

06

6. The digestive System (Digestion & Absorption)

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Objectives

- By the end of this lecture, the student should be able to:
- Identify on a diagram structures of human digestive systems and give the functions of each.
- Identify sources of carbohydrate, protein and lipid
- Trace the pathway traveled by ingested meal in human digestive system and describe step-by-step digestion of carbohydrate, protein and lipid.
- Describe the mechanism of the absorption of carbohydrate protein and lipid by intestinal villus, their fate and roles in human body.

Outlines

- Components of human Gastrointestinal Tract (GIT).
- Overall role of gastrointestinal tract with respect to the absorption of nutrients and excretion of waste products.
- Enzymes involved in complete digestion of carbohydrate, protein and lipid in human GIT.
- Intestinal villus and the explanation how its structure is adapted to its function.
- Mechanisms involved in absorption of carbohydrate, protein and lipid and associated conditions due to their mal-absorption.

Gastrointestinal Tract (GIT)

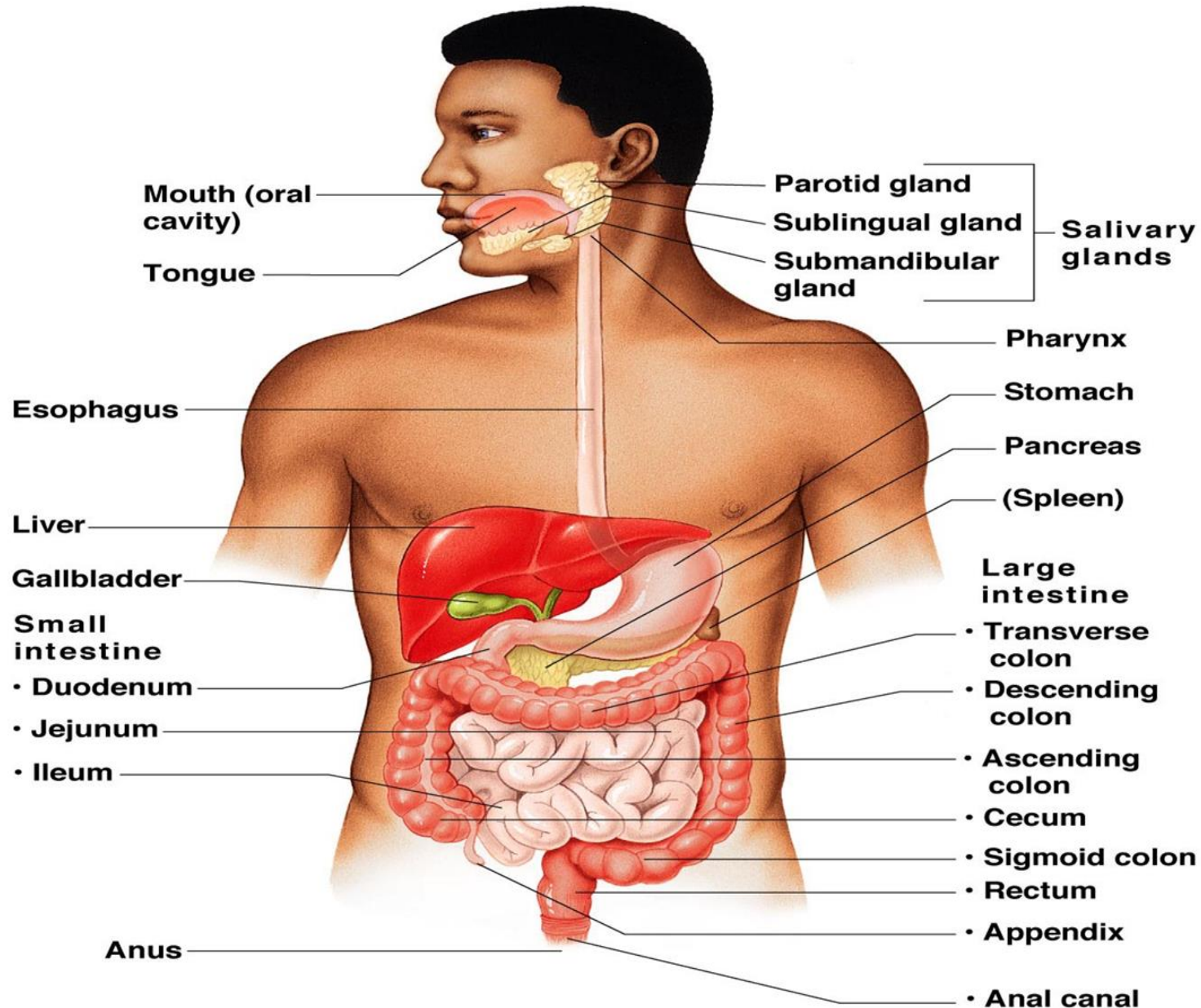
- **Physiological Anatomy of Digestive System**
- Digestive system consists of a long tube called Gastrointestinal Tract (GIT) or Alimentary canal plus associated glands.
- Segments of the GIT includes:
 1. Mouth
 2. Mouth cavity (Oral cavity)
 3. Pharynx
 4. Esophagus
 5. Stomach

- 6. Small intestine which includes:
 - Duodenum
 - Jejunum &
 - Ileum

- 7. Large intestine which includes:
 - Caecum (contains the appendix)
 - Colon &
 - Rectum (ends at the anus)

PHYSIOLOGICAL ANATOMY OF GIT

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Functions of the GIT

- 1: **Ingestion** (Nutrients like protein, carbohydrate, fat, water, vitamins, & minerals).
- 2: **Digestion** of food
- 3: **Absorption** of digested food
- 4: Formation of feces
- 5: **Excretion** of feces by anal canal known as Defecation.
- 6: Others like formation of RBCs

Digestion

- Digestion is the process of break down of polymeric molecules of the food into simple basic units i.e. absorbable forms e.g. :
- ***Proteins*** → Oligopeptides → Amino acids
- ***Carbohydrates*** → (Monosaccharides)
for example, Glucose
- ***Fat*** → Fatty Acids + Glycerol + Cholesterol

Digestion is done by:

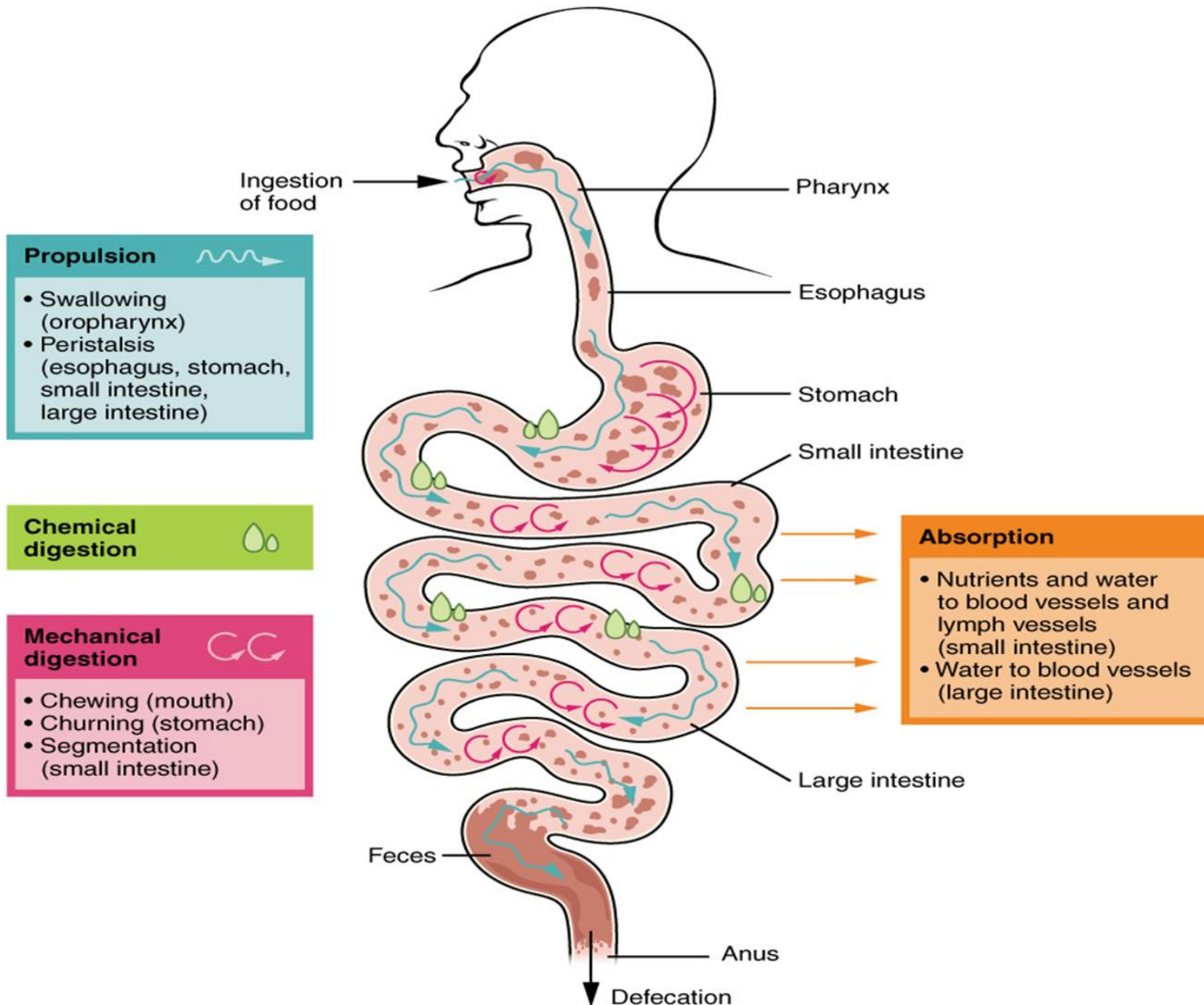
- Digestive juices and Enzymes
- Mostly secreted in an **inactive** form
- Mainly from :
 - Saliva & gastric juice
 - Pancreas in form of pro-enzymes for example Protease precursors which is necessary for the digestion and absorption of Proteins.
 - Liver & Gall bladder for example Bile which is necessary for the digestion and absorption of lipids.

Absorption

- It is defined as the transfer of the digested food contents from the lumen into blood or lymph
- Absorption of food occurs mainly in the small intestine primarily through the mucosal cells by the following mechanisms:
 - Diffusion, ■ Facilitated diffusion,
 - Active transport, ■ Secondary active transport,
 - Endocytosis & ■ Osmosis.
- Water, sodium and chloride are absorbed mainly in the colon.

■ DIGESTION AND ABSORPTION

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1. _____ is defined as the transfer of the digested food contents from the lumen into blood or lymph?

- A. Digestion
- B. Defecation
- C. Ingestion
- D. Absorption
- E. Transportation





2. Which of the following is a part of small intestine _____?

- A. Duodenum.
- B. Jejunum.
- C. Ileum.
- D. All of the above.





3. Which of the following is NOT a part of LARGE INTESTINE _____?

A. Caecum.

B. Colon.

C. Rectum

D. Ileum





4. Which of the following not considered as a function of the GIT?

- A. Ingestion of food and Digestion of food.
- B. Absorption of digested food.
- C. Transportation of absorbed food.
- D. Formation of feces and Excretion of feces.





5. _____ is defined as the process of breakdown of polymeric molecules of the food into simple basic molecules.

- A. Digestion.
- B. Ingestion.
- C. Absorption.
- D. Transportation.



6. Diffusion, facilitated diffusion, Active transport, Secondary active transport, Endocytosis & Osmosis are mechanisms of

- A. Digestion.
- B. Ingestion.
- C. Absorption.
- D. Transportation.





7. Water, sodium and chloride are mainly absorbed in the _____?

- A. Colon.
- B. Small intestine.
- C. Jejunum.
- D. Ileum.



Digestion of Carbohydrates (CHO)

- The typical standard diet is about 2,200 calories per day, with **50%** of calories from carbohydrates, **15%** protein, and **35%** fat.
- Carbohydrates in the diet provide primary energy source for cells.
- They account for 40-60% of the calories in the standard diet.
- Each gram of carbohydrate provides 4 calories.
- Complex carbohydrates such as starch are believed to be more healthy than the sugar so frequently consumed in the standard diet.

Sources of Carbohydrates

- Dairy: Milk, yogurt, and ice cream.
- Fruit: Whole fruit and fruit juice.
- Grains: Bread, rice, crackers, and cereal.
- Legumes: Beans, plant-based proteins.
- Starchy Vegetables: Potatoes and corn.
- Sugary Sweets: Juices, candy, cookies, and other desserts.

■ Examples of Carbohydrates

Monosaccharide :-

Glucose, fructose & galactose

Disaccharides :-

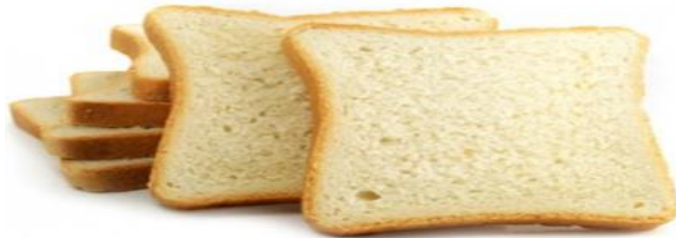
Sucrose & lactose

Polysaccharides :-

Cellulose & starch

- **Main dietary Carbohydrates include:**

- **Starch** from Bread (polysaccharide)



- **Sucrose** from Table Sugar (disaccharide)



- **Lactose** from Milk (disaccharide)

- **Glucose** and **Fructose** (monosaccharide)
- From Sugary juices, Candy.



- **Cellulose** (polysaccharide)
- From vegetables such as pumpkin, cabbage.



- Humans are unable to digest cellulose because the appropriate enzymes to breakdown the beta acetal linkages are lacking.
- **Indigestible** cellulose is the **fiber** which aids in the smooth working of the intestinal tract.

DIGESTION OF CARBOHYDRATES

Mouth

- Digestion starts in **mouth** by the action of an enzyme named **salivary α amylase**.
- This enzyme converts cooked starch to Disaccharides.

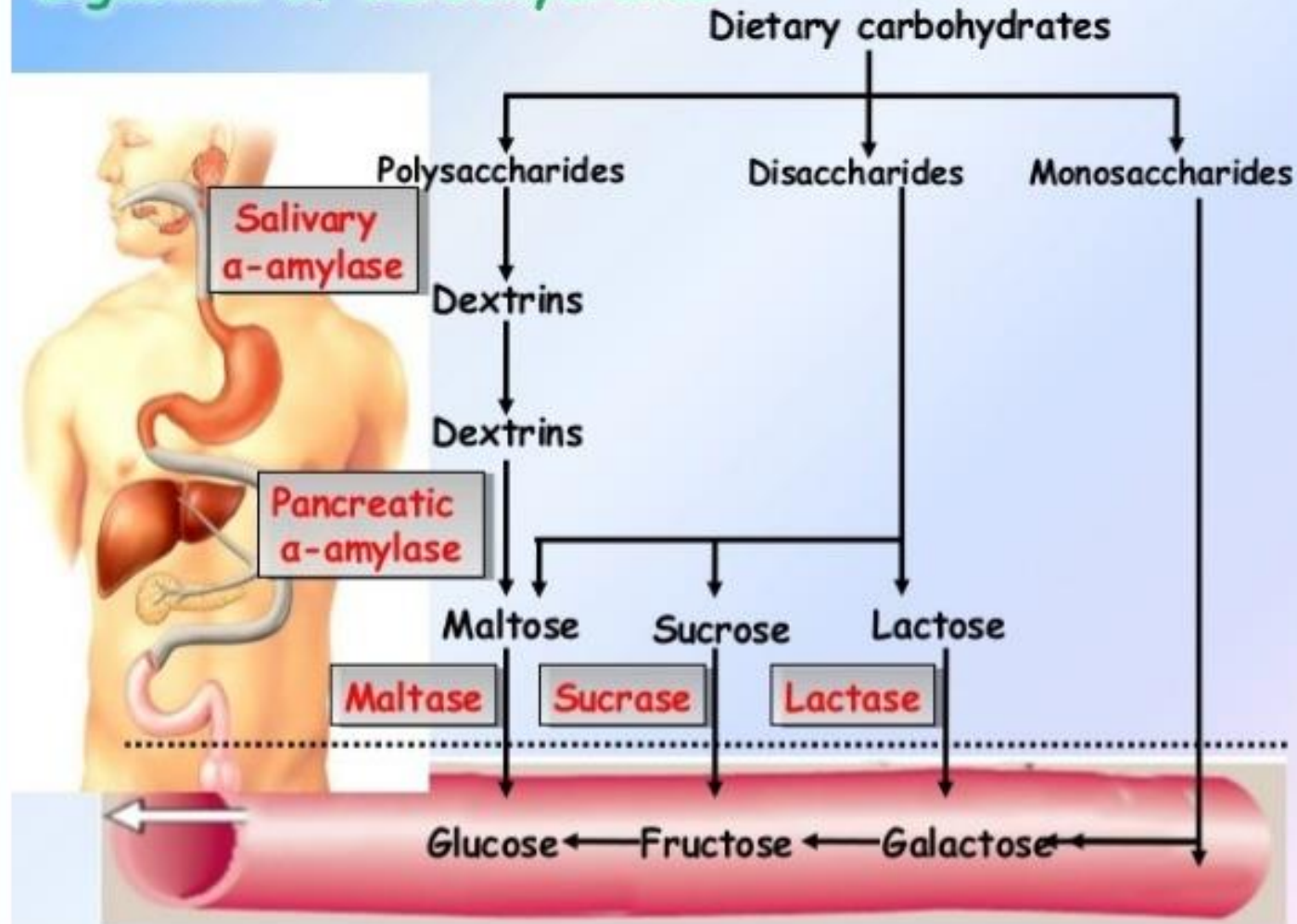
Stomach

Acid secretions of stomach stops the action of salivary α amylase.

Small Intestine

- **Pancreatic α amylase**. converts the uncooked and cooked starch to **disaccharides**.
- **Disaccharides** are finally broken down into monosaccharides by enzymes present in the brush border of the small intestinal wall.
- End products of digested carbohydrate are: **Glucose, Galactose, Fructose**.

Digestion of Carbohydrates

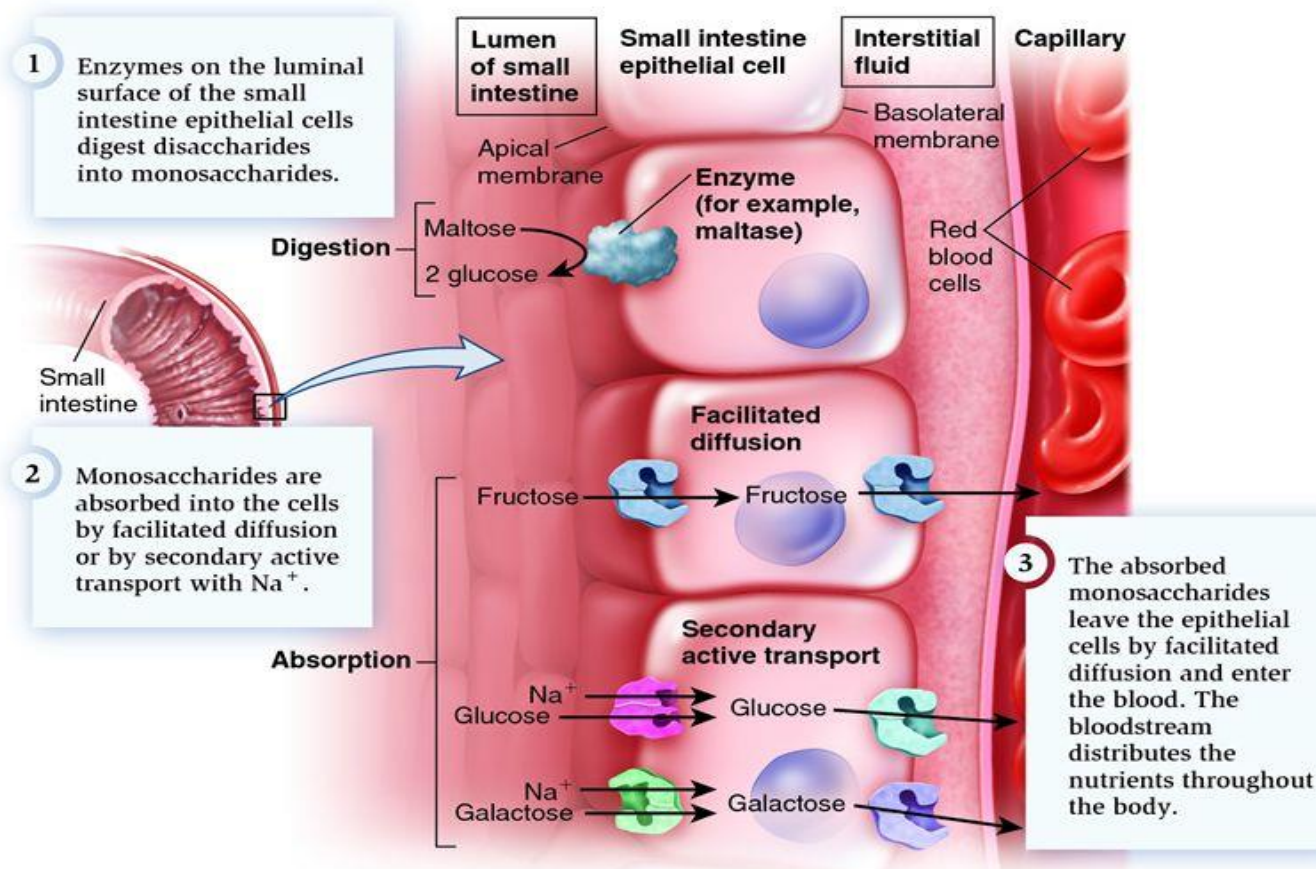


■ **ABSORPTION OF CARBOHYDRATES**

- Digested carbohydrates are absorbed into blood capillaries of the villi of small intestine.
- Glucose is absorbed as monosaccharide throughout the small intestine by:
 - Secondary active **transport coupled to Na⁺** (Sodium Glucose Transport-SGLT).
- Galactose is also absorbed by Sodium-dependent glucose cotransporter-1 (SGLT-1)

- Fructose is absorbed by:
 - Facilitated diffusion and does not require Na^+

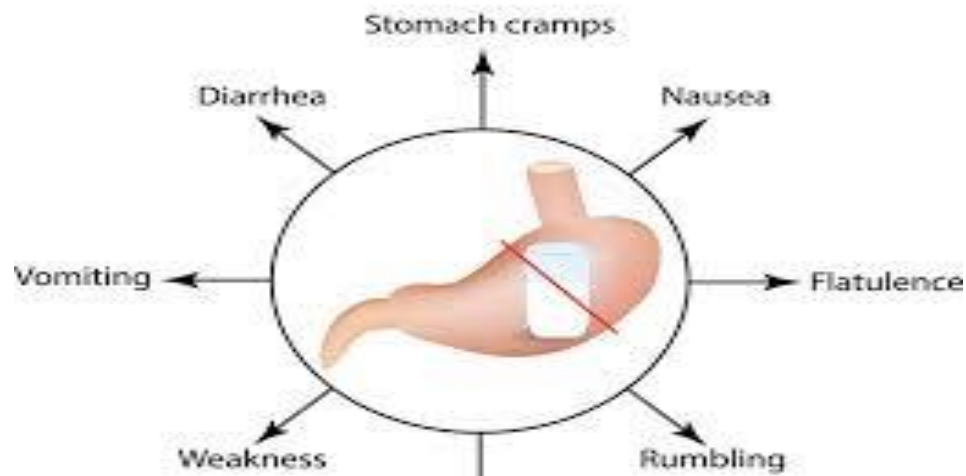
■ DIGESTION AND ABSORPTION OF CARBOHYDRATES



■ Lactose Intolerance

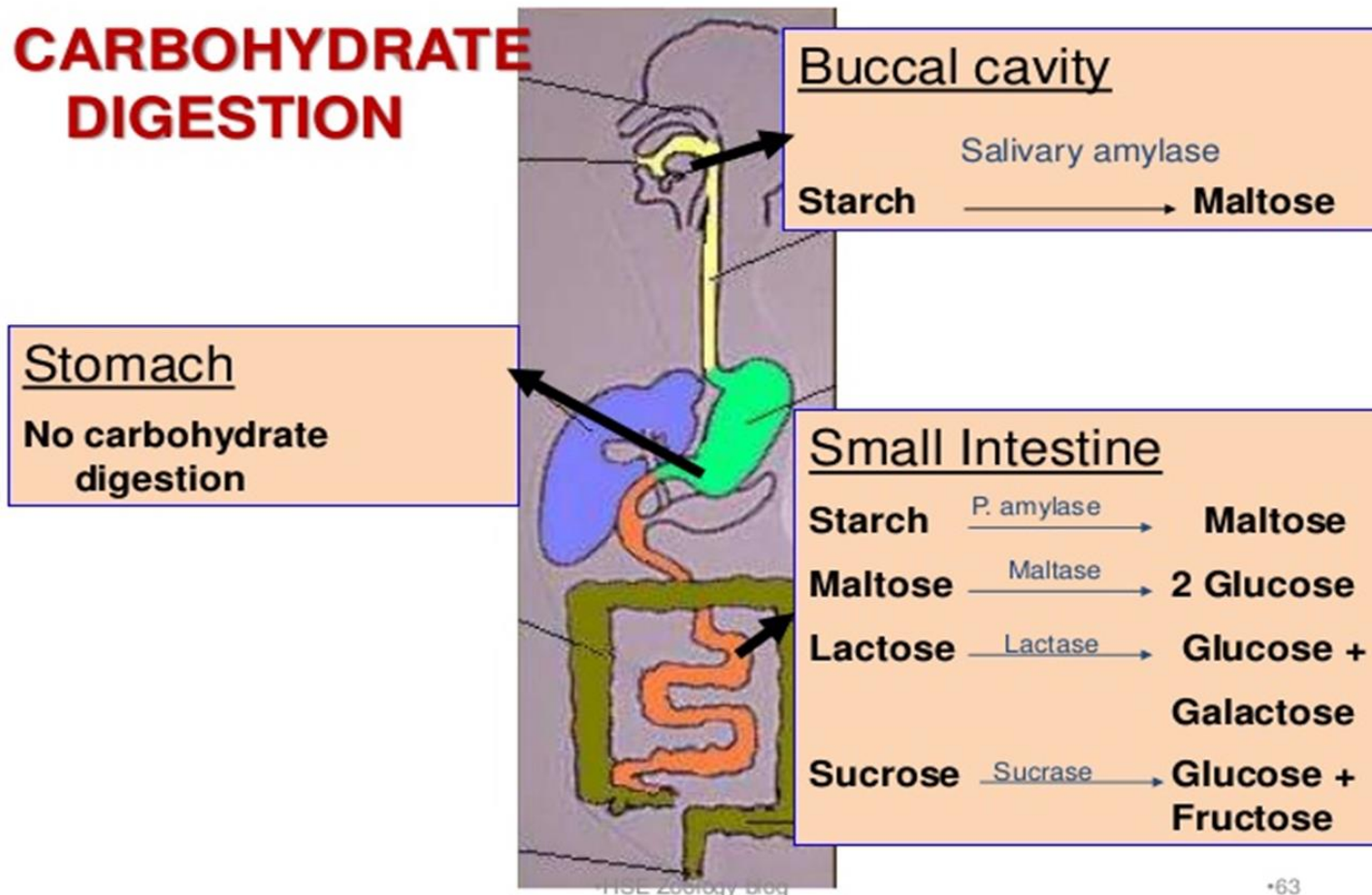
- **Lactase** is an enzyme that breaks down the disaccharide lactose (in milk) into its component parts, glucose and galactose, which are absorbed by the small intestine.
- Approximately half the adult world population produces only **small amounts** of lactase.
- Therefore unable to eat milk-based foods.
- This condition is commonly known as lactose intolerance.
- Symptoms, include bloating, diarrhea and abdominal cramps.

■ Lactose Intolerance



■ DIGESTION AND ABSORPTION OF CARBOHYDRATES

CARBOHYDRATE DIGESTION





8. Digestion of carbohydrates starts IN _____ BY _____ enzyme?

- A. Small intestine BY pancreatic amylase enzyme.
- B. Stomach BY pepsin enzyme.
- C. Mouth BY salivary amylase enzyme.
- D. Small intestine BY trypsin enzyme.



9. One gram of carbohydrates provide
_____?

- A. 4 calories
- B. 100 calories
- C. 20 calories
- D. 0.5 calorie





9b. Sucrose is an example of _____?

- A. Monosaccharides
- B. Disaccharides
- C. Polysaccharides
- D. Trisaccharide



10. Digestion of carbohydrates occurs in _____?

- A. Mouth
- B. Stomach.
- C. Small intestine.
- D. B and C.
- E. A and C.





11. Salivary amylase is secreted in _____?

- A. Duodenum.
- B. Mouth.
- C. Colon.
- D. Stomach.



12. Patients with lactose-intolerance are _____?

- A. Unable to breakdown lactose.
- B. Unable to absorb lactose.
- C. Unable to digest all types of carbohydrates.
- D. Have small amount of amylase enzymes



■ DIGESTION AND ABSORPTION OF PROTEIN

- Protein is one of the most important substances in the body.
- Muscles, hair, eyes, organs, and many hormones and enzymes are primarily made out of protein.
- It also helps to repair and maintain body tissues.

- **High-quality** protein sources, such as meat, fish, eggs, and dairy products, contain all nine of the essential amino acids.
- These are also called **whole proteins** or complete proteins.
- Other protein sources, such as nuts, beans, and seeds, only contain some essential amino acids.

■ SOURCES OF PROTEINS



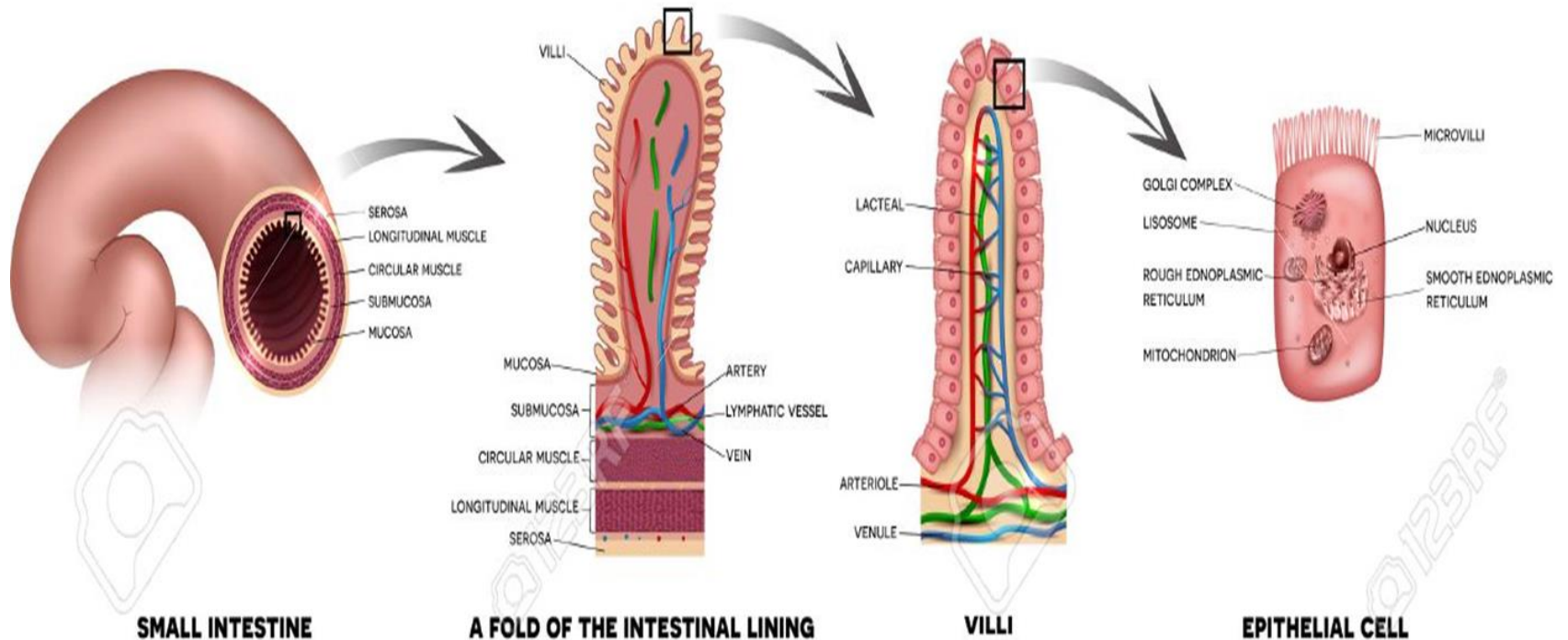
Stomach

- **Digestion of proteins** starts in stomach
- Acid secretions of stomach converts an enzyme **pepsinogen** into its active form **Pepsin**.
- Pepsin causes break down of food proteins into polypeptides

Small Intestine

- Two enzymes **chymotrypsinogen** and **trypsinogen** secreted by the **pancreas**.
- These enzymes are converted into their active forms named **chymotrypsin** and **trypsin** in duodenum (small intestine) by brush border enzyme called **enterokinase**
- The active enzymes break down **proteins** into **polypeptides**, which are then broken down by various **exopeptidases** and **dipeptidases** into amino acids.

SMALL INTESTINE



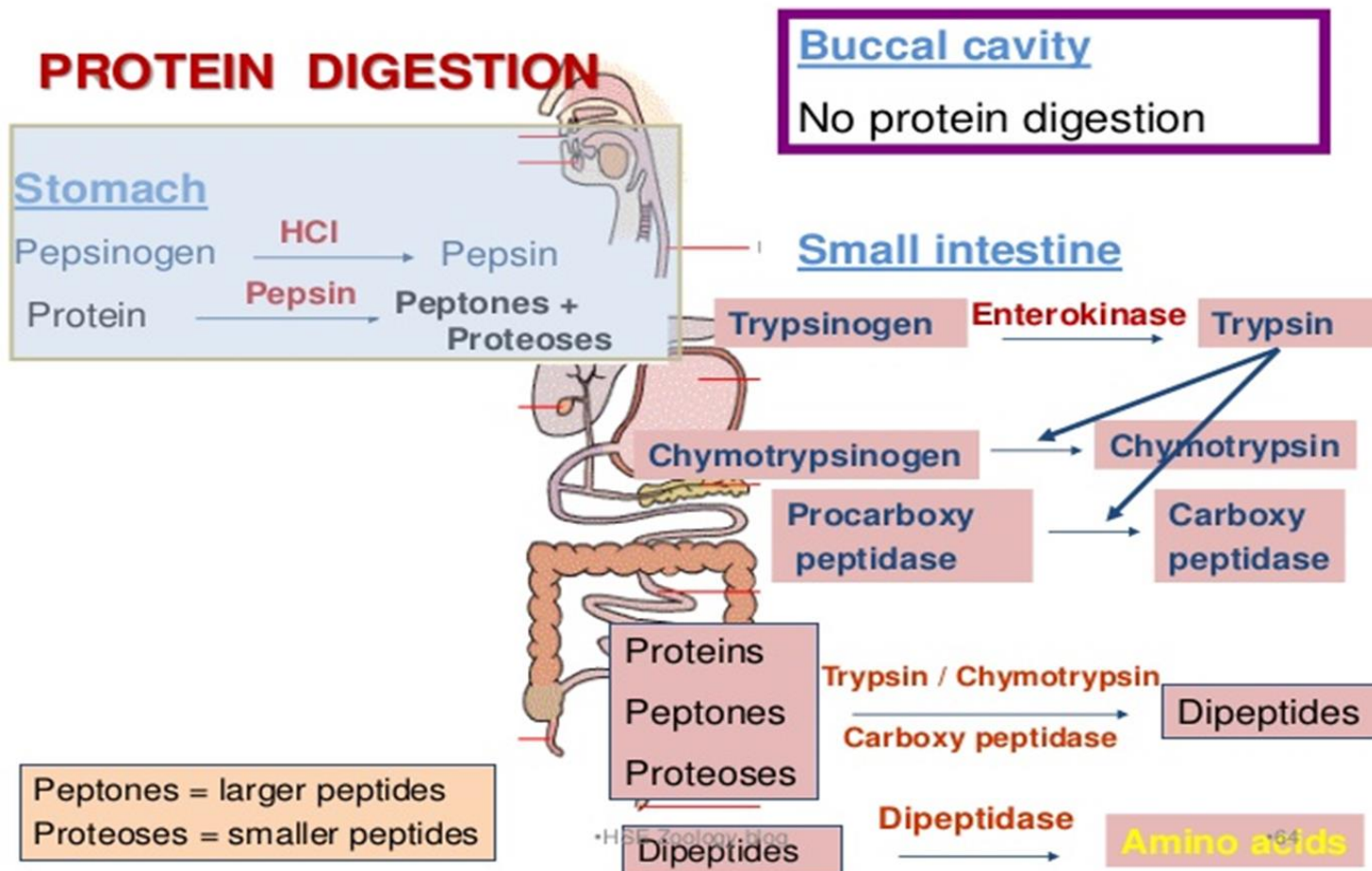
■ Absorption of Proteins

- Most of proteins are absorption is in form of **amino acids** after complete digestion into blood capillaries of villi of small intestine.
- **L-amino** acids are absorbed more rapidly than D- amino acids.
- D- amino acids are absorbed slowly by **simple diffusion**.

- L- amino acids are actively absorbed into mucosal cells by **Na⁺ cotransport** (like glucose)
- These are then transported to extra cellular fluid (ECF) by facilitated diffusion.

(via transport system)

DIGESTION AND ABSORPTION OF PROTEINS



■ **PROTEIN INTOLERANCE**

- Lysinuric protein intolerance is a disorder caused by the body's inability to digest and absorb certain proteins namely lysine, arginine, and ornithine.



13. Digestion of proteins start in stomach by the action of _____ enzyme?

- A. Pepsin
- B. Chymotrypsin
- C. Trypsin
- D. Amylase
- E. None of the above



14. Chymotrypsinogen and trypsinogen are converted into active form by _____?

- A. Enterokinase
- B. Pepsin
- C. Amylase
- D. Dipeptidases
- E. Lipase



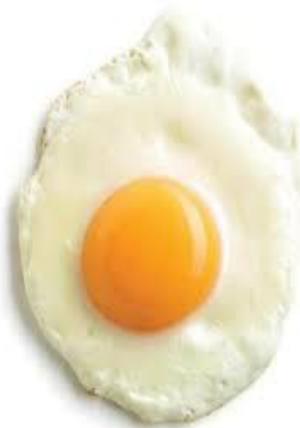
15. Chymotrypsinogen and trypsinogen are secreted by _____?

- A. Salivary glands
- B. Stomach
- C. Small intestine
- D. Pancreas



■ SOURCES OF FAT (LIPIDS)

- Butter, margarine, and shortening .
- Palm oil, cocoa butter, coconut oil, whipped toppings, and coffee creamers.
- Milk, cheese, egg yolk.
- All contain a great deal of saturated fat.



DIGESTION OF LIPIDS

Mouth

- Fat digestion starts in the mouth by an enzyme named **lingual lipase**.
- This enzyme causes breaks down of short chain lipids into diglycerides.

Stomach

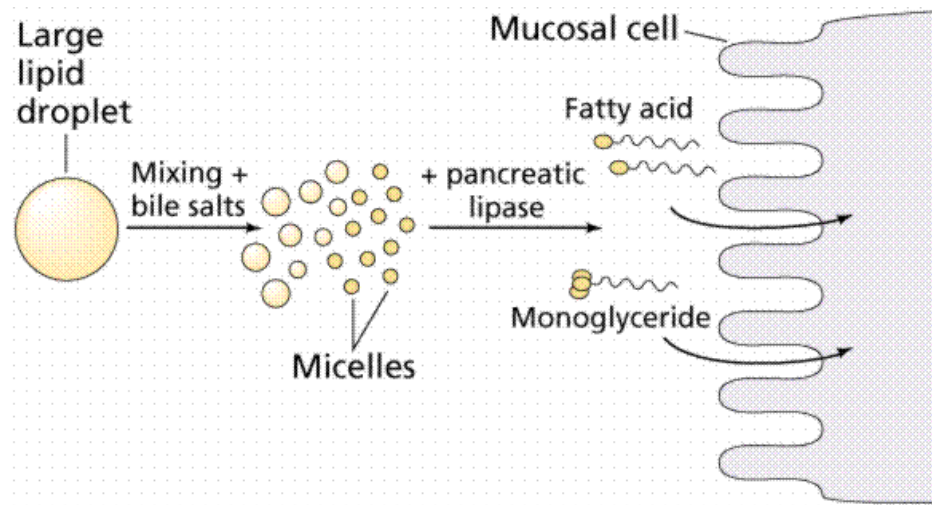
- Fat digestion continues in the stomach by the enzyme **gastric lipase**

Small Intestine

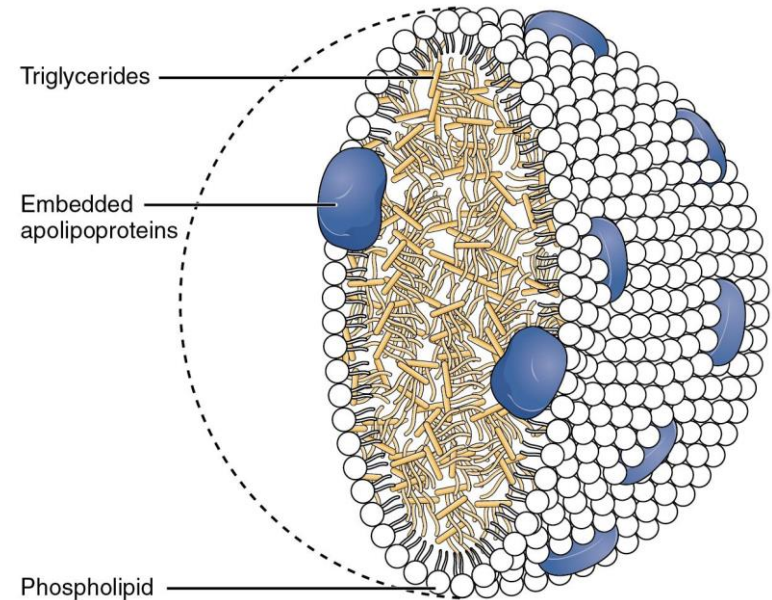
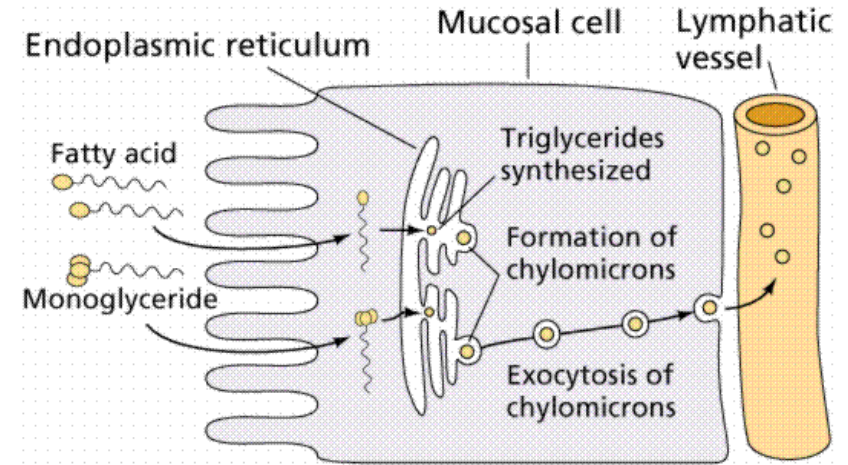
- By two enzyme:
 - **Pancreatic lipase** secreted by pancreas convert fat into fatty acids and glycerol.
 - **Bile secreted** by gall bladder is responsible for the activation of pancreatic lipase and **emulsification** of fats.
- Complete digestion of one molecule of fat results in **three fatty** acid molecules and **one glycerol** molecule.

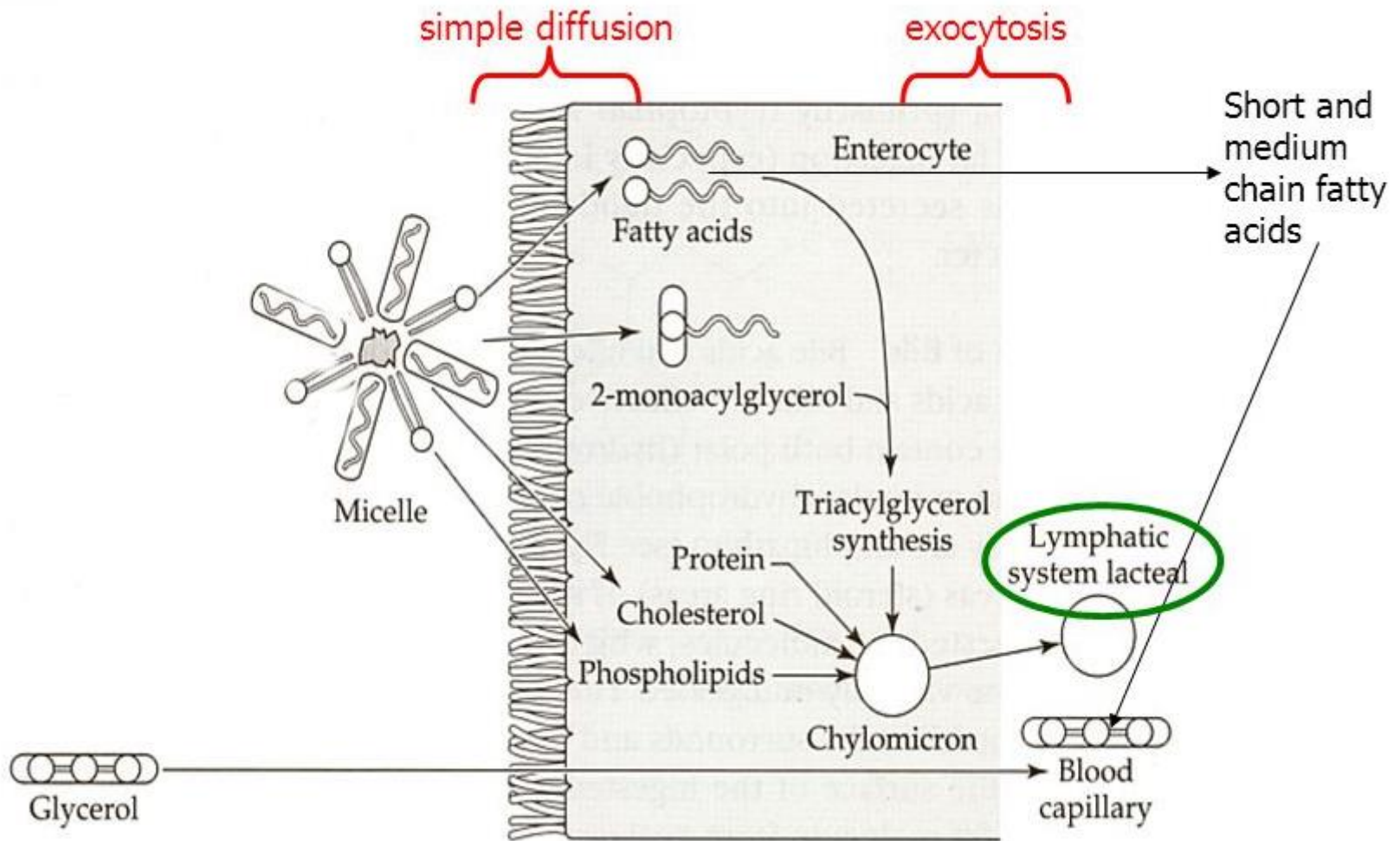
ABSORPTION OF FAT

- Fat is absorbed into the **intestinal cells** as:
 - Fatty acids, monoglycerides & cholesterol.
- Short chain Fatty acids (less than 12 carbon atoms) can pass freely into the extracellular fluid (ECF) as free fatty acids.



- Long chain Fatty acids **make** cholesteryl esters and **triglyceride**.
- Cholesteryl esters and triglycerides are coated with a layer of:
 → Phospholipids Cholesterol and Proteins
 → to form **chylomicrons**
- Chylomicrons enter extracellular fluid (ECF) by exocytosis and then carried by the **lymphatics**.





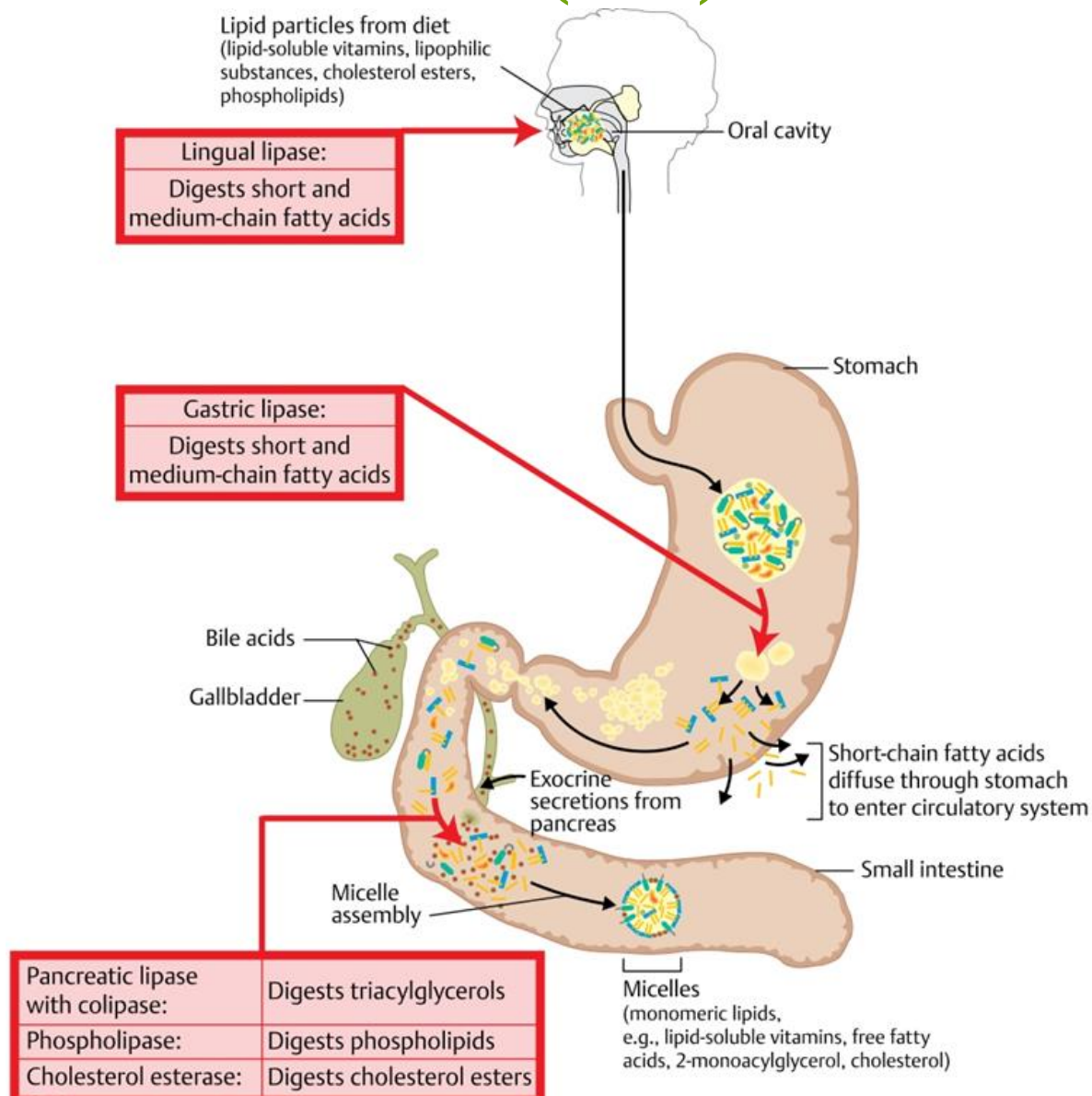
Steatorrhea

- This is a disease produced as a result of mal absorption of lipids.
- Most commonly due to Pancreatic diseases or **deficiency of bile acids**.
- Excretion of abnormal quantities of fat with the feces owing to reduced absorption of fat by the intestine.
- Stools has **pale** and oily appearance and foul-smelling.



■ DIGESTION AND ABSORPTION OF LIPIDS (FAT)

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16. _____ is a disease produced as a result of mal absorption of lipids?

- A. Steatorrhea.
- B. Diabetes.
- C. Rickettsia.
- D. Anemia.





17. Fat digestion starts in the mouth by:

- a) **Lingual lipase**
- b) Gastric lipase
- c) Pancreatic lipase
- d) Gastric protease
- e) Gastric amylase

18. The following enzyme digest fat?

- A. Amylase
- B. Trypsin
- C. Lipase
- D. Protease.



Summary

- Components of human GIT
- Digestion and absorption of food in mouth, stomach and intestine.
- Large intestine and elimination of feces (defecation).
- Pancreas as a source of digestive enzymes and role of bile in the digestion of fat.
- Physiological mechanisms involved in absorption of carbohydrate, protein and lipid.
- Mal-absorption of carbohydrate, protein and lipid.

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