
بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ
In the name of Allah, the most gracious, the most merciful

Gain Attention

DIGESTION OF LIPID

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KGMC (2022)

BY THE END OF THIS LESSON THE STUDENT WILL BE ABLE TO….

Inform Learner of Objectives

KNOW

- How the complex lipids present in foodstuffs are broken down to simpler forms in the GI tract.
- How the simpler forms are digested in the GI tract.
- Digestion of dietary lipids in mouth and stomach.
- Study the role of lingual lipase , gastric lipase and pancreatic enzymes.
- Role of Enterogastrone in delaying the rate of emptying of stomach
- Digestion of lipids in duodenum and small intestine

Inform Learner of Objectives


RECALL

Stimulate Recall of Prior Learning

LIPID

The heterogeneous group of water insoluble (hydrophobic) organic molecules which can be extracted from tissues by non polar solvents.

Stimulate Recall of Prior Learning

LIPID CLASSIFICATION

- SIMPLE
- COMPOUND
- DERIVED

SOURCES

Animal Sources

Dairy products- Meat, butter, ghee , Fish, Pork, eggs

Mostly saturated fats except fish oil.

Plants Sources

Cooking oils- Sun flower oil, Mustard oil, Ground nut oil

Fats from other vegetable sources etc

Mostly unsaturated fats except coconut and palm oil.

DISTRIBUTION IN OUR BODY

The lipid are generally found **either** compartmentalized as in

(a) membrane associated lipid

(b) droplets of triacylglycrol in adipocytes

or transported by plasma in association with proteins as lipoprotein particles.

Dietary fat

The average normal Pakistani/Indian diet contains about 20-30gm lipids/day. Western diet is 60-150gm/day.

Dietary fat Composition

- More than 90-95% are triacylglycerides,(TGs)
- Cholesterol,
- Cholesterol esters,
- Phospholipids,
- Free fatty acids.
- Vitmin A,D,E,K

Digestion of Lipids

- Lipids are insoluble in water.
- Lipolytic enzymes are soluble in aqueous media.
- GIT possesses specialized machinery to

1-increase the surface area of lipid for digestion

2-solubalize the fat for digestion.

- Emulsification of fat by bile salts.

DIGESTION OF LIPID

A. Preparatory Phase

B. Transport Phase

C. Transportation Phase

A. Preparatory Phase

- The large lipid particles are broken down into smaller particles (micelles) with the help of lipolytic enzymes ,bile salts and gut peristalsis.

A. Preparatory Phase

- Lingual Lipase:
- Gastric Lipase: (Ca^{++} coenzyme)
- Pancreatic enzymes:

  1.Pancreatic Lipase(steapsin)

  2.Phospholipase A2(lecithinase)

  3.Cholesterol esterase (Cholesterol hydrasease)
- Bile salts and acids :
- Ca^{++} :

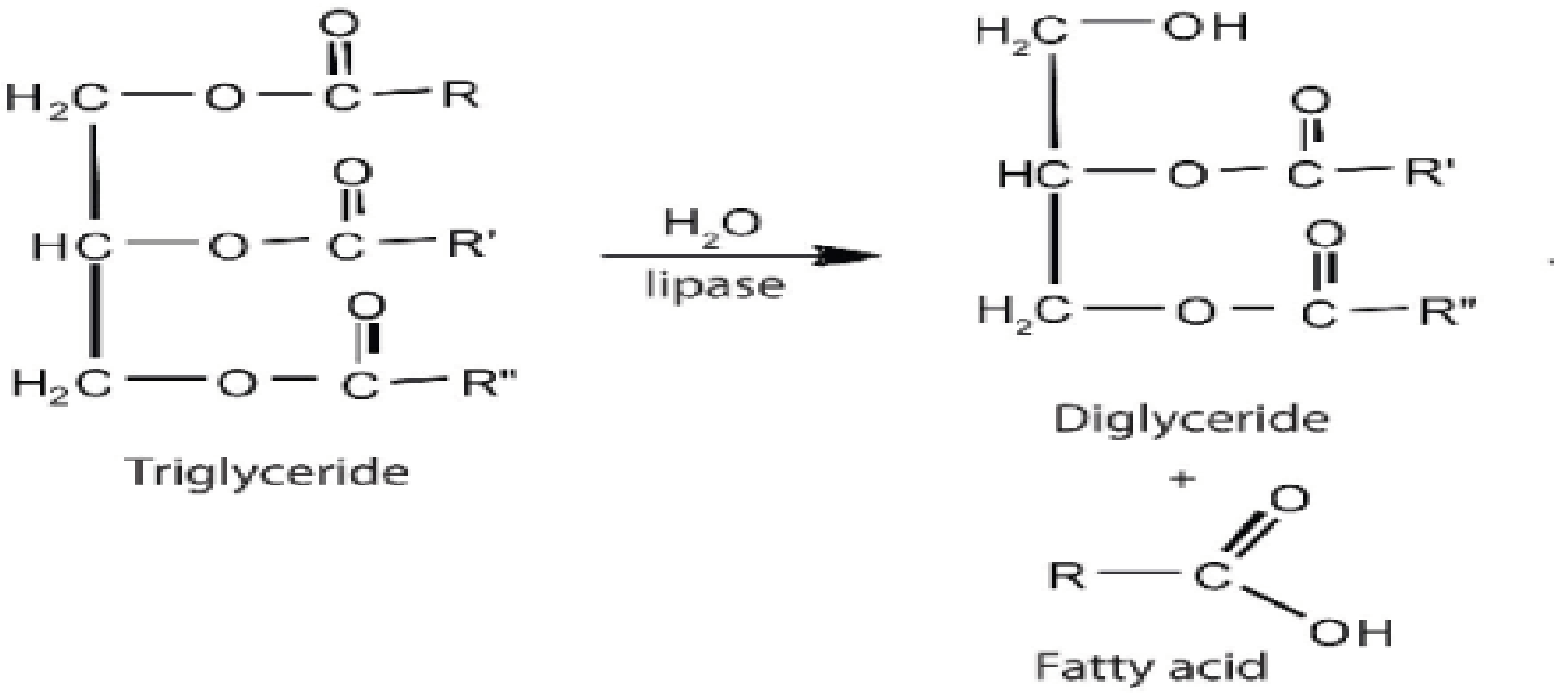
Digestion in Mouth

Lingual Lipase

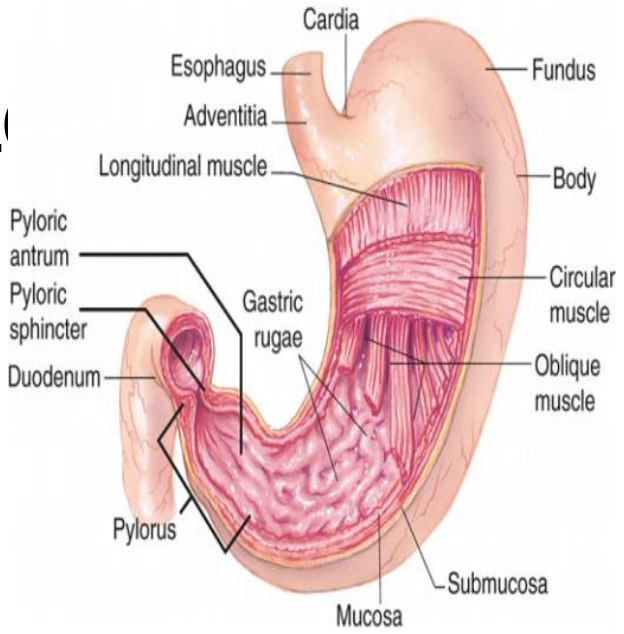
- Secreted by dorsal surface of tongue(Ebner,s glands)
- Optimum pH 4.0-4.5
- Ideal substrate-Short chained TGs.
- Milk fat contains short chain fatty acids, so best substrate for lingual lipase
- Enzymatic action continues in stomach
- Short chain fatty acids, released and absorbed directly from the stomach wall and enter the portal vein.

Digestion in Mouth

Hydrolysis of triacylglycerols is initiated by lingual lipase which attack the *sn-3* ester bond forming 1,2-diacylglycerols and free f

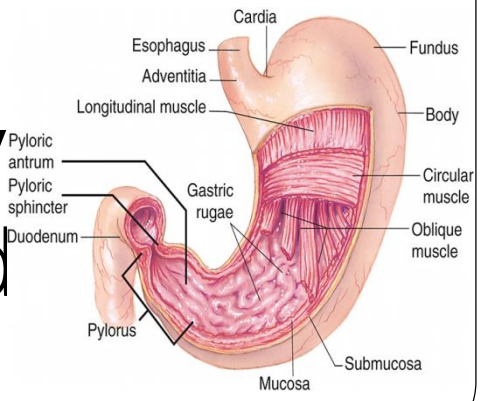


Digestion in Stoma



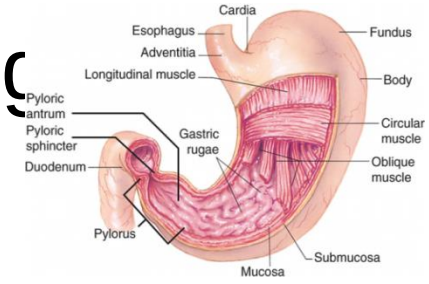
Digestion in Stomach

- Gastric Lipase- secreted in small quantities
- More effective at alkaline pH (Average pH 7.8)
- Requires the presence of Ca^{++}
- Less effective in stomach due to acidic pH
- Not effective for long chain fatty most effective for short and med chain fatty acids



Digestion in Stomach

- The heat of the stomach liquidizes the lipids.
- Breakdown of lipids starts in the stomach by peristaltic contraction.
- Both lingual lipase and gastric lipase acts on short chain triglycerides and 30% of TGs are digested in stomach.
- Milk, egg yolk and fats containing short chain fatty acids are suitable substrates for its action
- So, the action of these lipase is sig newborns.



Gastric Lipase

- Negligible digestion of fat due to:
    1: No emulsification
    2: Small quantity of enzyme
    3: Unfavorable PH
    4: Ca++

Significance of Lingual and Gastric Lipases

- lipid digestion in **neonates** since milk is the main source of energy.
- Important digestive enzymes in pancreatic insufficiency such as **Cystic fibrosis , pancreatic cancer etc.**

Role of fats in gastric emptying

- Fats delay the rate of emptying of stomach.
- Action is brought about by secretion of Enterogastrone.
- Enterogastrone inhibits gastric motility and retards the discharge of fatty food from the stomach.
- Thus fats have a high satiety value.

Digestion in small intestine

Digestion in small intestine

- **Secretion of pancreatic juice is stimulated by-**
  - Passage of acidic gastric contents chyme in to the duodenum
  - By secretion of the gastro intestinal hormones.

Gastro Intestinal hormones

- **Secretin-** Increases the secretion of electrolytes and fluid components of pancreatic juice and also discharges the bile in to the duodenum.
- **Pancreozymin** -stimulates the secretion of the pancreatic enzymes
- **Cholecystokinin -**causes the contraction of the gall bladder and discharges the bile in to the duodenum.
- **Hepatocrinin-** Released by intestinal mucosa, stimulates more bile formation.

Digestion in small intestine

- Major site of fat digestion.
- Effective digestion due to the presence of Pancreatic lipase and bile salts.
- Bile salts act as effective emulsifying agents for fats.

Emulsification and digestion

- Lipids are hydrophobic, and thus are poorly soluble in the aqueous environment of the digestive tract.
- The digestive enzyme, lipase, is water soluble and can only work at the surface of fat globules.
- This problem in digestion & absorption of lipids is overcomes by increasing the surface area of lipids for digestion.

Emulsification and digestion

- Digestion is greatly aided by **emulsification**, the breaking up of fat into much smaller emulsion droplets by peristalsis of gut and mixing with bile salts and acids **by reducing surface tension.**
- Emulsification is the process of dispersion of lipids into small droplets by reducing surface tension.
- Emulsification of lipids by bile salts help in solubilising the digested product for absorption.

Emulsification

Emulsification can occurs by three complementary mechanisms

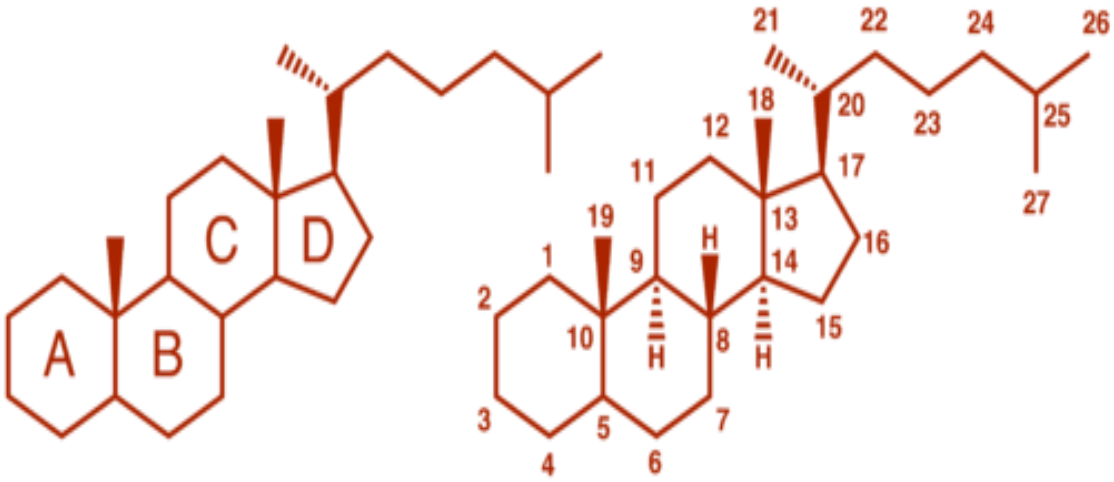
1-Detergent action of bile salts.

2-Surfectant action of degraded lipids.

3-Mechenical mixing due to peristalsis of gut.

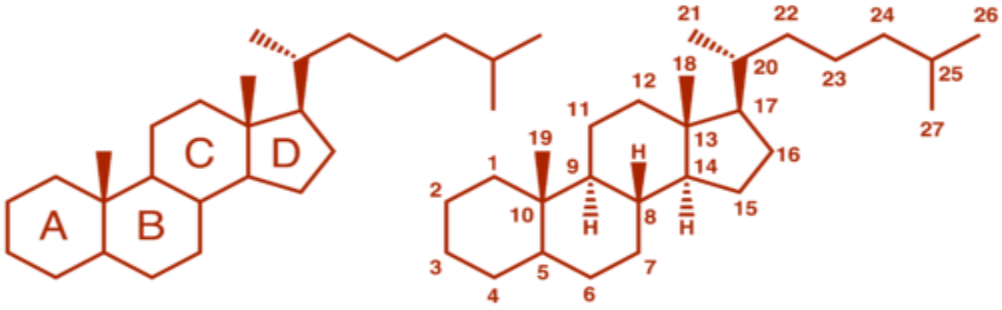
salts

- Bile salts are synthesized in the liver and stored in the gall bladder
- They are derivatives of cholesterol
- They consist of a sterol ring structure with a side chain to which a molecule of glycine or Taurine is covalently attached by an amide linkage



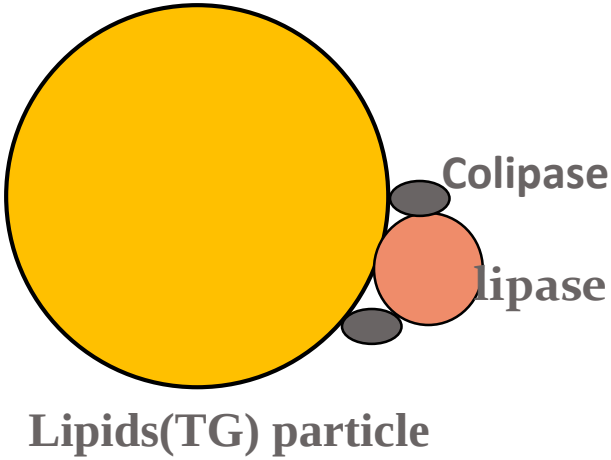
1-BILE SALTS:

- Biological detergent ,Chemically these are Sodium glycocholate and Sodium taurochlate
- By emulsifying action convert lipid and aqueous content of duodenum into emulsifying droplets and than into much smaller micelles.
- Prevents and stabilize the particle from coalescing.



Role of Bile Salts in pancreatic lipase activity

- Bile salts are required for the proper functioning of the pancreatic lipase enzyme.
- Bile salts help in combination of lipase with two molecules of a small protein called as colipase. This combination enhances the lipase activity and prevent the surface denaturation by bile acids.



Enterohepatic circulation

- Bile ,synthesized in the liver accumulate in gall bladder and Secreted into small intestine
- Serve as emulsifying agents for fats and fat soluble vitamins.
- A large portion of the bile salts are reabsorbed and returned to the liver through portal vein.
- The bile salts are recycled and reused several times in a day.
- About 15-30g of bile salts are secreted per day
- Small portion of 0.5 g/day is lost in the feces.
- (0.5g/day)is synthesized in liver to replace the lost bile salts.
- The fecal excretion of bile salts is the only route for the removal of cholesterol from the body.

Emulsification

2-Surfectant action of degraded lipids.

- The initial digested product catalyzed by lipases promote emulsification as surfactants by increasing the interfacial area of lipid droplets.

3- Mechanical Mixing due to peristalsis:

The peristaltic movements of the gut increases the surface area of the particles by broken down into small pieces

Ca ++

- Ca ++ Act as co- enzyme to increase the action of lipase.

Contents of Pancreatic Juice

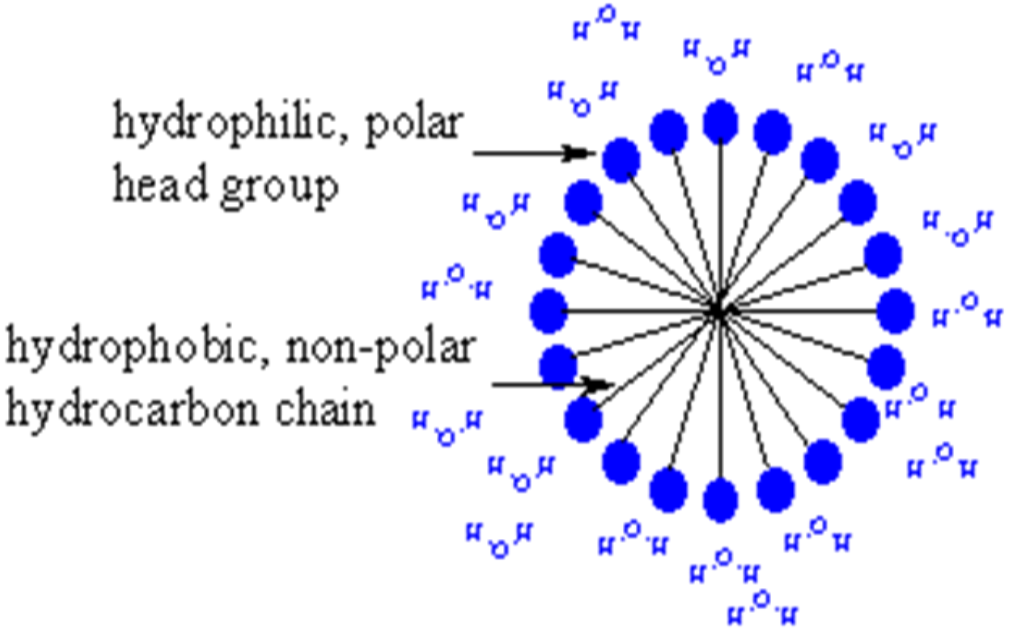
- Pancreatic Lipase- For the digestion of triglycerides(TGs)
- Phospholipase A2- for the digestion of Phospholipids
- Cholesterol esterase-For the digestion of Cholesterol esters
- Bile acids and bile salts
- HCO_3
- Ca^{++}

Significance of Pancreatic Lipases

- The enzyme is present in high concentration in pancreas. Only very severe **pancreatic lipase deficiency such as in cystic fibrosis** results in malabsorption of fats due to impaired digestion.
- **Orlistat**, an antiobesity drug inhibits , gastric and pancreatic lipases, there by decreasing fat digestion and absorption resulting in weight loss.

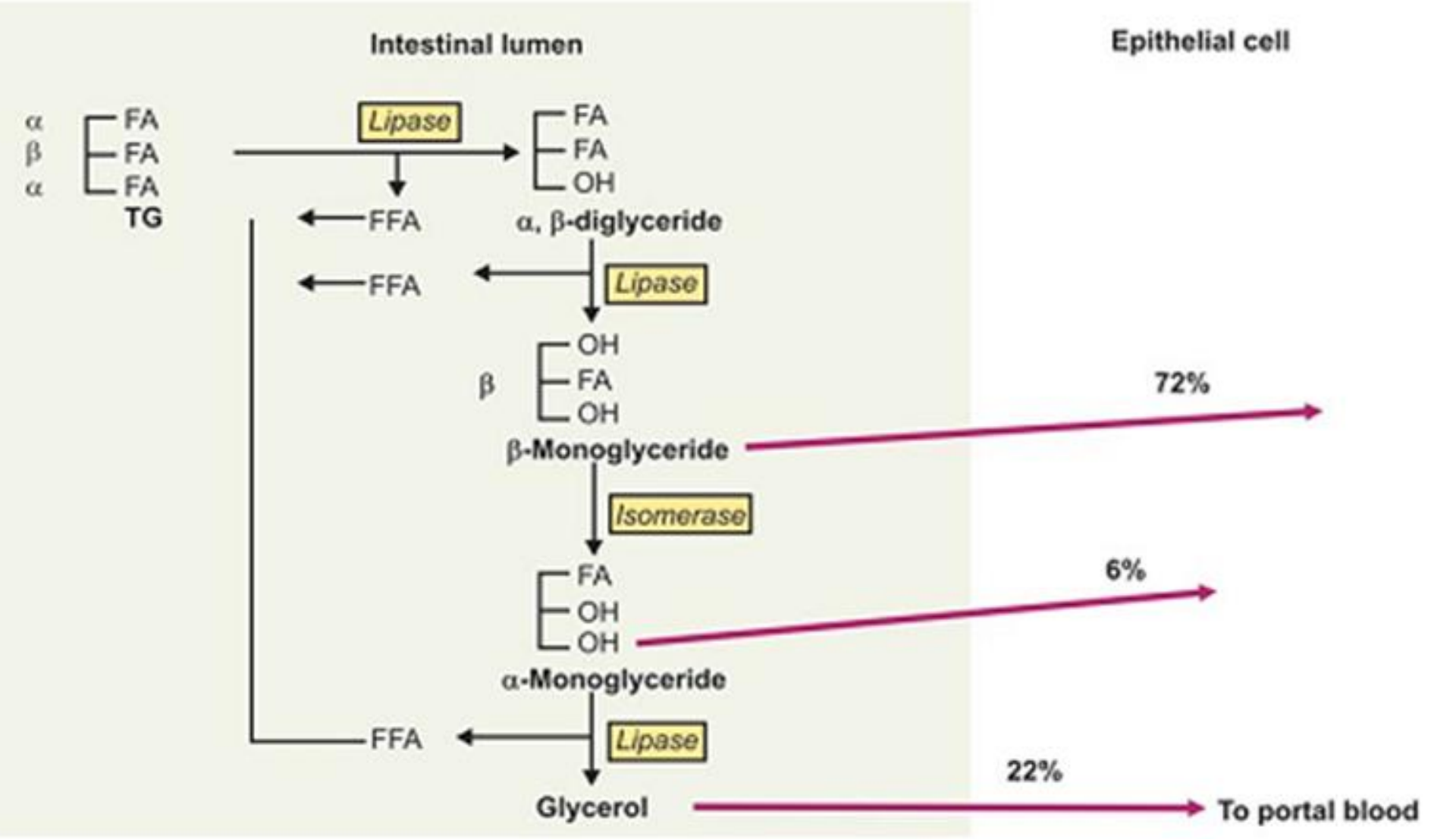
Micelles

- Micelles are disk shaped clusters of amphipathic lipids (Higher FA + mono + diglycerides +triglycerides+ cholesterol + bile salts + PL +bicarbonate + Vit A,D,E,K) with their hydrophobic groups on the inside and their hydrophilic groups on the outside of clusters
- Micelles are much smaller then emulsified droplets and soluble in the aqueous environment of the intestinal lumen

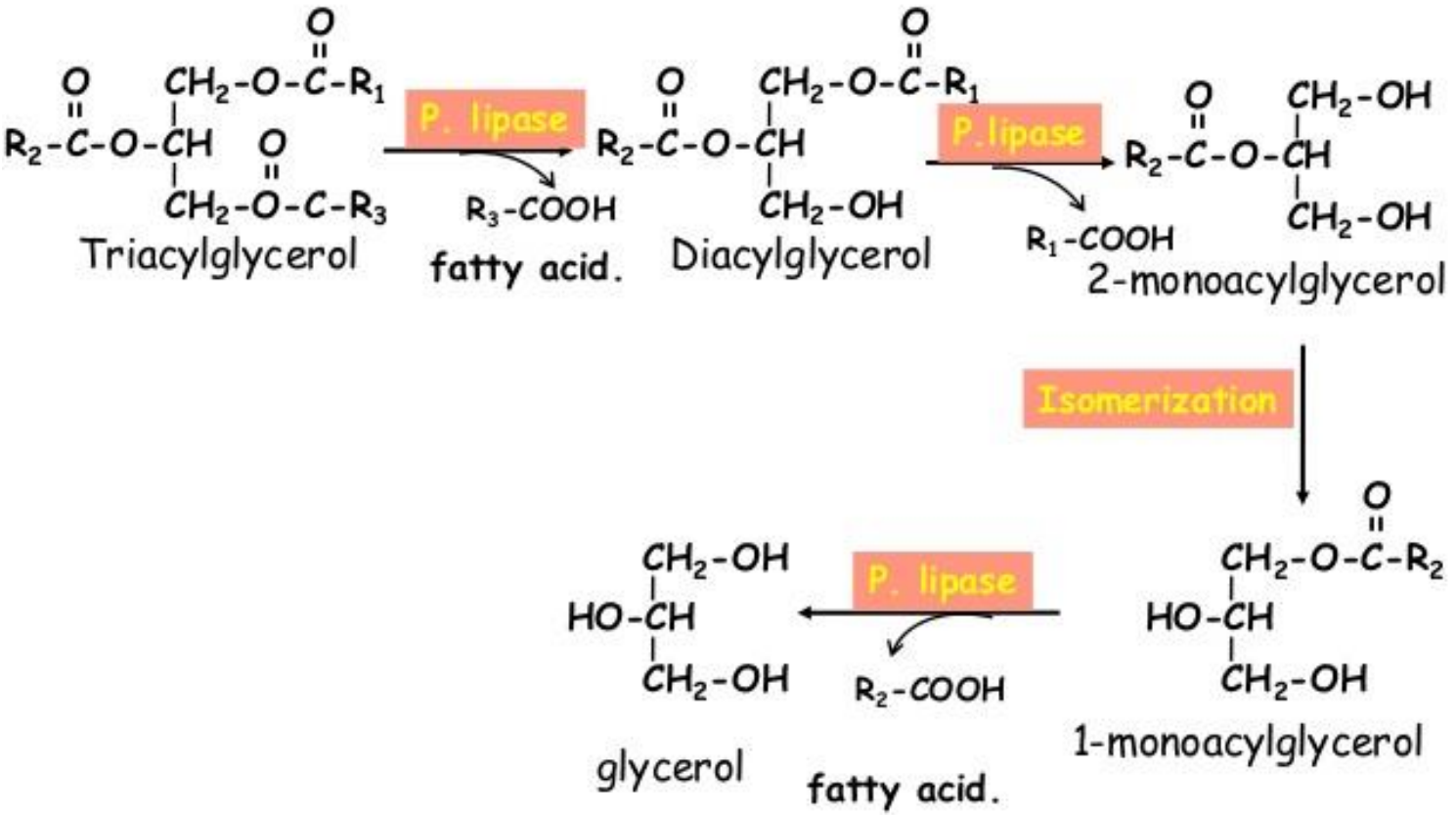


- Glycerol, short and medium chain fatty acids (Chain length less than 14 carbons) are directly absorbed from the intestinal lumen in to the portal vein and taken to liver for further utilization.
- Long chain fatty acids, free cholesterol ,lysophospholipid, vit A,D,E,K and β- acyl glycerol together with bile salts form mixed micelles.

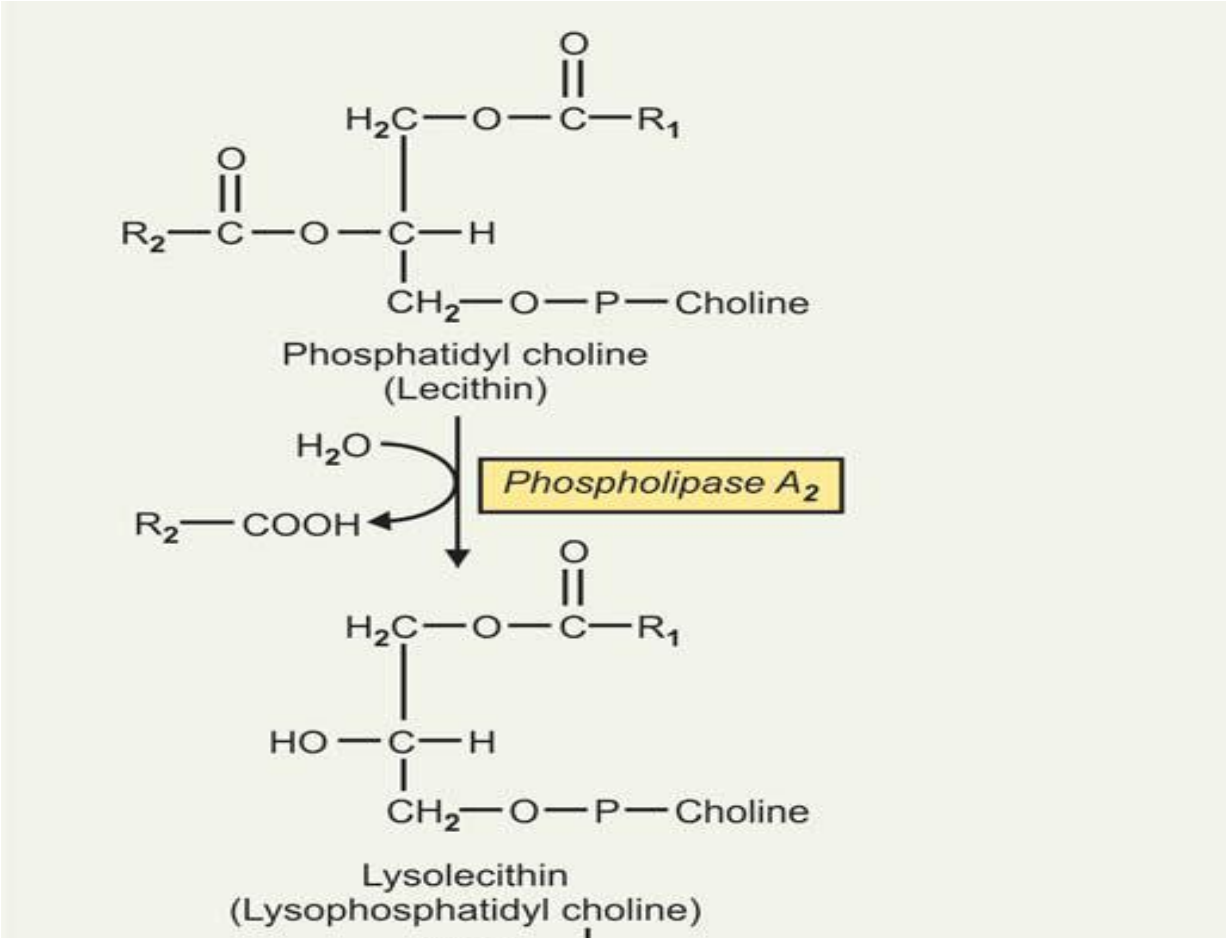
Digestion in intestinal lumen



Hydrolysis of TGL by lipase



Hydrolysis Of Phospholipids By Phospholipase A2-



Cholesteryl ester degradation

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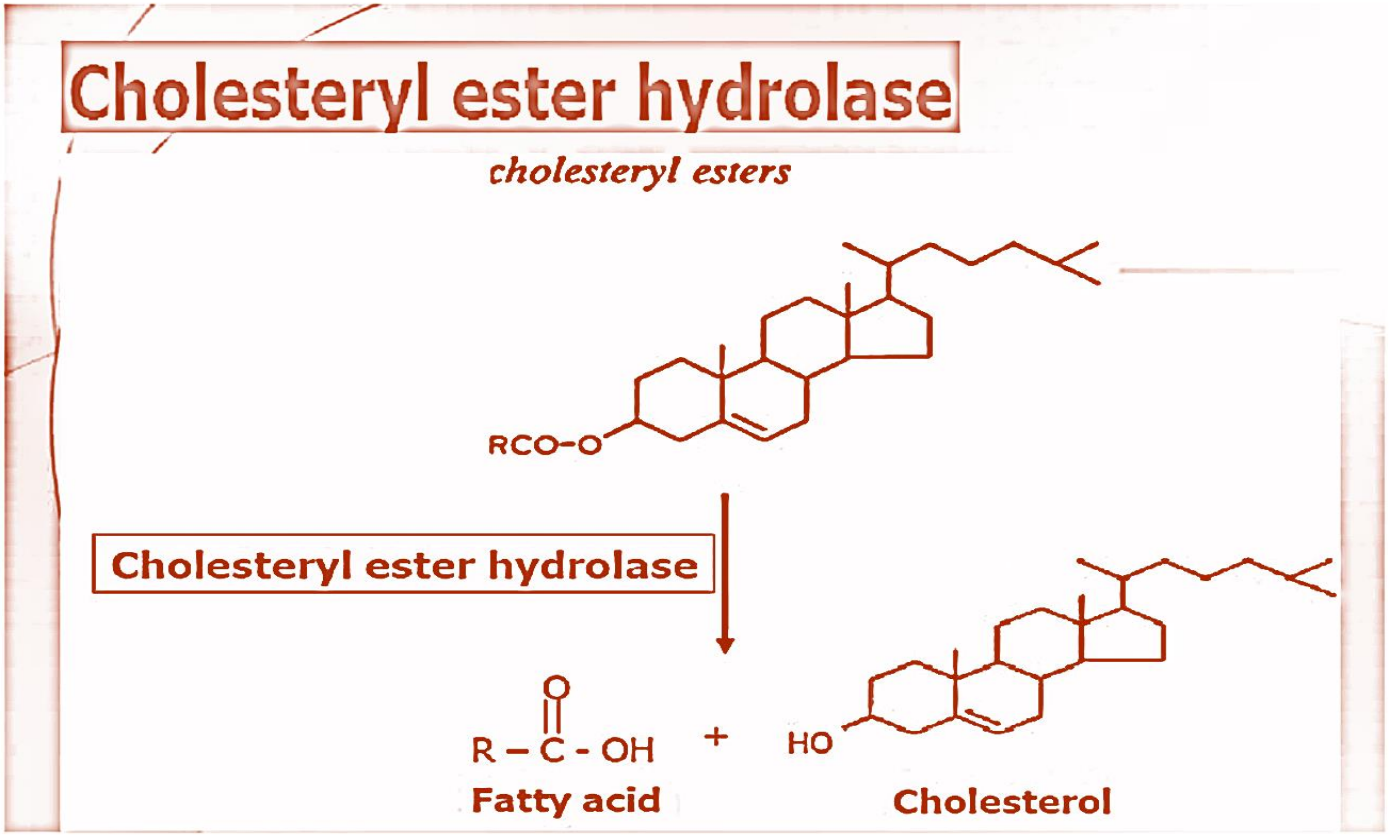
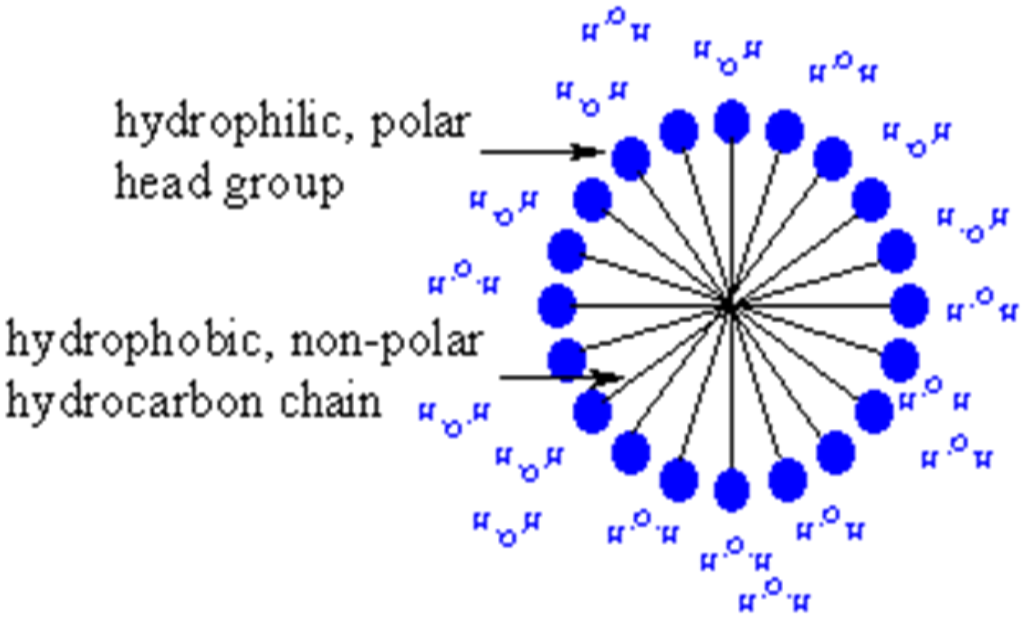


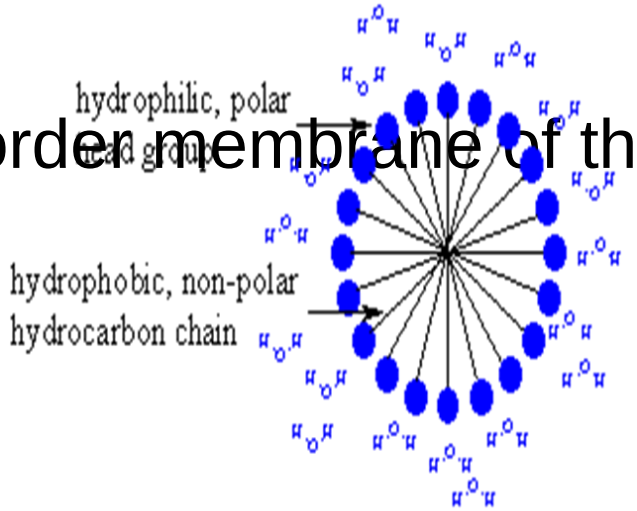
Mixed Micelles

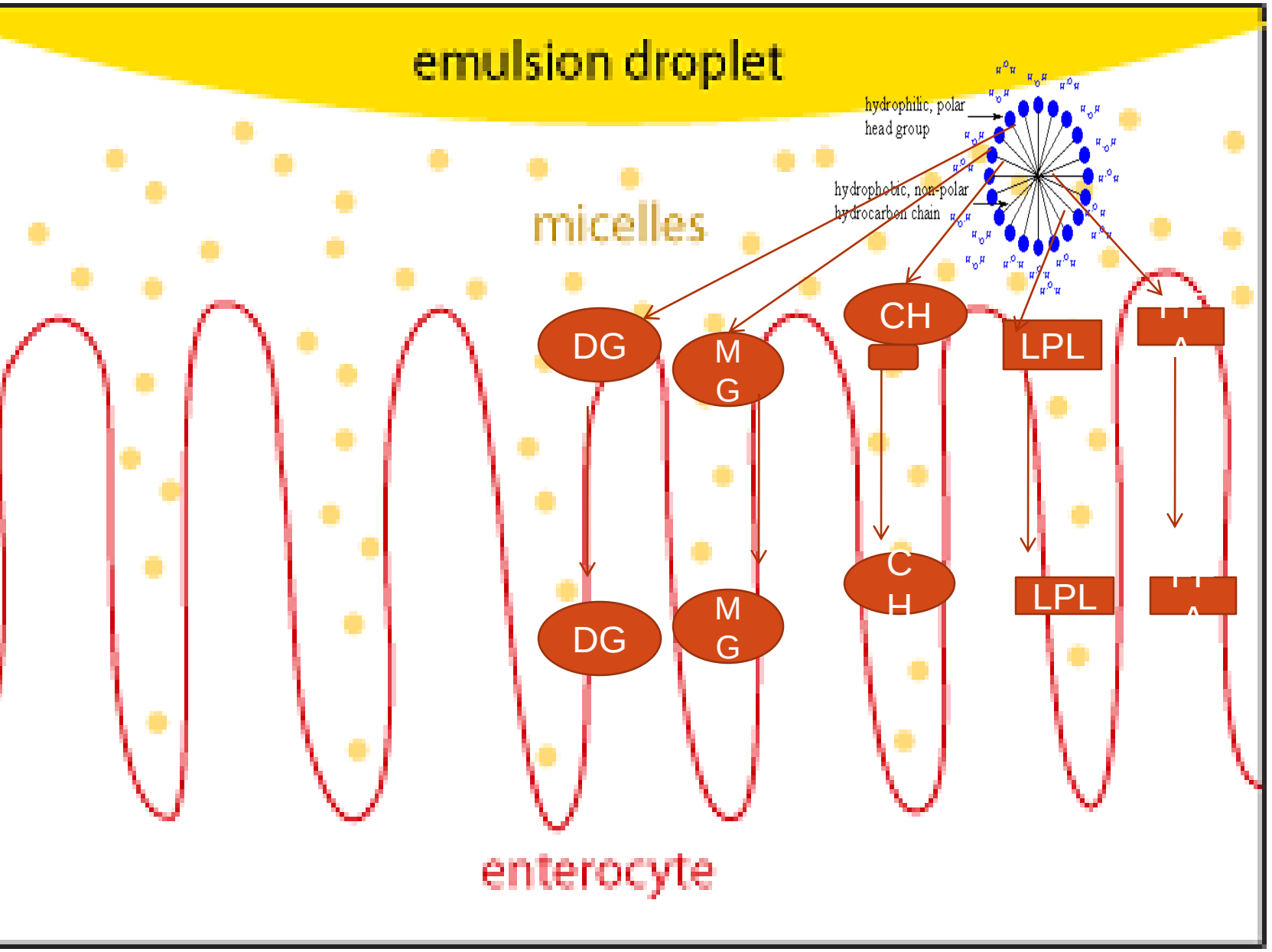
- Triacylglycerol=FFF + Monoacylglycerol + diacylglycerol + glycerol
- Cholesterol ester= FFA + Cholesterol
- Phospholipid= FFA+ lysophospholipid
- Bile salts
- Vit A ,D , E, K



Mixed Micelles

- Micelles constantly break down and re-form,
- It is the monoglycerides and fatty acids that are free in solution that are absorbed, NOT the micelles.
- Because of their nonpolar nature, monoglycerides and fatty acids can just diffuse across the plasma membrane of the intestine.
- Some absorption may be facilitated by specific transport proteins
- The micelles approach the brush border membrane of the enterocytes.




emulsion droplet
hydrophilic, polar
head group
hydrophobic, non-polar
hydrocarbon chain
micelles
DG
M
G
CH
LPL
DG
M
G
C
H
LPL
enterocyte

Micelles

micelles (smallar than drops of emulsified fat)

The lipid part of the micelles are absorbed by duodenum and jejunum .

The bile salt are released and used in other micelle formation --------reabsorbed by lower part of small intestine ----------enterohepatic circulation-------- ------- LIVER ------Portal circulation.

Functions of Micelles

- Transport cholesterol from the liver into the intestine via the biliary tree
- Participate in fat digestion and absorption.

B:Transport Phase

- FFA +α and β diglycerides +cholesterol +lysophospholipid enter the microvillus by simple diffusion through cell membrane
- In rough endoplasmic reticulum ----------resynthesized TG
- In smooth endoplasmic reticulum with lipoprotein (apo B48) a complex form called chylomicron.
- Very less amount about 5% of fat absorption takes place by pinocytosis.

C:Transportation Phase

In intestinal mucosal cell

- Alpha monoglycerides-$^{-hydrolysis---}$ FA + glycerol

- FA ----Thiokinase---- Acyl-coA
  ATP AMP+ppi

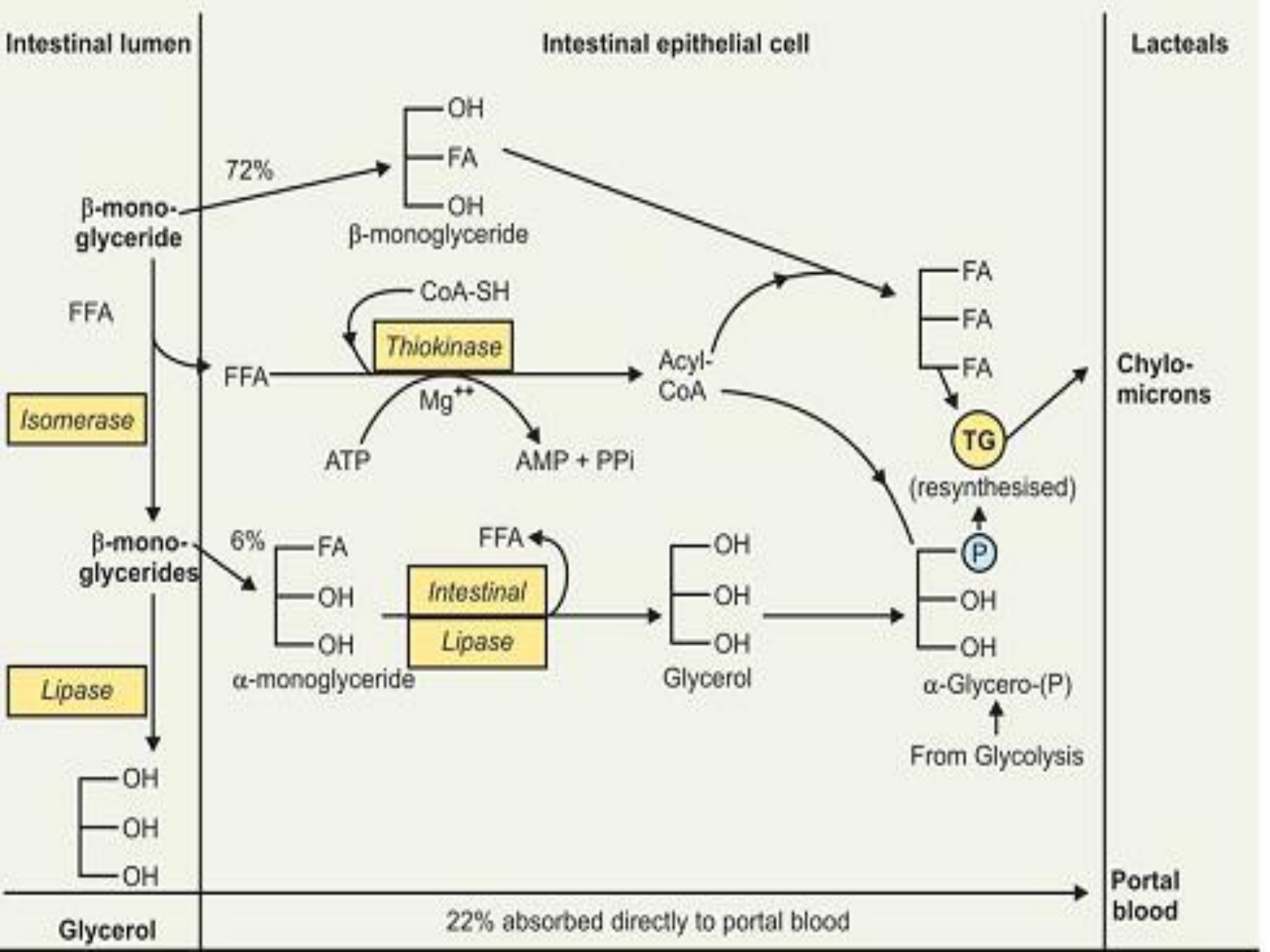
Glycerol— glycerokinase--- alpha glycerol
ATP AMP

Acyl-coA + alpha glycerol----------→ TG

Acyl-coA + beta monoglycerol-----→ TG

Products of Lipid Digestion

- Following are the end products of lipid digestion
- Free Fatty acids
- Triacylglycerol
- Diacylglycerol
- Monoacylglycerol
- Cholesterol esters
- Phospholipid
- glycerol
- vitamins (A, D, E and K)


Intestinal lumen
Intestinal epithelial cell
Lacteals
β-mono-glyceride
72%
OH
FA
OH
β-monoglyceride
FFA
CoA-SH
Thiokinase
FFA
Mg++
ATP
AMP + PPi
Acyl-CoA
FA
FA
FA
Chylo-microns
TG
(resynthesised)
Isomerase
β-mono-glycerides
6%
FA
OH
OH
α-monoglyceride
FFA
Intestinal
Lipase
OH
OH
OH
Glycerol
P
OH
OH
α-Glycero-(P)
From Glycolysis
Lipase
OH
OH
OH
Glycerol
22% absorbed directly to portal blood
Portal blood

ANY QUESTION

- CHATTERJEA BIOCHEMISTRY
- LIPPINCOTT BIOCHEMISTRY
- HARPERS BIOCHEMISTRY
- SATYANARAYANA BIOCHEMISTRY
- INTERNET

Thank you