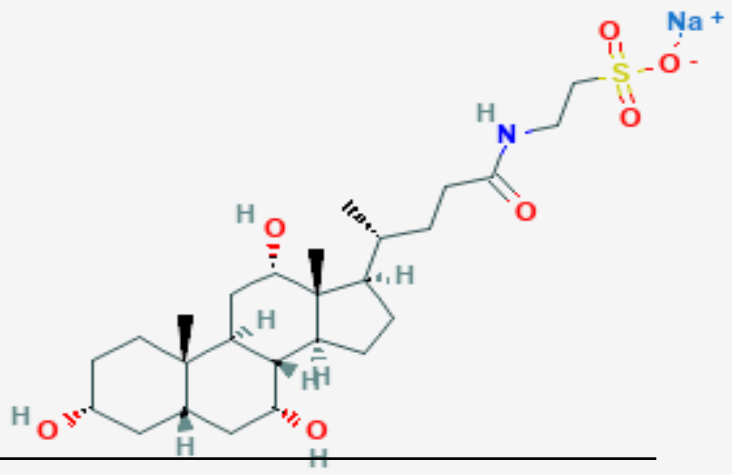
Taurocholic acid

- **Name Of Bile salts :**

–Sodium Glycocholate

–Sodium Taurocholate





Role Of Bile Salts In Formation of Emulsions During Emulsification

- **Emulsifying agents/Emulsifiers:**

  – **Emulsifying Agents/Surfactants:**

    - **Bile Salts**

      (Sodium Glycocholate, Sodium Taurocholate)

    - **Amphipathic Lipids**

      (Phospholipids)

- Bile salts **have detergent like action**

- **Bile salts serve as :**
  - **Emulsifying agents**
  - **Responsible for fat Emulsification**

- **Bile salts** and dietary Amphipathic Lipids by their **detergent like action:**
  - **Reduces surface tension**
  - **Increases surface area** of Fats/Oil and make them miscible with aqueous phase.

- **Emulsions bring non polar dietary Lipids in close contact with Lipid digesting Enzymes** present in aqueous phase of intestinal juices.

What Is Emulsification?

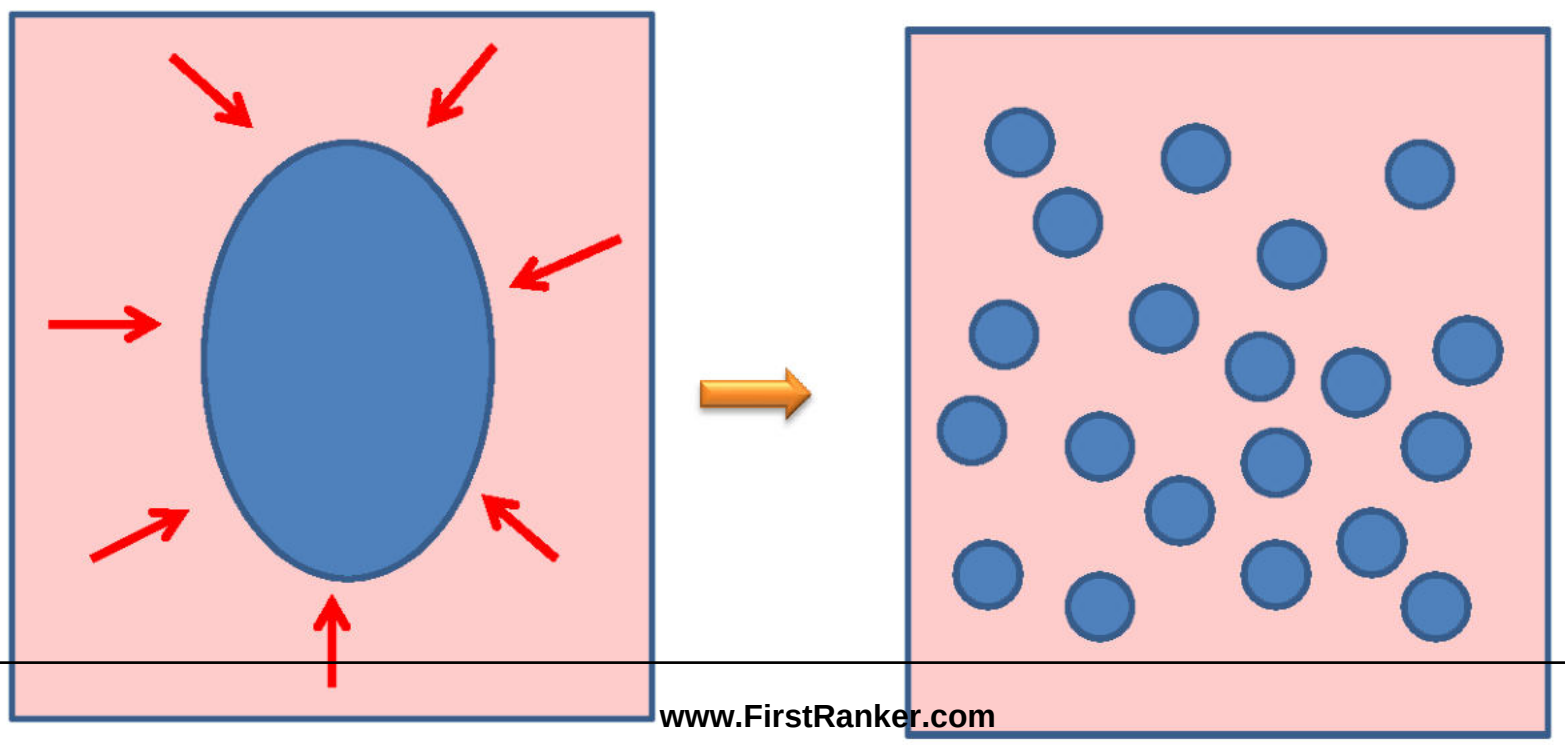
Emulsification

Takes Place In Small intestine

Which
Initiate and Completes
Significant Digestion of
Dietary Lipids

A-Emulsification

- Breakdown of large fat globule → small ones



Emulsifiers brings out Emulsification and forms Emulsions

D. The emulsifying agent stabilizes the emulsion.

A-Emulsification

- Breakdown of large fat globule ⟹ small ones
- Occurs in:

  Mouth by chewing

  Stomach by peristaltic contractions

  Intestine by peristaltic movement,

  bile salts

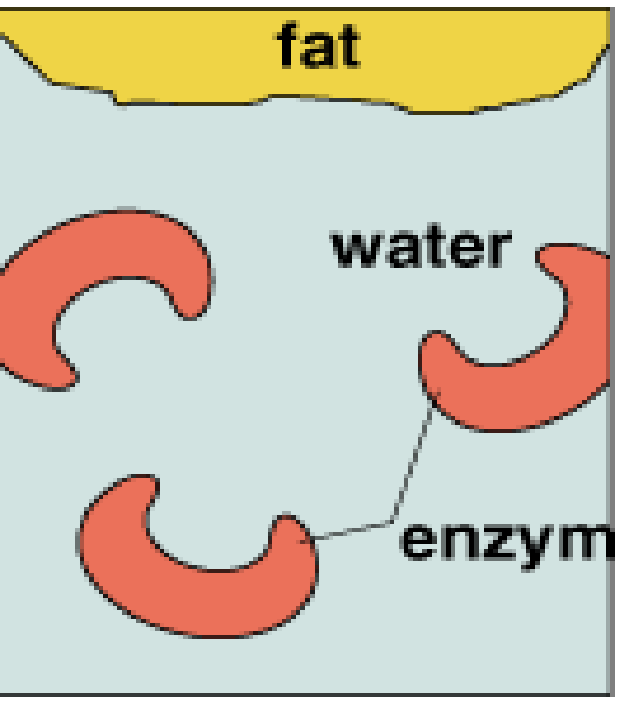
  lysophospholipids

- **Emulsification is an Essential Prerequisite Physicochemical Process**

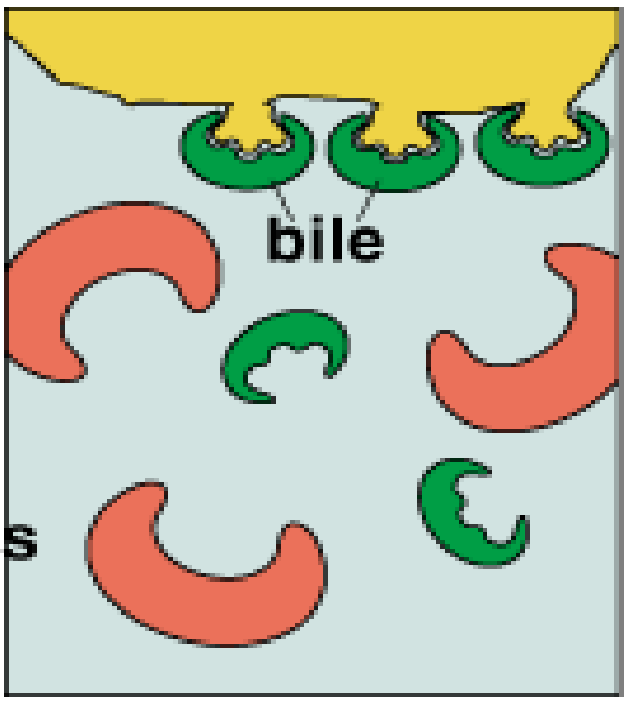
- Which **forms Emulsions** from dietary ingested Lipids.

- Emulsification takes place in the **lumen of small intestine**.

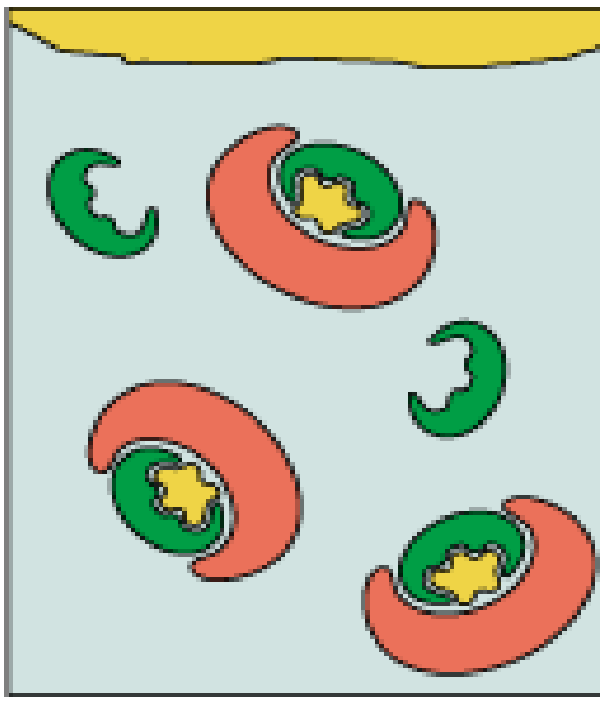
- Emulsification process **occur before digestion** of dietary Lipids.



Fat and water tend to separate. Enzymes are in the water and can't get at the fat.



Bile (an emulsifier) arrives. Bile has an affinity for both fat and water and can therefore bring the fat into the water.

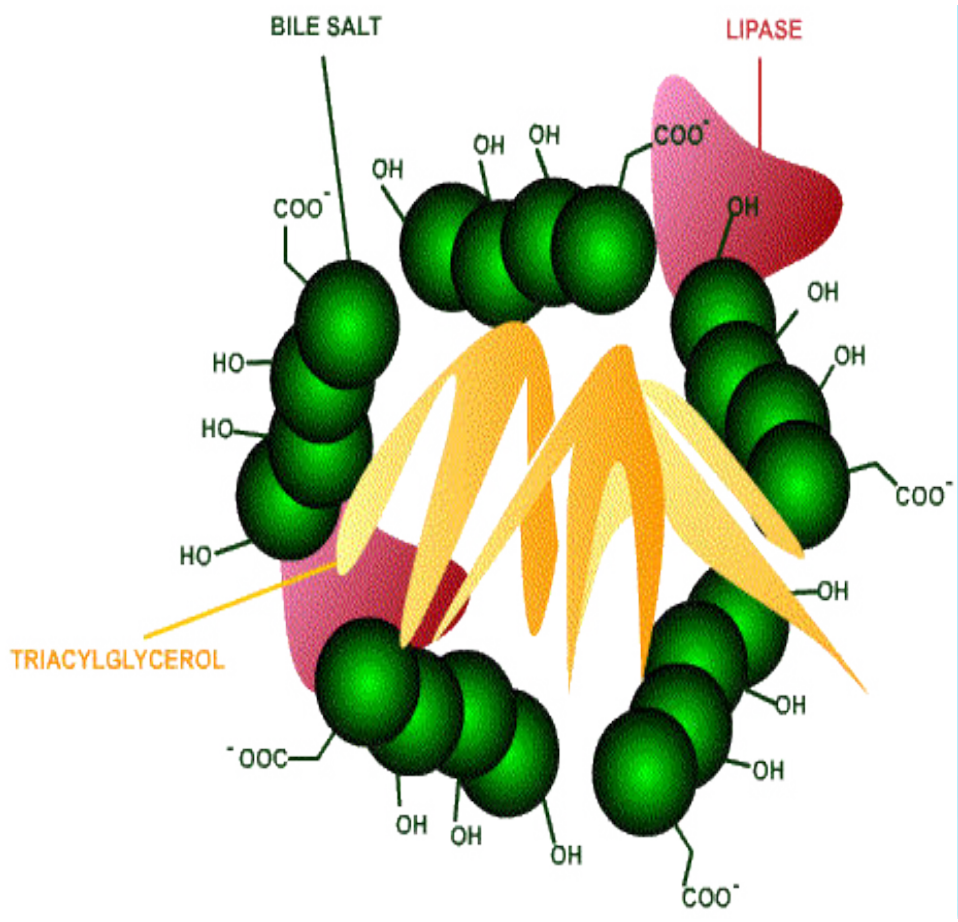


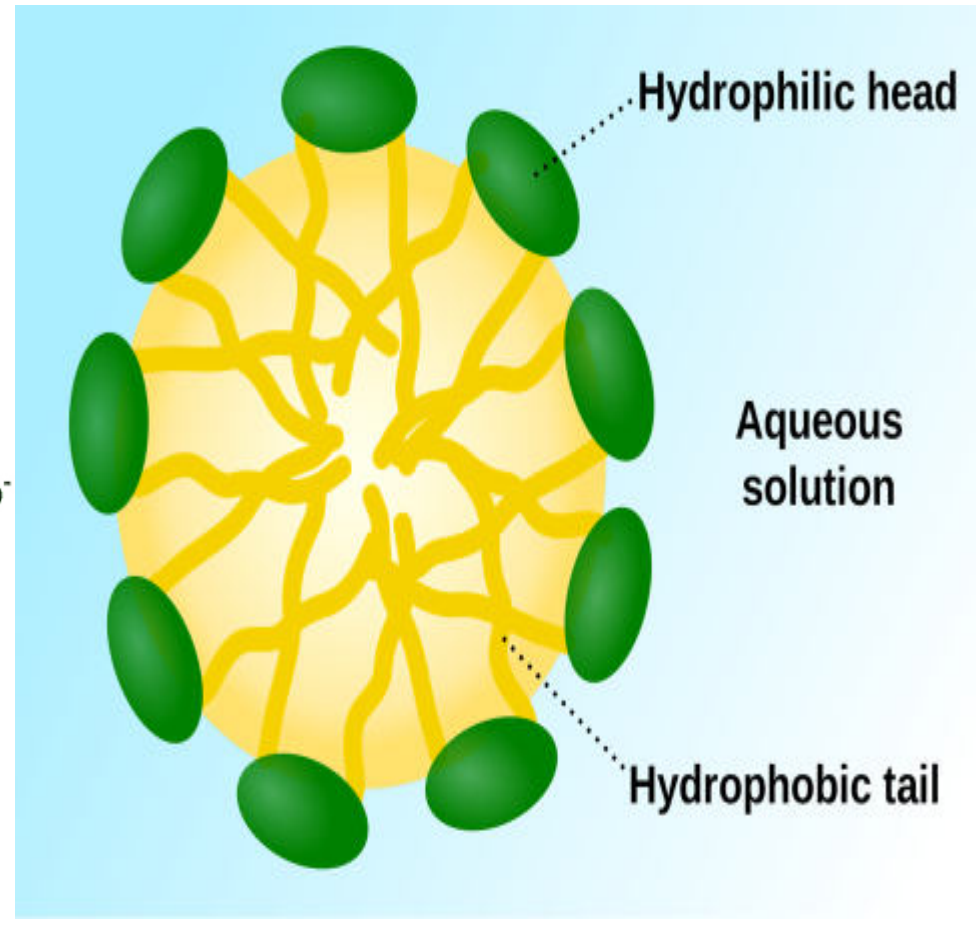
After emulsification, the fat is mixed in the water solution, so fat-digesting enzymes have access to it.

- During the process of Emulsification there is **dispersion of large droplets** of **Fats/Oils**
- Into **small, miscible droplets** which are termed as **Emulsions.**

- **Emulsions** have non polar lipids (TAG) in center

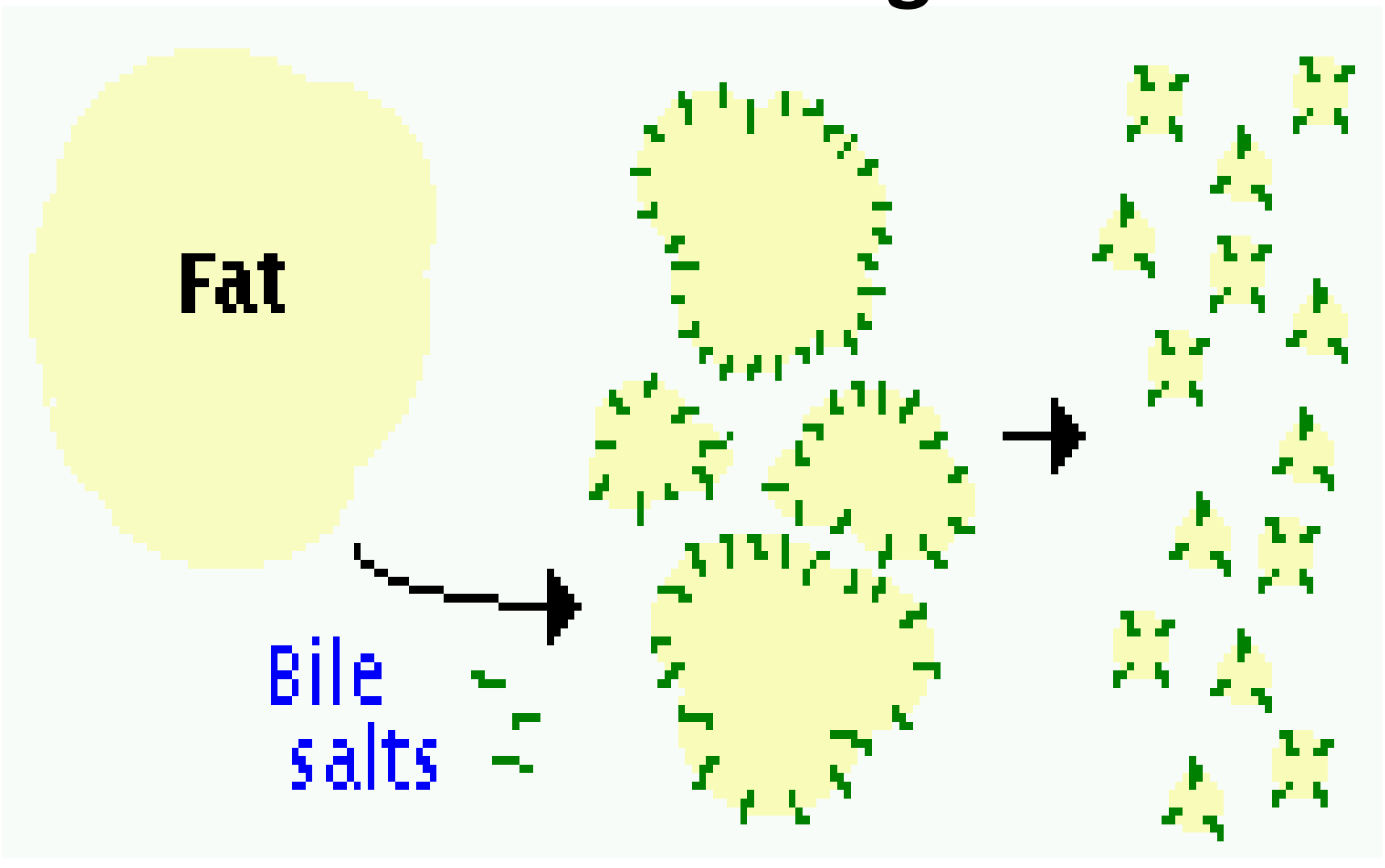
- Covered with a **peripheral layer of Bile salts** and **Amphipathic Lipids.**





Emulsions formed by Bile salts, Triacylglycerols and pancreatic lipase.

Emulsification Forming Emulsions



Significance Of Emulsification

- **Emulsification facilitate digestion of dietary Lipids in small intestine by:**
  - **Reduces surface tension, increasing surface area** of Lipids
  - **Forms Emulsions**
  - **Improves miscibility** of non polar Lipids TAG in aqueous phase.
  - **Brings contact** of dietary Lipids with Lipid digesting enzymes.
  - **Facilitates cleavage** of **Ester bonds** of dietary Lipids.