

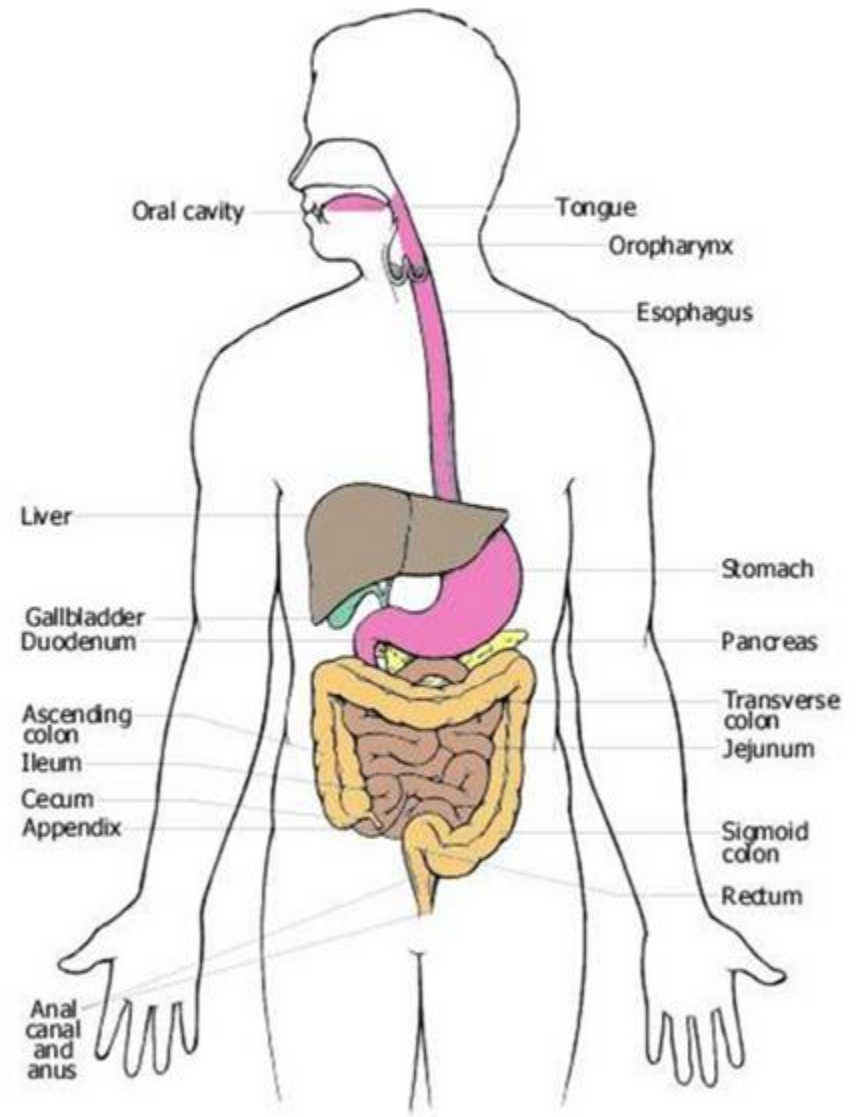


SEMESTER 1:
**Chapter 3: Digestion
and Absorption**

Slide 1

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Physiology of Digestion and Absorption



Although most foods contain a mix of nutrients, some foods are richer than others in a specific nutrient.



Carbohydrate-rich foods

(Carbohydrates contain 4 calories per gram.)
Breads, pasta, grains, cereals, potatoes, fruits



Protein-rich foods

(Proteins contain 4 calories per gram.) **Fish, eggs, poultry, beef, pork, nuts, legumes, milk, cheese, tofu**



Fat-rich foods


(Fats contain 9 calories per gram.)
Milk, cheese, meats, butter, olives, avocados, fried foods, oils, chips



DIGESTION

- The process of **breaking down** food into molecules the body can use is called digestion.

Substance - unit or monomer - usage

- Carbohydrates - **monosaccharide** - as energy source
 - Proteins - **amino acids** - as building material
 - Lipids - **fatty acids** - as energy source and building material
 - Vitamins - for body regulation
- 

Overview of the Digestive System

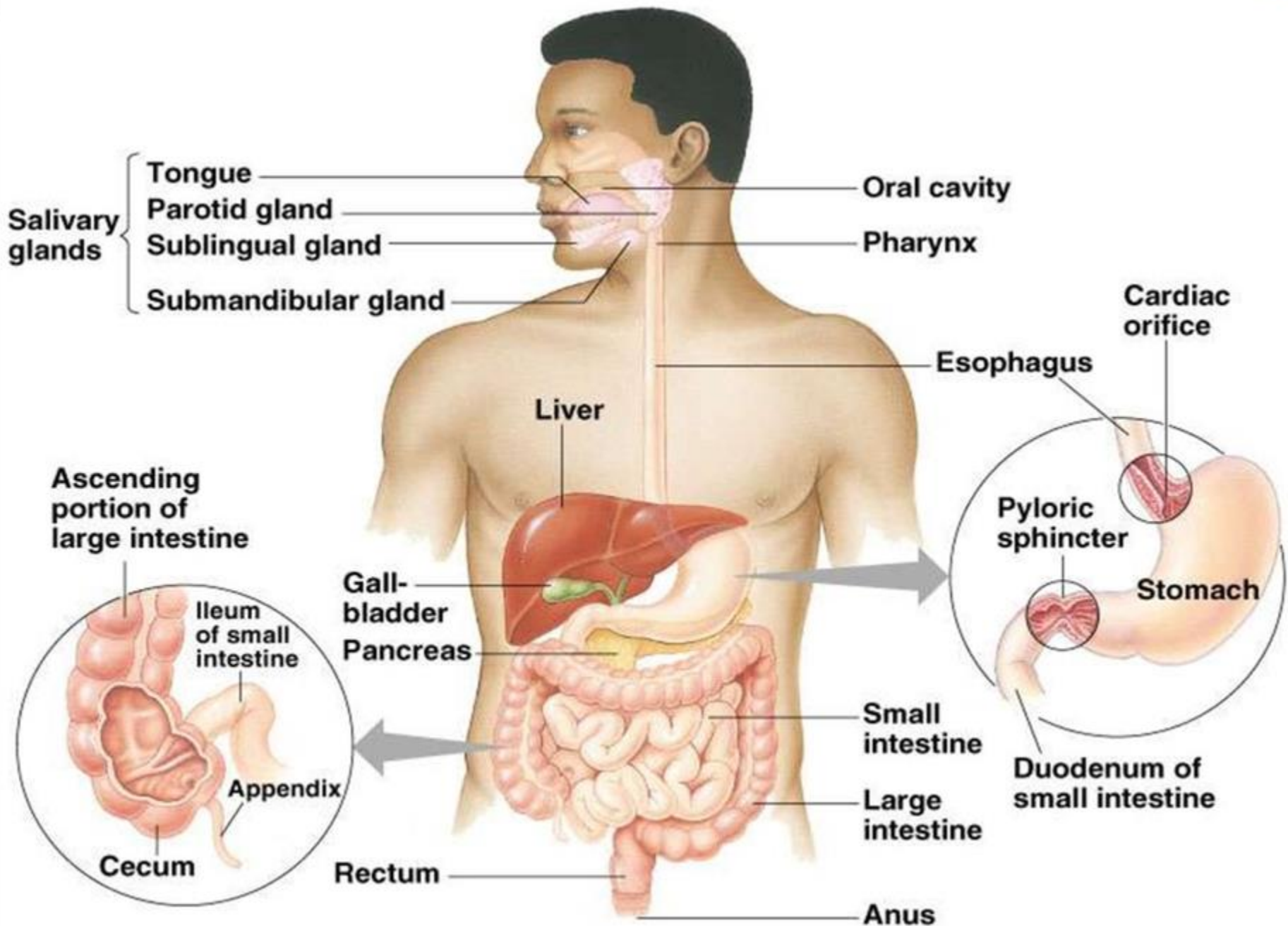
The Digestive System Consists of ;

a) Long hollow muscular tube or canal or tract called gastrointestinal tract or (GIT):

- it is about 5 meters long

b) Accessory glands: include:

- Salivary glands
- Liver and gall bladder
- Pancreas



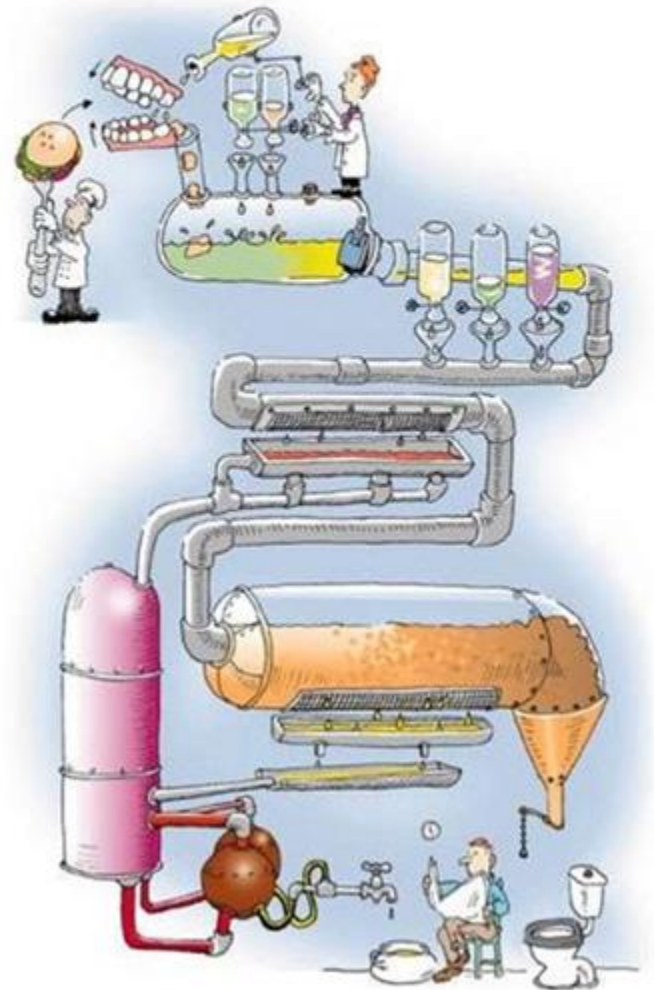
Main Functions of Digestive Tract

- 4 major activities of GI tract
 1. **Motility**
 - Propel ingested food from mouth toward rectum
 2. **Secretion of juices e.g. saliva**
 - Aid in digestion and absorption
 3. **Digestion**
 - Food broken down into absorbable molecules
 4. **Absorption**
 - Nutrients, electrolytes, and water are absorbed or transported from lumen of GIT to blood stream

4 STEPS OF DIGESTION

○ There are 4 main steps of digestion in human body:

1. Ingestion of food
2. Digestion of polymers
 - a. *Mechanical digestion*
 - b. *Chemical digestion*
3. Absorption of monomers
4. Elimination of waste



HUMAN DIGESTIVE SYSTEM

- The digestive system **takes in food**, **breaks it down** into molecules small enough for the body to absorb, and **gets rid** of undigested molecules and waste.
- Food travels **more than 8 m** through the human digestive tract.



HUMAN DIGESTIVE SYSTEM PARTS

○ Mouth

teeth – salivary glands –
tongue

○ Esophagus

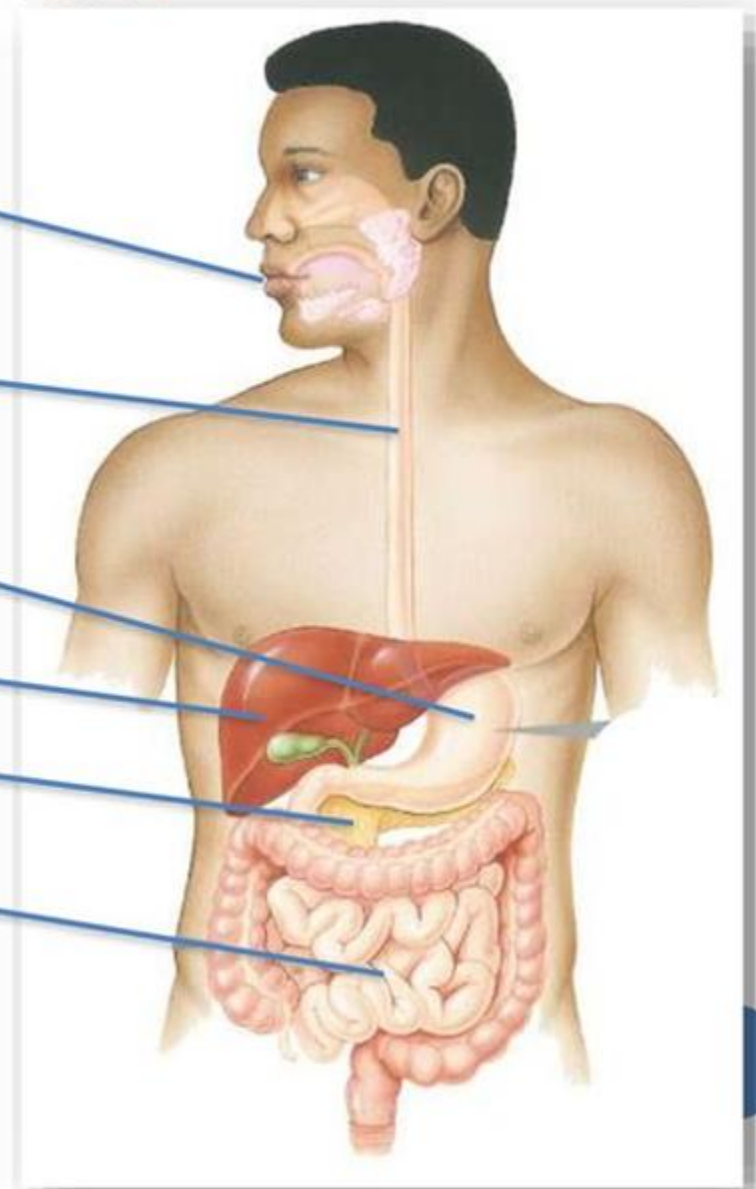
○ Stomach

○ Liver

○ Pancreas

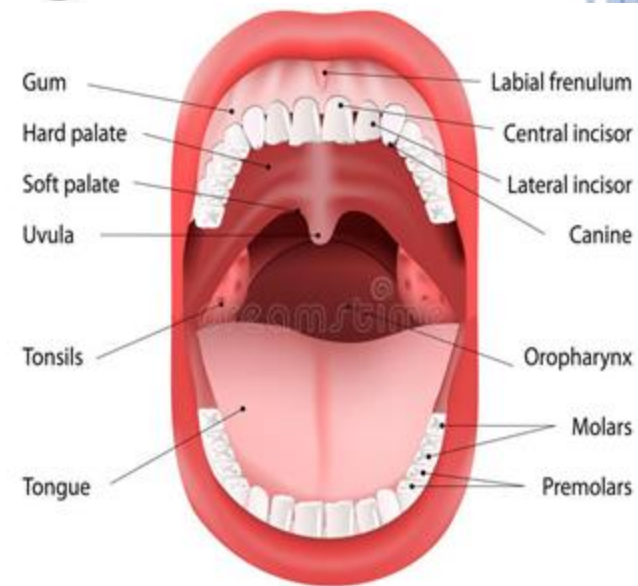
○ Intestine

small intestine – large
intestine - rectum



MOUTH

- Food enters the body through the mouth.
- **Mechanical** and **chemical** digestion occur in mouth.
- **Teeth** help in **mechanical** digestion.
- Salivary glands produce **saliva** that helps in **chemical digestion**



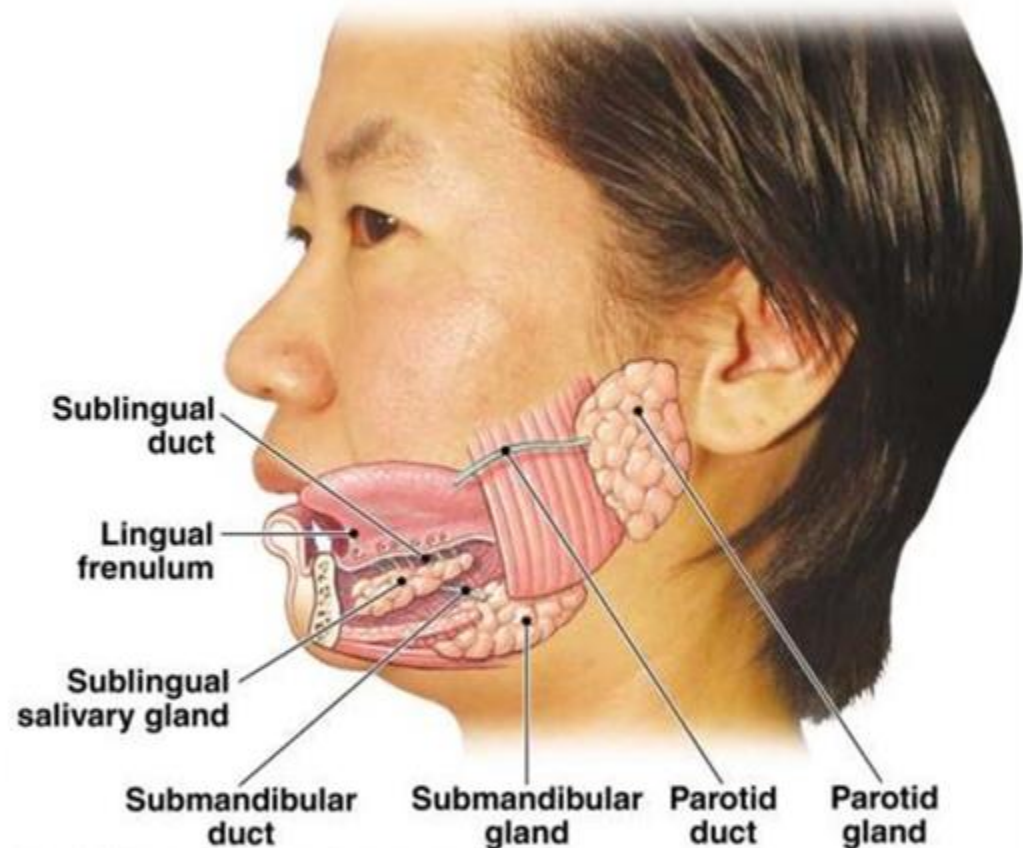
Secretions of GIT in Mouth

Salivary Glands

- **Three pairs of glands**
 - Parotid
 - Sublingual
 - Submandibular

Functions of saliva

1. Lubricates, cleanses oral cavity
2. Dissolves chemicals
3. Suppresses bacterial growth
4. Digest starch by amylase



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TEETH

- **Teeth are designed for mechanical digestion of food.**
- **Each tooth is composed of a crown, neck and a root.**
- **The crown is covered with enamel. It is hardest material in our body.**
- **Enamel is formed from calcium, phosphorus and fluoride**



TYPES OF TEETH

○ There are 4 types of teeth

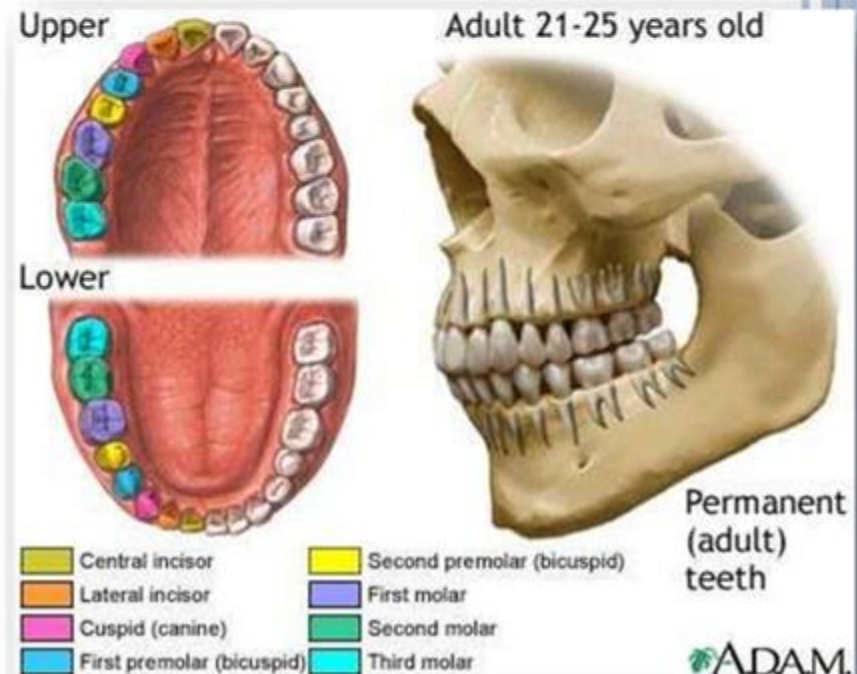
1- Molars 12

2- Pre molars 8

3- Canines 4

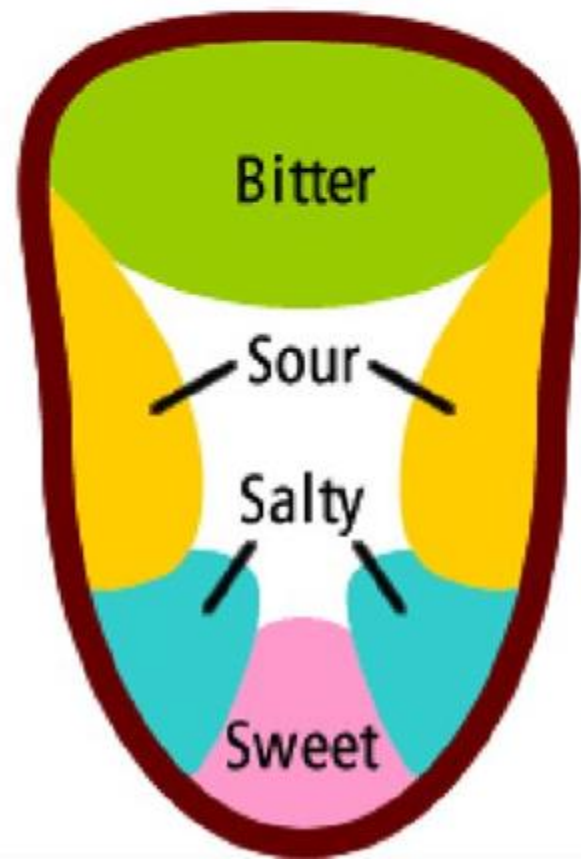
4- Incisors 8

○ **TOTAL 32**



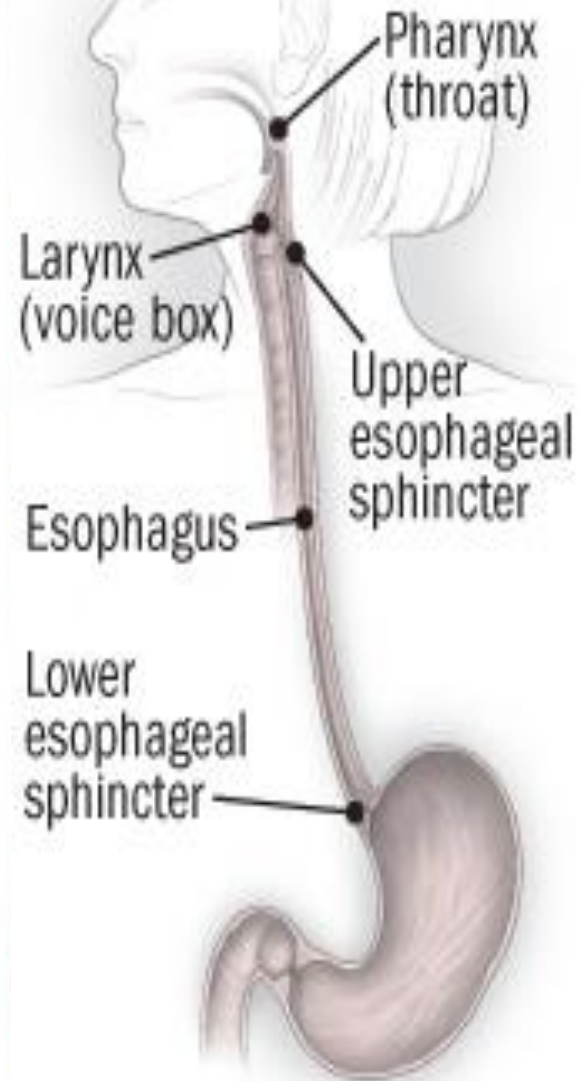
TONGUE

- Tongue helps in **mixing food** with saliva
- A **bolus** formed and swallowed
- During chewing taste buds differentiate between **bitter**, **sweet**, **salty** and **sour** tastes



ESOPHAGUS

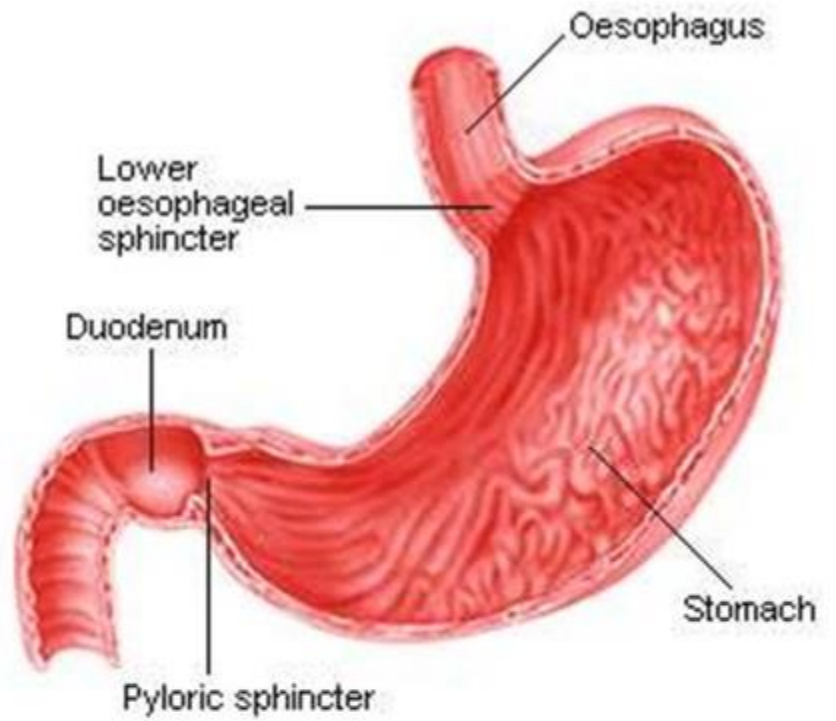
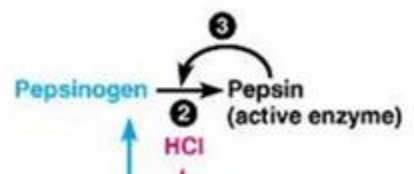
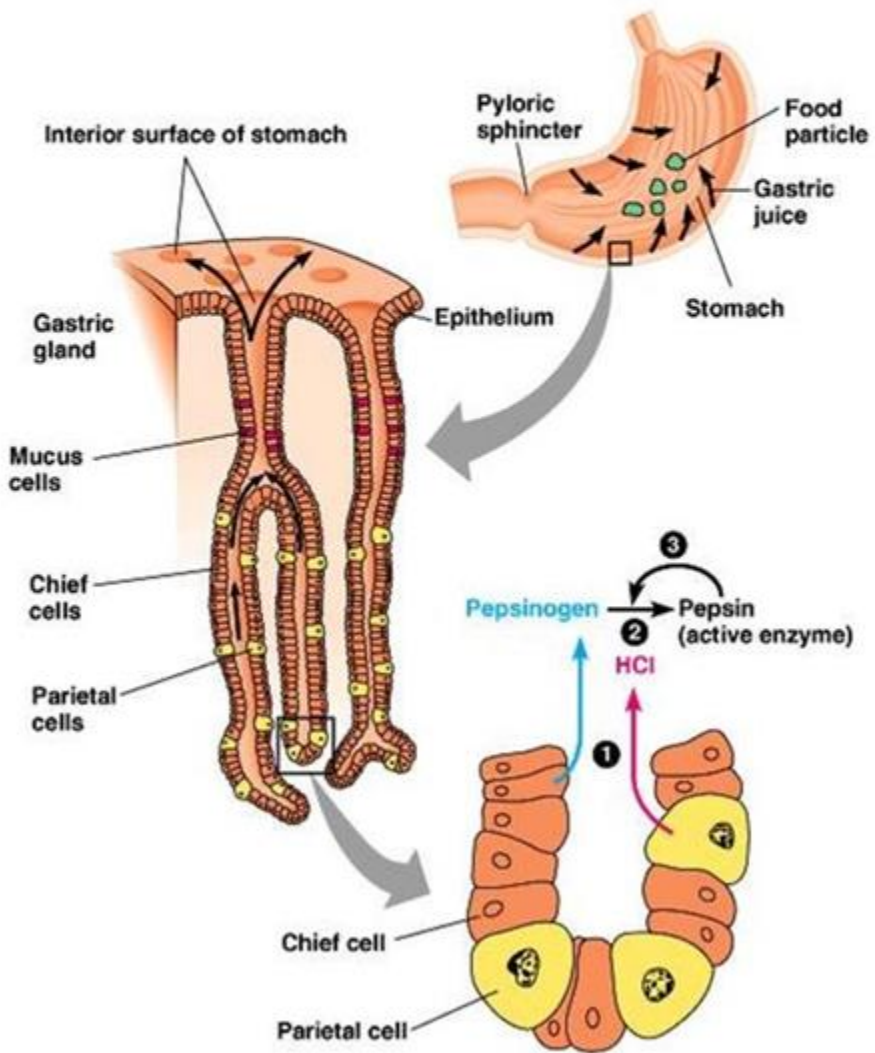
- The esophagus is a long tube that **connects** the **mouth** to the **stomach**.
- It is 25 cm in length and 2 cm in width
- Waves of smooth muscle contractions is called **peristalsis** that move the food toward the stomach.
- No digestion occurs in the esophagus.



STOMACH

- Food is stored temporary in the stomach.
- It is J shaped, 25 cm in length, 12 cm in width, 1250 cm³ volume, surface area 600 m²
- **Mechanical** and **chemical** digestion occur in the stomach.
- Food is broken down mechanically into smaller particles by the contractions of the muscles.
- Stomach secretes enzymes for chemical digestion of proteins.





GIT secretions in Stomach

Opening of gastric gland

Lumen of stomach

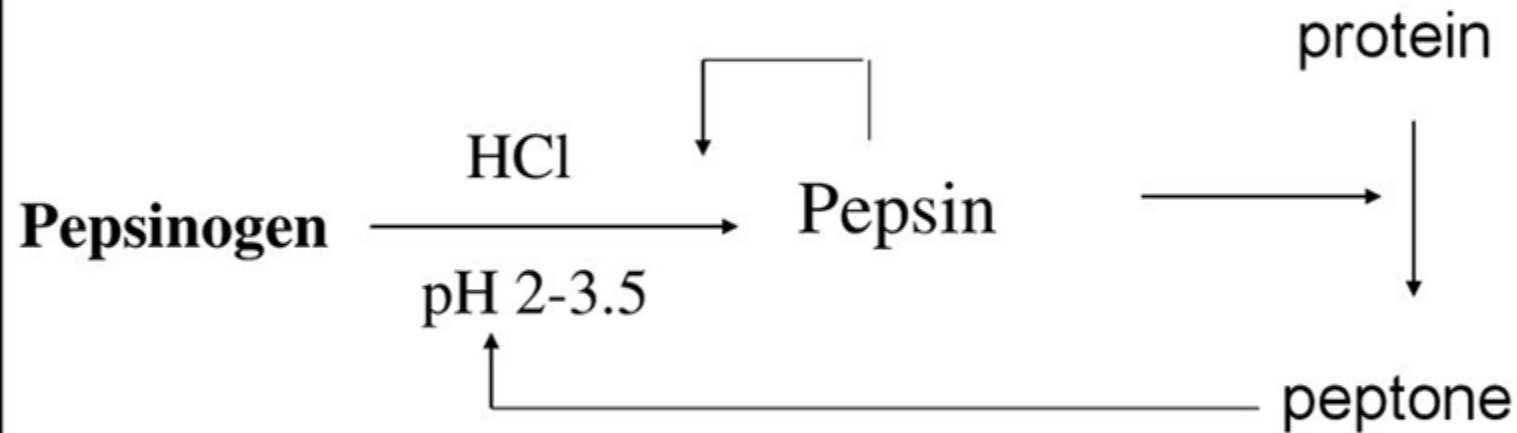
Source	Substance Secreted	Function
Mucous neck cell	Mucus	Physical barrier between lumen and epithelium
	Bicarbonate	Buffers gastric acid to prevent damage to epithelium
Parietal cells	Gastric acid (HCl)	Activates pepsin; kills bacteria
	Intrinsic factor	Complexes with vitamin B ₁₂ to permit absorption
Enterochromaffin-like cell	Histamine	Stimulates gastric acid secretion
Chief cells	Pepsin(ogen)	Digests proteins
	Gastric lipase	Digests fats
D cells	Somatostatin	Inhibits gastric acid secretion
G cells	Gastrin	Stimulates gastric acid secretion

Function of Gastric HCL

1. Activates pepsinogen into pepsins
2. Provides optimum for pH for action of pepsins
3. Denatures protein denaturation → help its digestion
4. Kills bacteria in food
5. Help Fe^{2+} 、 Ca^{2+} absorption.
6. Promotes pancreatic, small intestinal and bile secretion

Function of pepsins

Function of pepsinogen



Function of mucous and intrinsic factor

Mucus secretion

- Soluble and insoluble mucus are secreted by cells of the stomach.
- **Soluble mucus** mixes with the contents of the stomach and helps to lubricate chyme.
- **Insoluble mucus** forms a protective barrier against the high acidity of the stomach content.

Intrinsic Factor

- Help absorption of vitamin B12



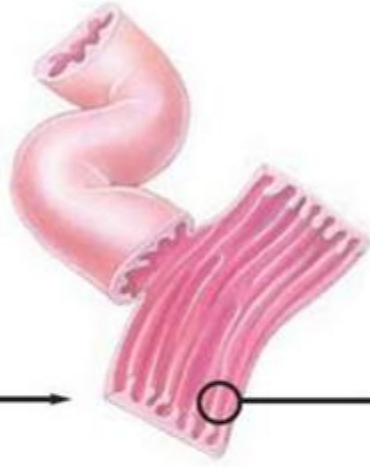
SMALL INTESTINE

- Most **chemical digestion** and all **absorption** occur in small intestine.
- The lining of the small intestine is covered with fingerlike projections called **villi**, which increase the surface area (up to 600 square meter) available for absorption of nutrients.
- The small intestine has three parts. They are **duodenum**, **jejunum** and **ileum**.

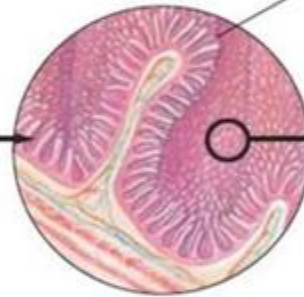




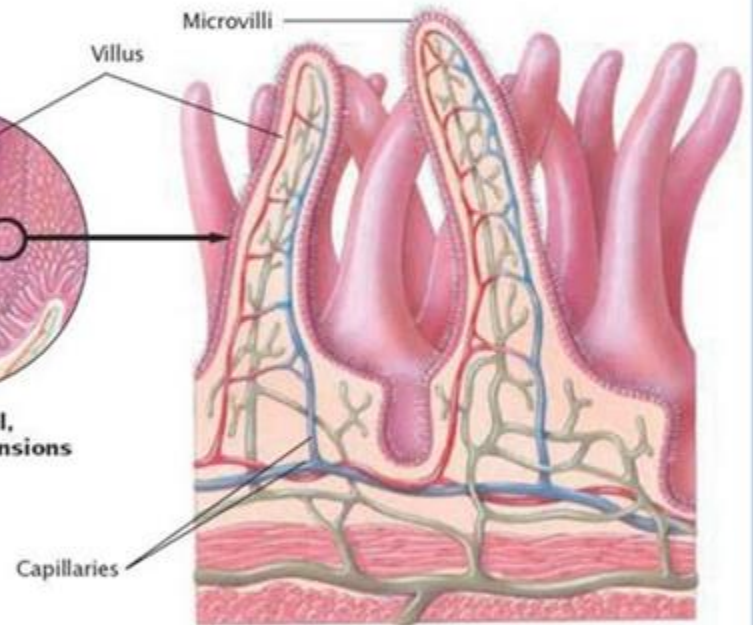
a The small intestine is located in the lower abdomen.



b The highly folded lining of the small intestine has ...



c ... many small, fingerlike extensions called villi.



d Inside each villus are capillaries and tiny lymph vessels. It is here that nutrients enter the bloodstream.



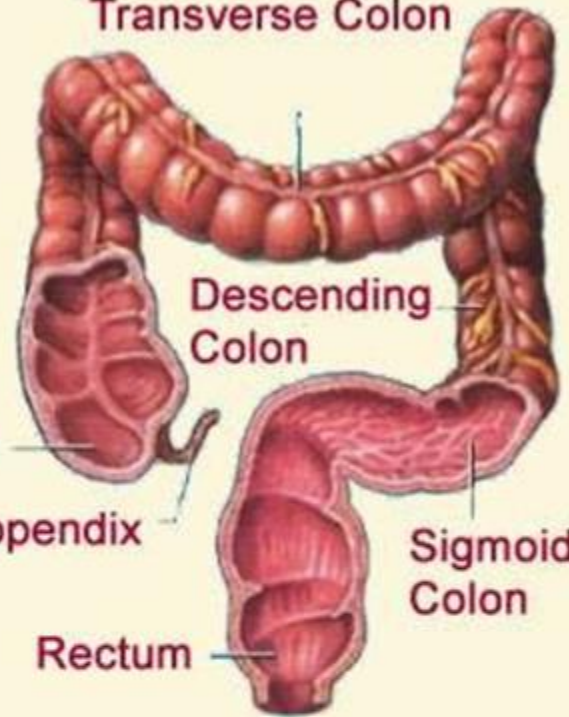
LARGE INTESTINE

- **Wastes** move into the large intestine (or colon) from small intestine. Between them there is a valve.
- Large intestine has 3 parts **caecum**, **colon** and **rectum**
- **No digestion** takes place in the **colon**. Mineral ions and water are absorbed through the walls of the large intestine.
- The large intestine contains many **bacteria**. They produce vitamins such as **vitamin K**.
- The large intestine has a fingerlike extension, the **appendix**, that makes a minor contribution to body defense.
- Large intestine is opened to the outside of the body through the anus.





Transverse Colon



Ascending
Colon

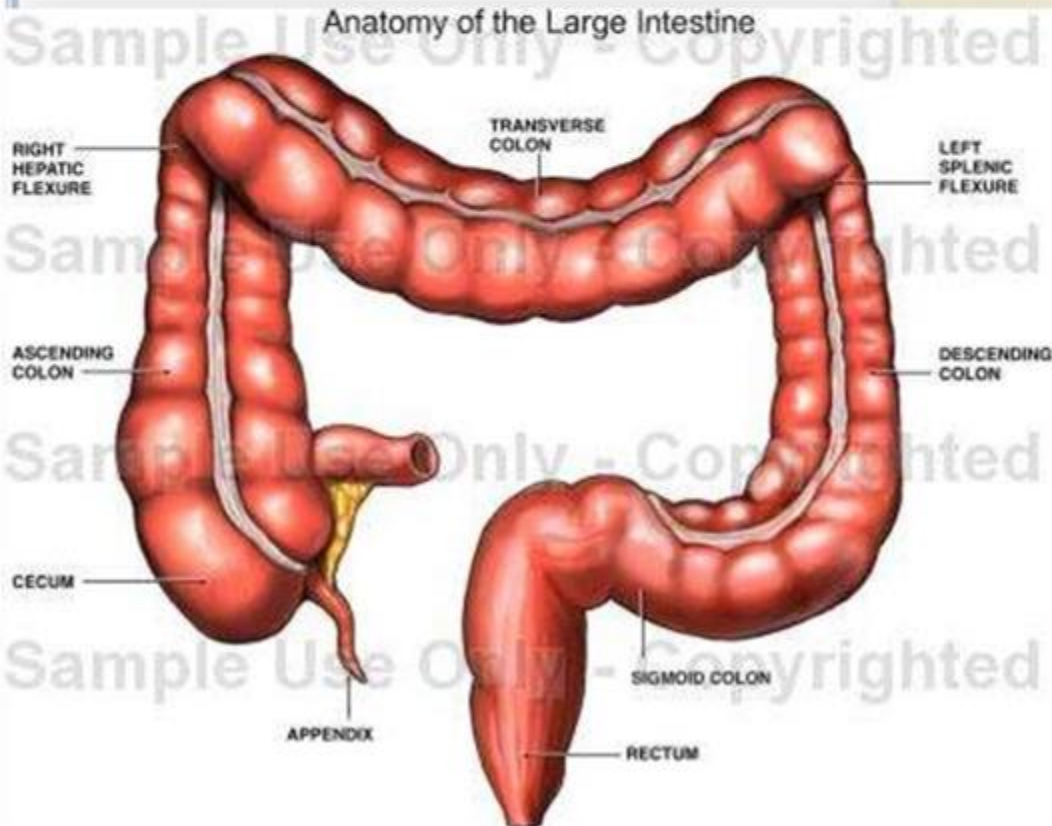
Appendix

Descending
Colon

Sigmoid
Colon

Rectum

Anatomy of the Large Intestine



Salivary glands

Tongue
Parotid gland
Sublingual gland
Submandibular gland

Oral cavity
Pharynx

Ascending portion of large intestine
Ileum of small intestine
Appendix
Cecum

Liver
Gall-bladder
Pancreas
Rectum

Esophagus
Cardiac orifice
Pyloric sphincter
Stomach
Duodenum of small intestine
Small intestine
Large intestine
Anus

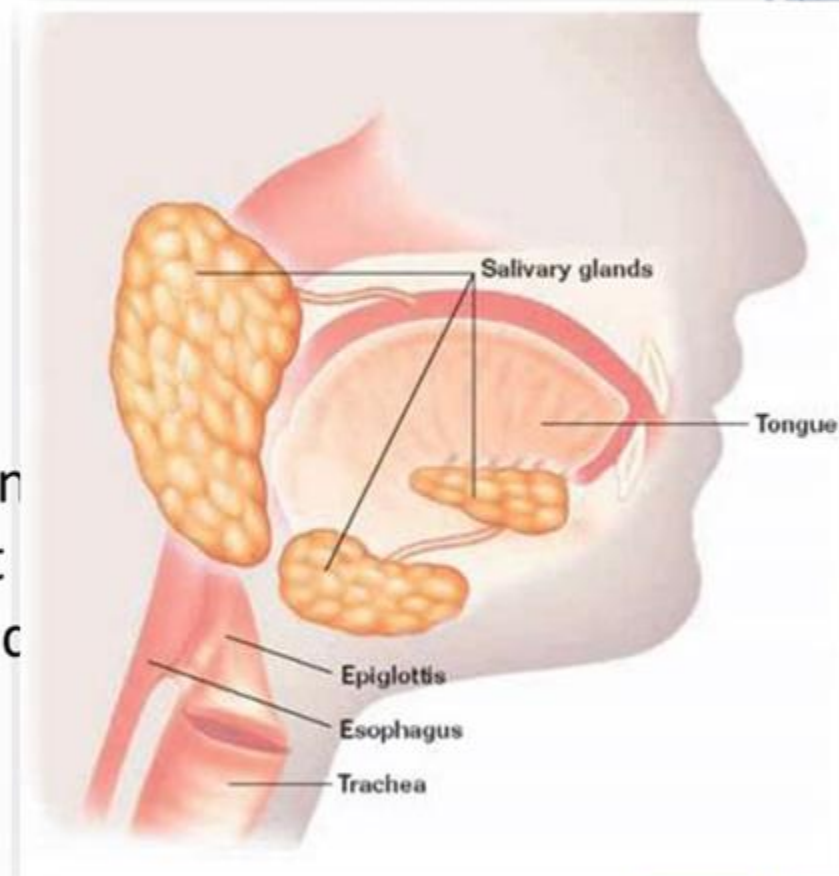
DIGESTIVE SYSTEM GLANDS

- Salivary glands
- Gastric glands in stomach
- Intestinal glands
- Liver
- Pancreas



SALIVARY GLANDS

- There are **three pairs of salivary glands** in the lining of the mouth.
- They are sublingual, submandibular and parotid glands
- Salivary glands secrete enzyme **AMYLASE** into the mouth. Amylase helps in chemical digestion of carbohydrates.
- Saliva contains a slippery glycoprotein called **mucin**, which protects the soft lining of the mouth from abrasion and lubricates the food for easier swallowing.



GASTRIC GLANDS IN STOMACH

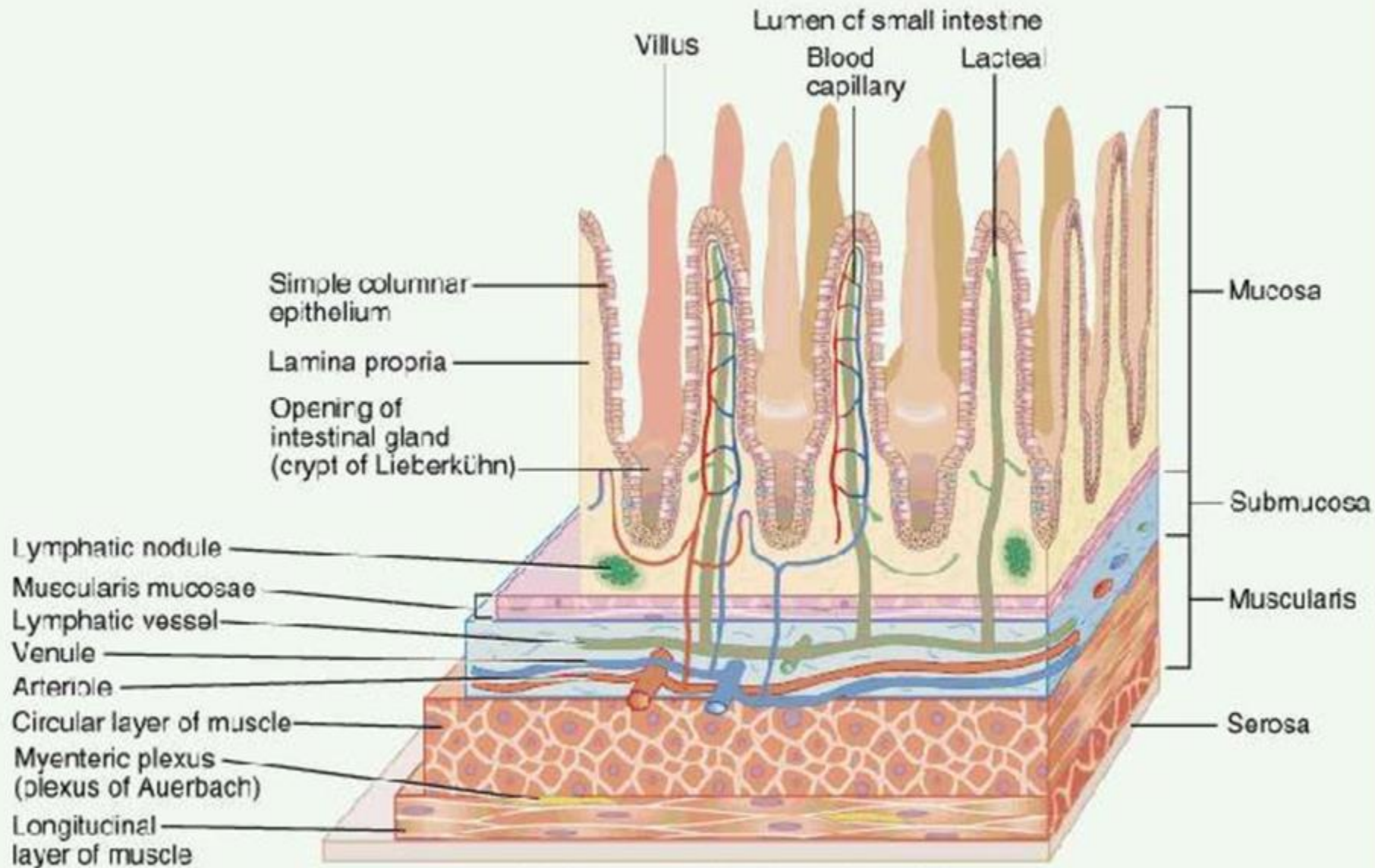
- The Gastric glands that line the inside of the stomach release **gastric juice**.
- Gastric juice is a combination of **HCl acid and PEPSIN**.
- Pepsin is a digestive enzyme produced by the stomach.
- Pepsin breaks down **proteins**.



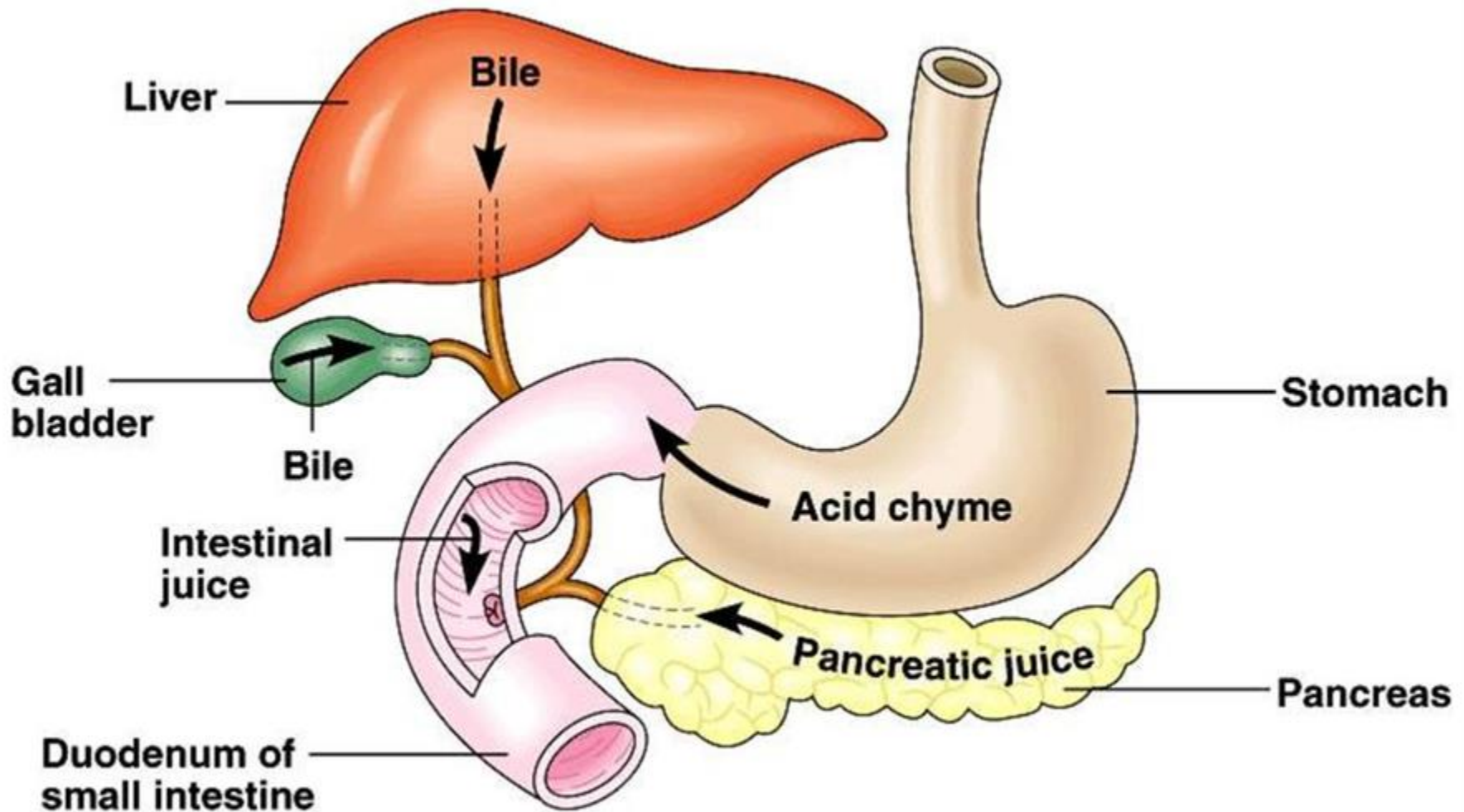
INTESTINAL GLANDS

- Intestinal glands secrete several enzymes which help chemical digestion of **carbohydrates** (disaccharides), **nucleic acids** and **proteins**.





(a) Layers of the small intestine showing villi



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LIVER

- Liver cells are known as **hepatocytes**
- *Hepatic means related to liver*
- The liver secretes **bile**, which aids the breakdown of fats.
- Bile also promotes the **absorption** of fatty acids and the fat-soluble vitamins **A, D, E, and K**.
- Bile is stored in the **gall bladder** until needed.



Inferior vena cava

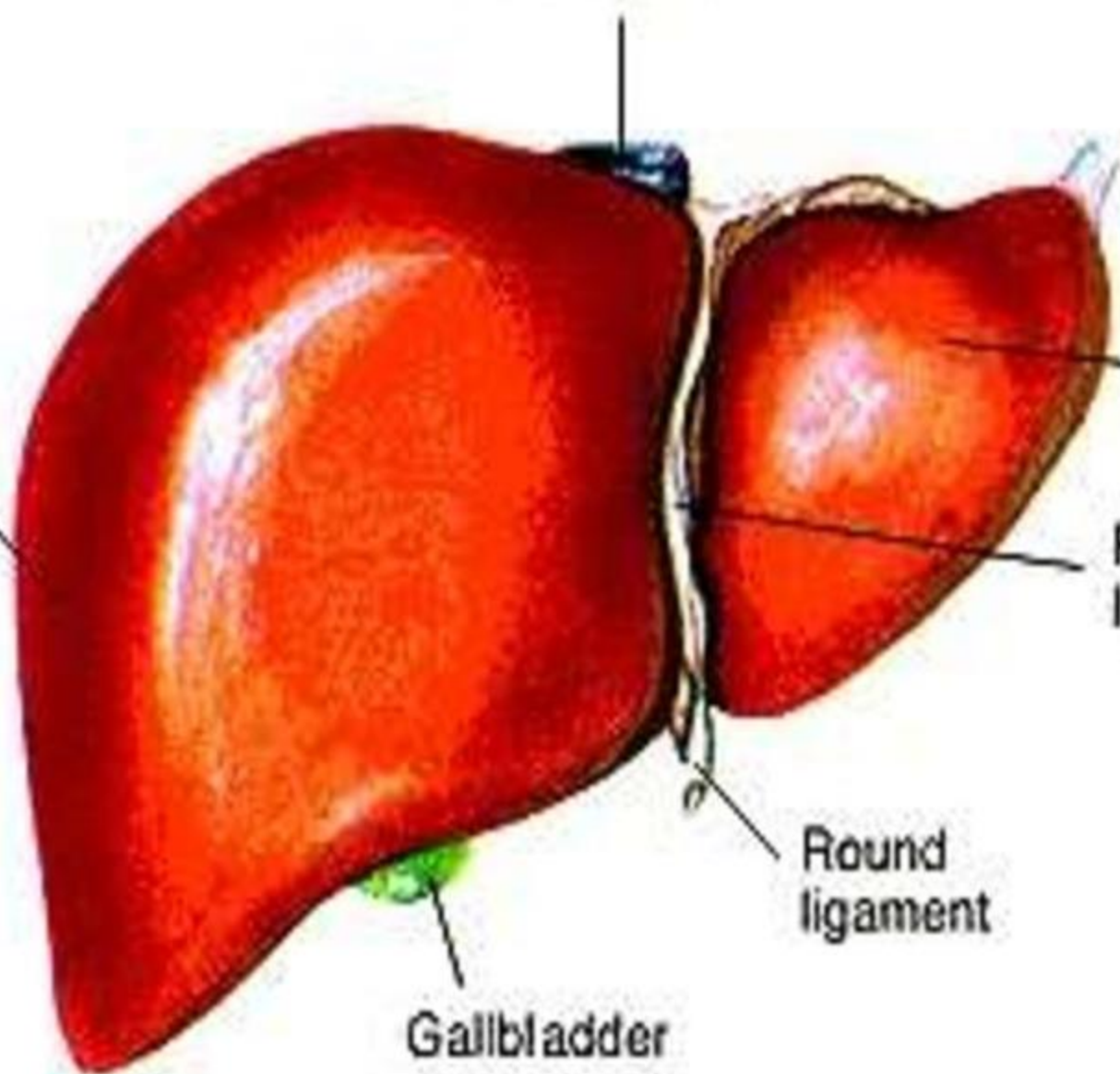
Right
lobe

Left
lobe

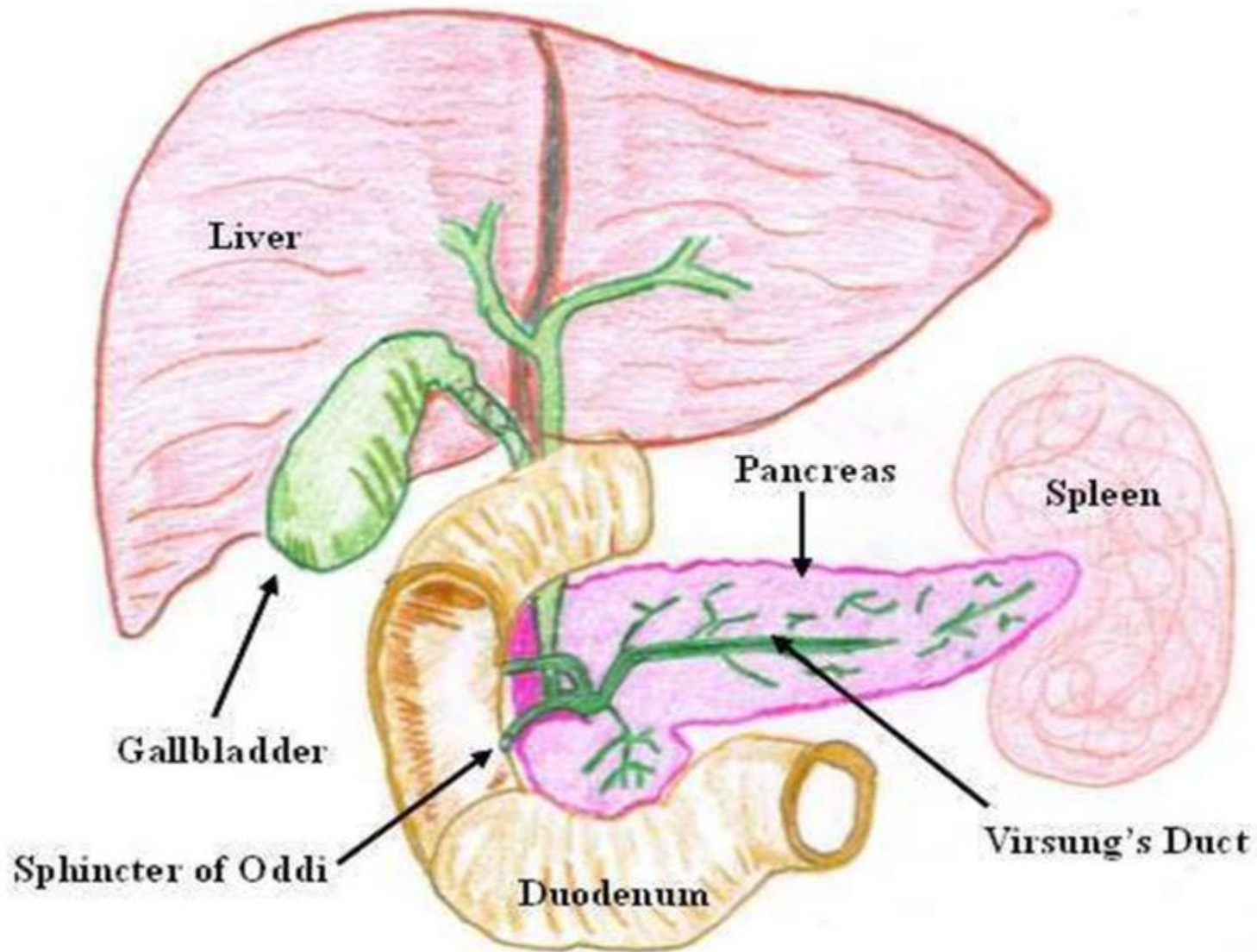
Falciform
ligament

Round
ligament

Gallbladder



Liver and Gallbladder



Liver

Functions of the Liver:

1) Metabolic regulation

- Store absorbed nutrients, vitamins
- Release nutrients as needed

2) Hematological regulation

- Plasma protein production
- Remove old RBCs

3) Production of bile

- Required for fat digestion and absorption

PANCREAS

- The pancreas secretes **pancreatic juice** that includes many enzymes, which aids the breakdown of proteins, fats, carbohydrates and nucleic acid.
- Pancreas also secretes hormones **insulin** and **glucagon** to regulate blood glucose level.



DIGESTION OF POLYMERS

- Polymers are chemically digested in different parts of digestive tract

Polymers:

- Carbohydrates
- Proteins
- Lipids or fats
- Nucleic acids



DIGESTION OF CARBOHYDRATES



- **In mouth:** digestion begins in mouth by AMYLASE enzyme. Amylase breaks down starch into dextrin and maltose.
- Starch+water AMYLASE > dextrin+maltose
- **In stomach:** no carbohydrate digestion, amylase doesn't function in acidic area
- **In intestine:**
 - Pancreas release enzymes including amylase which act on polysaccharides.
 - Intestinal glands secrete enzymes maltase, lactase and sucrase that act on disaccharides.



- **Intestinal reactions:**

- Dextrin+H₂O $\xrightarrow{\text{AMYLASE}}$ glucose+glucose...

- Maltose+H₂O $\xrightarrow{\text{MALTASE}}$ glucose+glucose

- Sucrose+H₂O $\xrightarrow{\text{SUCRASE}}$ glucose+fructose

- Lactose+H₂O $\xrightarrow{\text{LACTASE}}$ glucose+galactose

- **Maltase, sucrase and lactase are disaccharidases**

- **Digestion of carbohydrates are finished in intestine**



DIGESTION OF PROTEINS



- **In mouth:** no chemical digestion
- **In stomach: begins** in stomach by gastric juice and pepsinogen, **reactions in stomach:**
- Pepsinogen(inactive)+HCl=Pepsin(active)
- Protein+H₂O $\xrightarrow{\text{PEPSIN}}$ peptones



- **In intestine:** the final breakdown of proteins occur in intestine. **Pancreas** produces **trypsinogen** and **chymotrypsin** and **intestinal glands** produce **enterokinase** and **erepsin** for protein digestion.
- **Reactions in Intestine:**
- Trypsinogen+enterokinase=trypsin
- Peptones+H₂O TRYPSIN > peptides+amino acids
- Peptides+H₂O EREPSIN > amino acids+amino acids...





DIGESTION OF LIPIDS

- **In mouth:** no chemical digestion
- **In stomach:** no chemical digestion
- **In intestine: begins in intestine**
- The cells of the liver produce **bile**. Then it is stored in **gall bladder**.
- Bile **does not contain enzyme** but it aids mechanical digestion of lipids. This process is called **emulsification**



Reaction in small intestine:

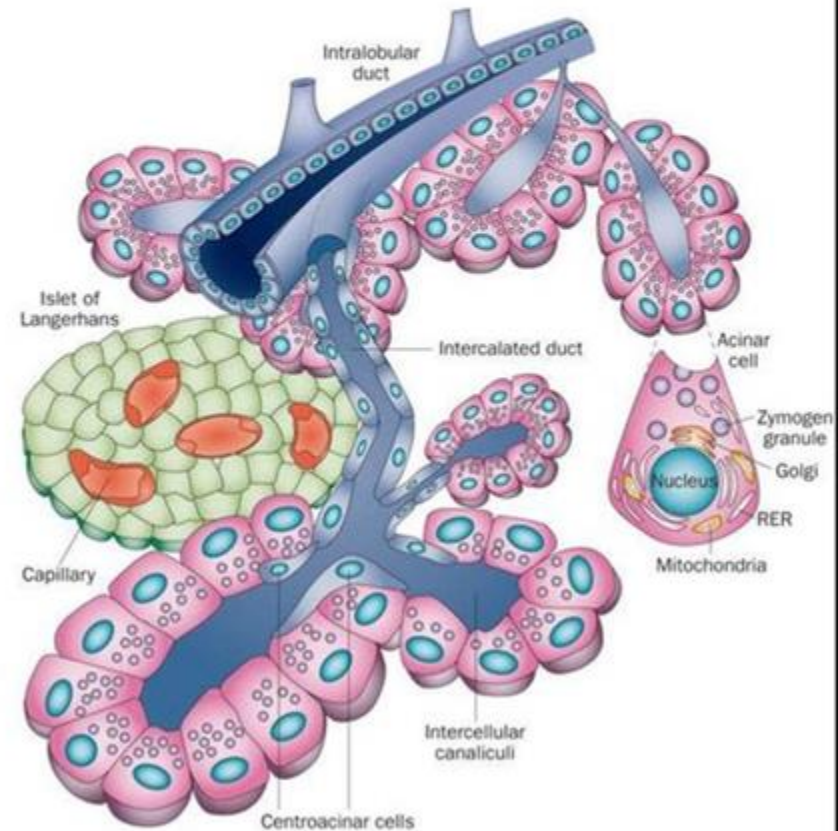
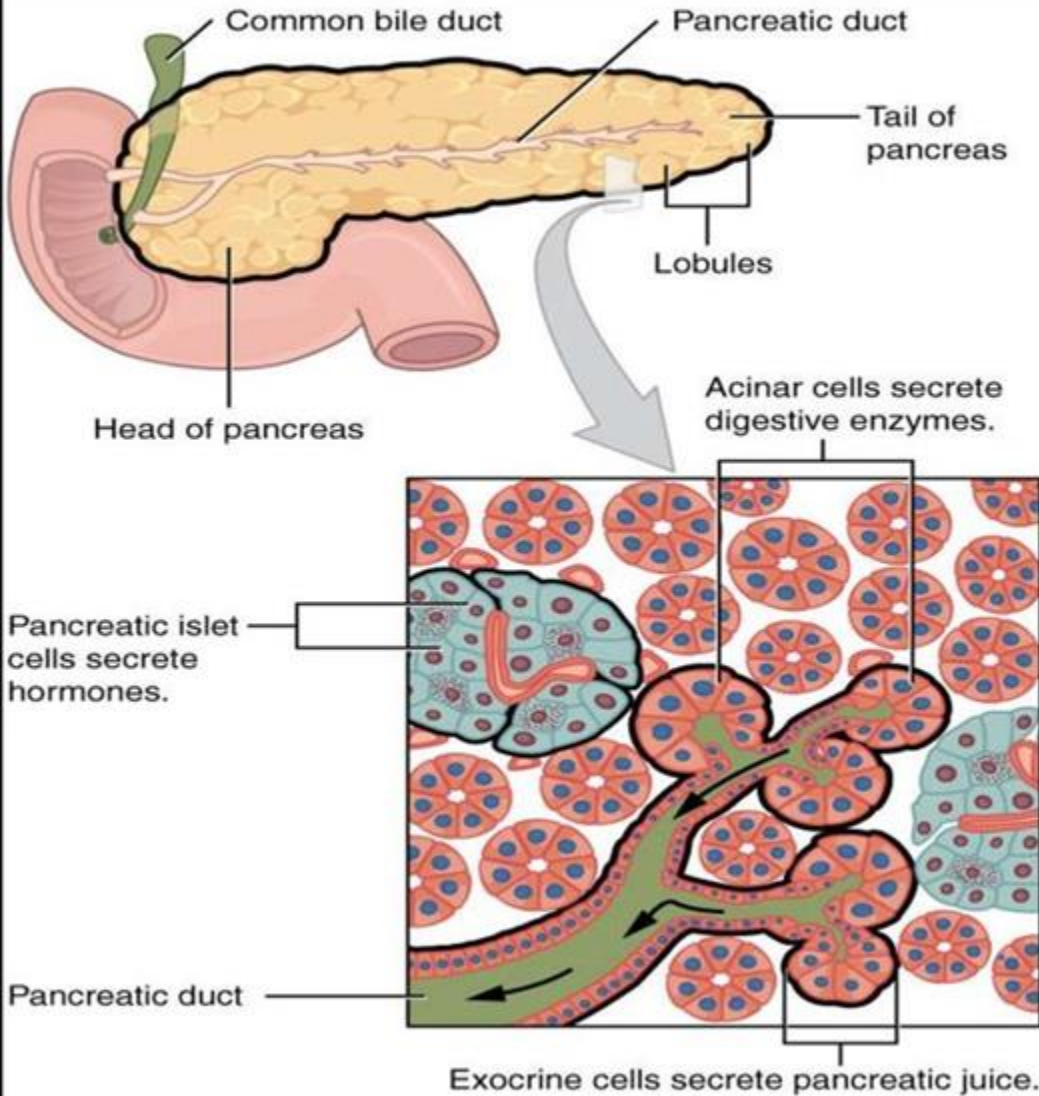
- Lipid $\xrightarrow{\text{BILE}}$ emulsified lipid, small particles



- After emulsifying **LIPASE** is secreted from pancreas and it breaks down lipid molecules into fatty acids and glycerol.
- Lipid + H₂O $\xrightarrow{\text{LIPASE}}$ 3 fatty acids + glycerol



Pancreas



Pancreatic Secretion

- Pancreas has **2 functions**:
 - a) **Endocrine functions**: secretes insulin and glucagon from islets of Langerhans
 - b) **Exocrine function**: secretion of pancreatic juice
 - It has **2 components**: aqueous and enzymatic components.
 - **Aqueous component** (contains HCO_3) is important for neutralizing stomach acid in the duodenum so pancreatic enzymes can function properly
 - **Enzymatic component** is essential for the proper digestion and absorption of carbohydrates, fats, and proteins
 - **Pancreatic enzymes** include trypsin, chemotrypsin, lipase, and amylase

Functions of pancreatic juice enzymes

Starch $\xrightarrow[\text{pH } 7.0]{\text{pancreatic amylase}}$ Maltose + Maltotriose

Fat (Triglyceride) $\xrightarrow[\text{pH } 8.0]{\text{Lipase + colipase}}$ Monoglyceride + Fatty acids

Trypsinogen $\xrightarrow{\text{Enterokinase}}$ Trypsin \rightarrow protein

Chymotrypsinogen $\xrightarrow{\text{Trypsin}}$ Chymotrypsin \rightarrow protein

Carboxypeptidase \rightarrow polypeptide \rightarrow amino acid

Small intestine Enzymes

Dipeptides $\xrightarrow{\text{Dipeptidases}}$ Amino acids

Maltose $\xrightarrow{\text{Maltase}}$ Glucose + Glucose

Lactose $\xrightarrow{\text{Lactase}}$ Glucose + Galactose

Sucrose $\xrightarrow{\text{Sucrase}}$ Glucose + Fructose

Nucleotides $\xrightarrow{\text{Nucleotidases}}$ Nucleosides $\xrightarrow{\text{Nucleosidases}}$ Sugars + Bases

Di and Monoglycerides $\xrightarrow{\text{Lipases}}$ Fatty acids + Glycerol

Motility of GIT

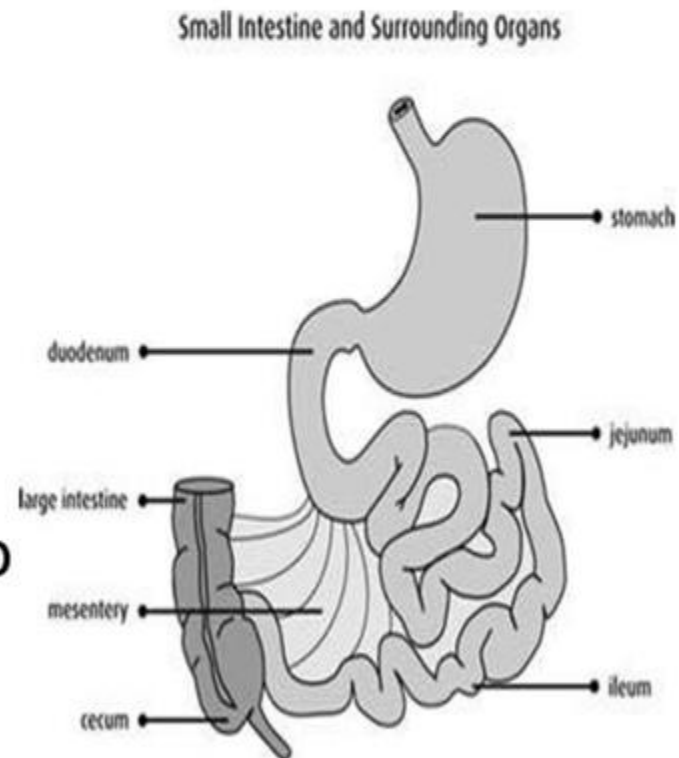
4. Motility of Small intestine

Types:

- Two basic motility patterns exist **segmentation** and **peristalsis**.

Significance:

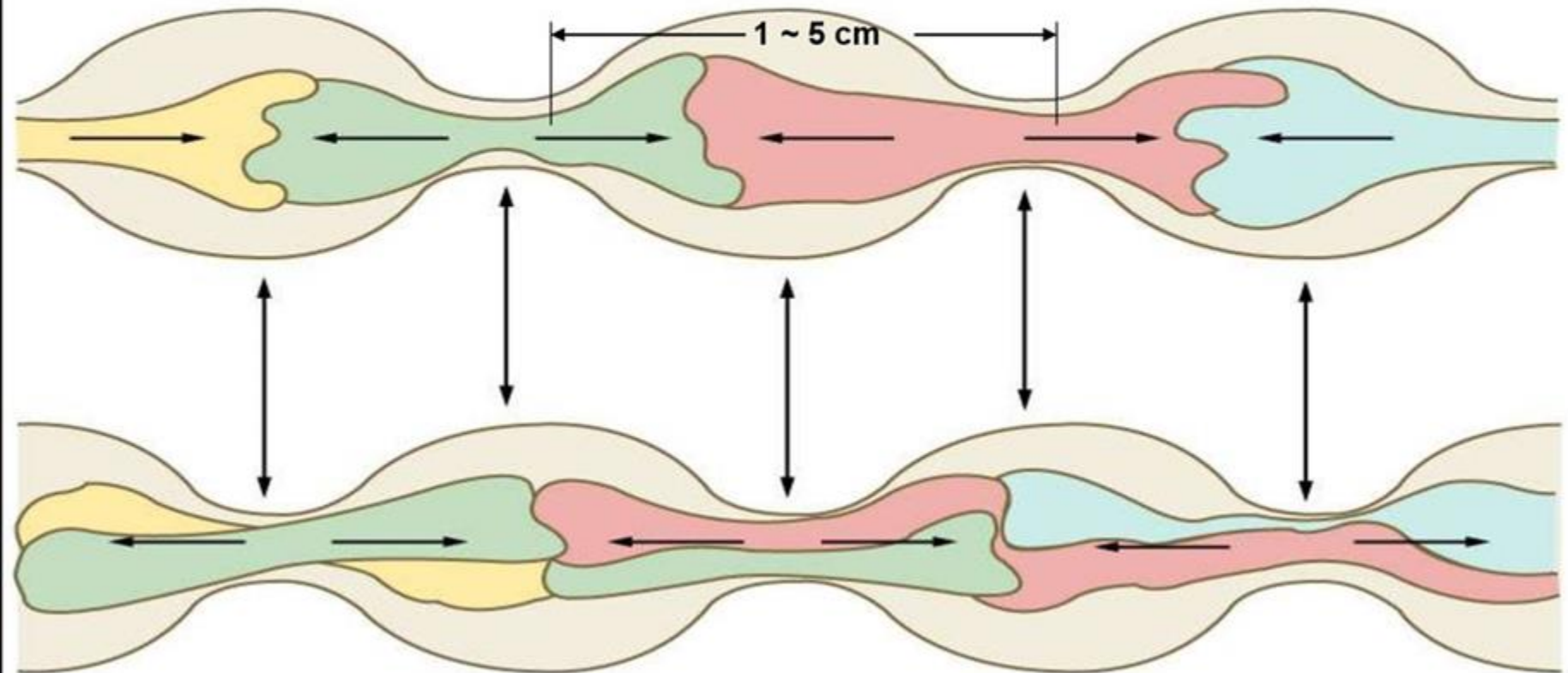
- Motility of the small intestine serves 3 functions:
 1. **Mixing** contents with enzymes and other secretions → help digestion
 2. Maximizing **exposure of the contents** to membranes of intestinal cells → help absorption and digestion.
 3. **Propulsion** of contents into the large intestine.



Motility of GIT

Segmentation movements

Segmental contractions are responsible for mixing and cutting

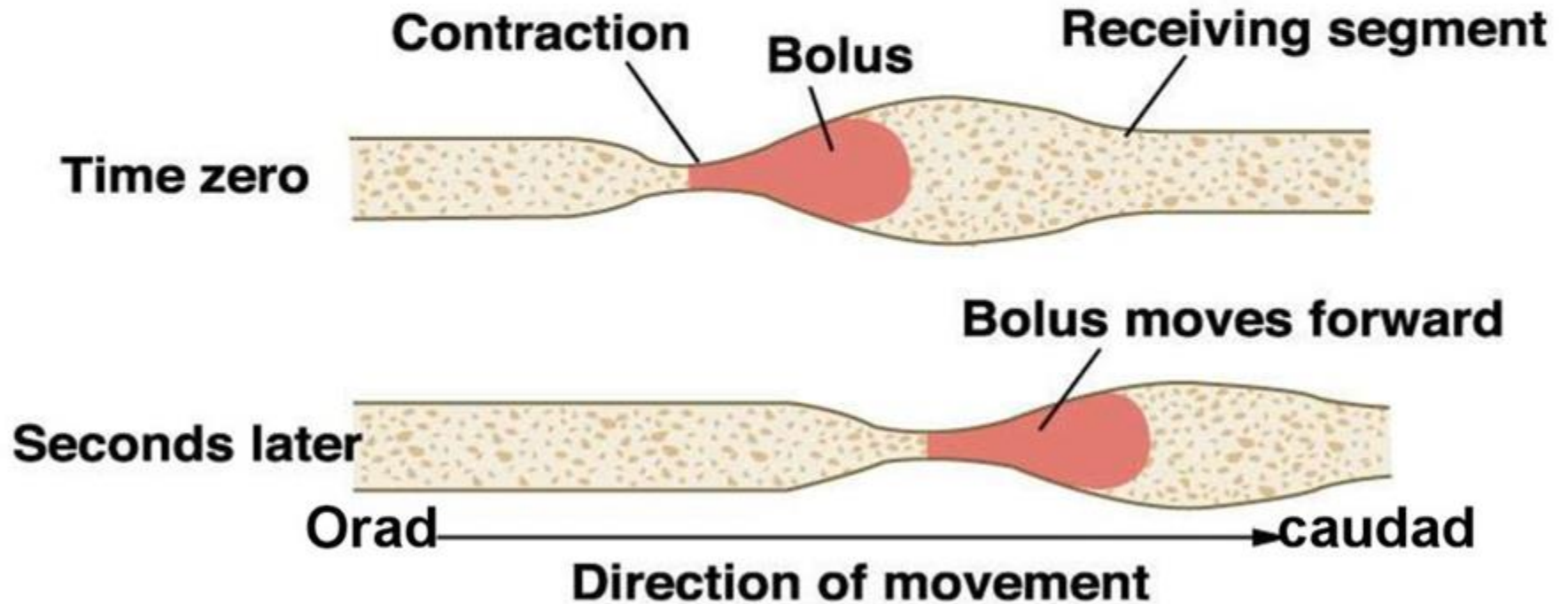


No net forward movement

Motility of GIT

Peristalsis

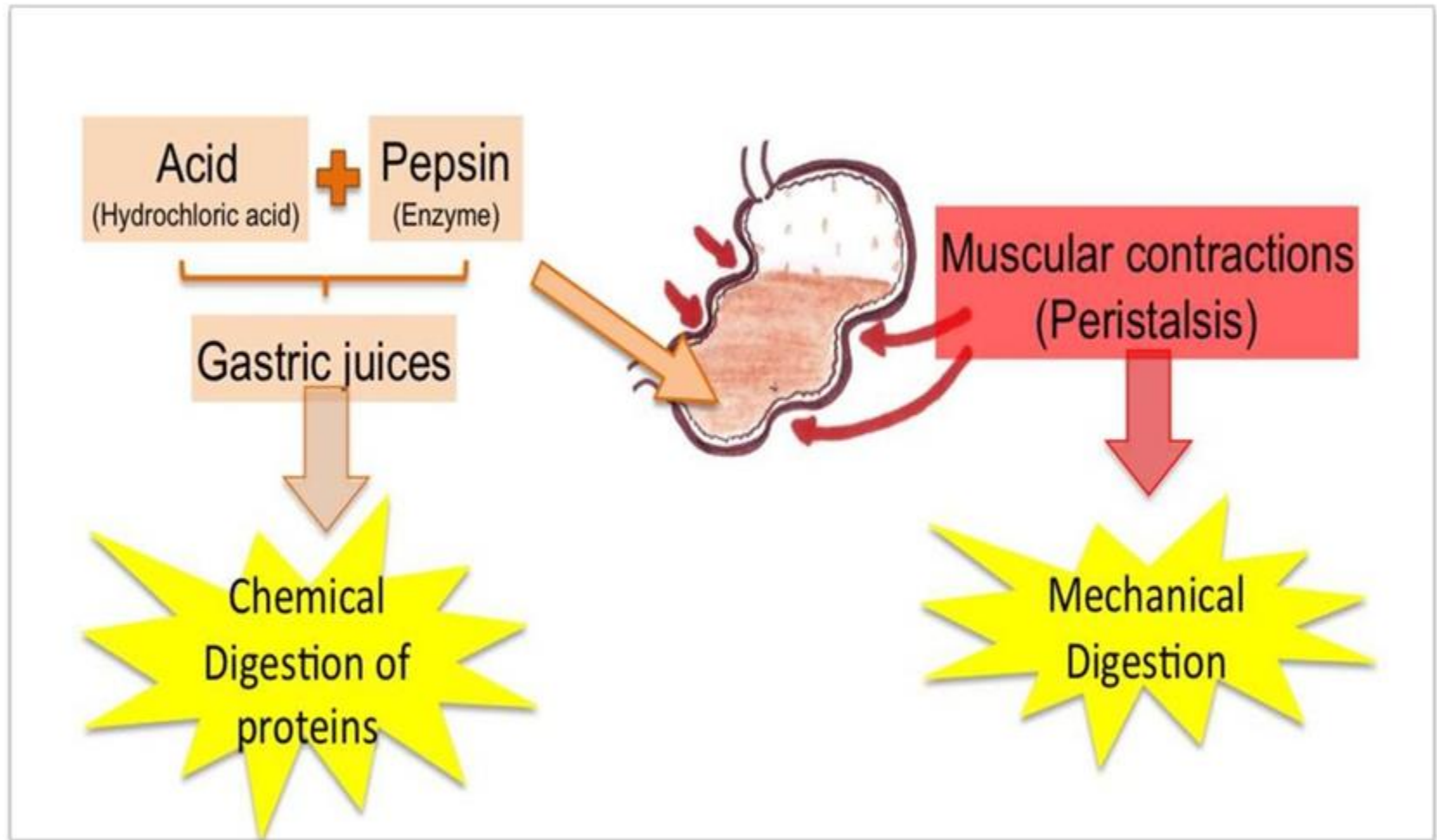
Peristaltic contractions are responsible for forward movement



Digestion and Absorption

- **Digestion is a process essential for the conversion of food into a small and simple form.**
- ✂ **Mechanical digestion** by mastication and swallowing
- ✂ **Chemical digestion** by enzymes
- **Absorption is the process of transporting small molecules from the lumen of the gut into blood stream or lymphatic vessel.**

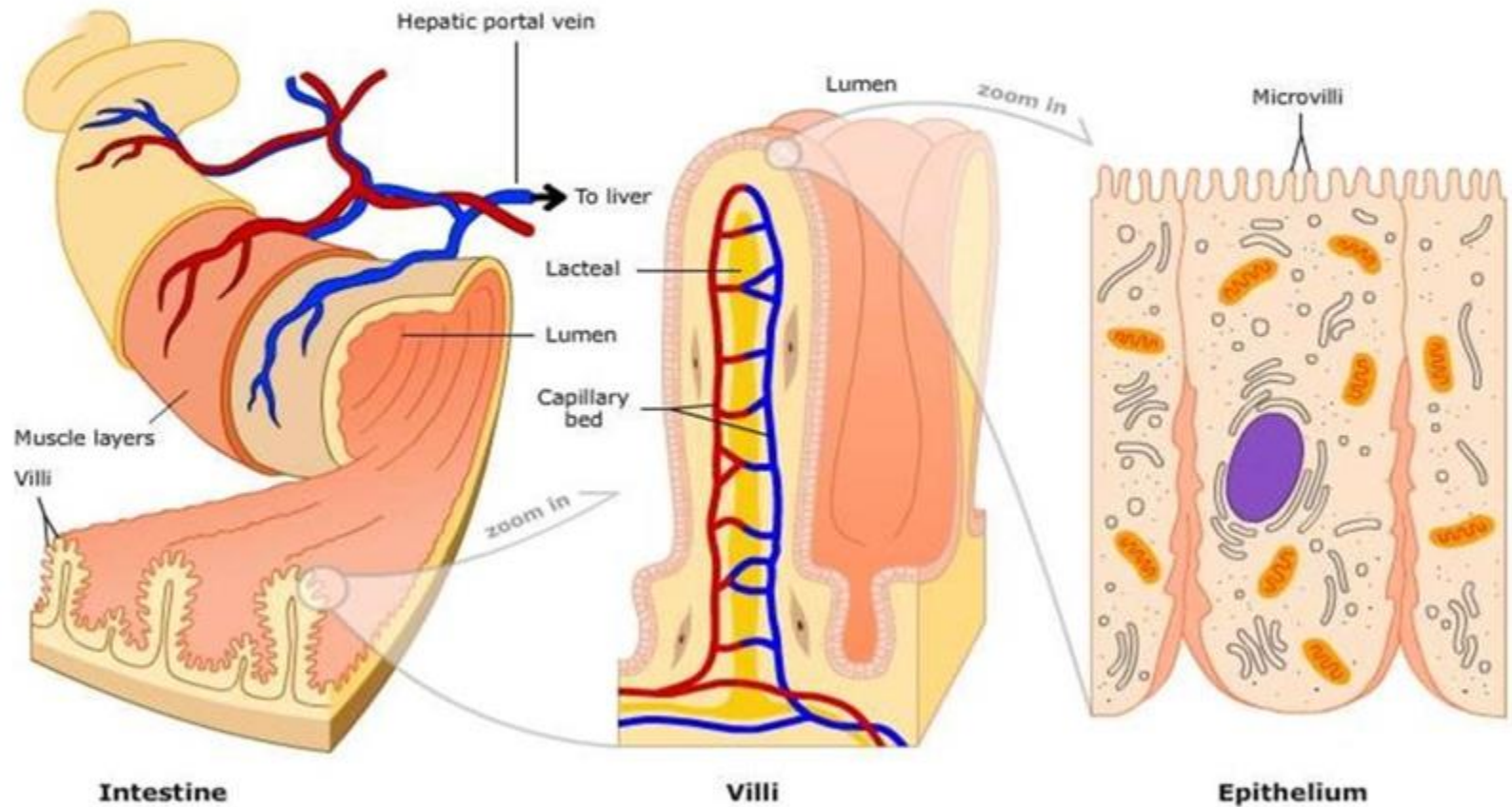
Chemical and Mechanical Digestion



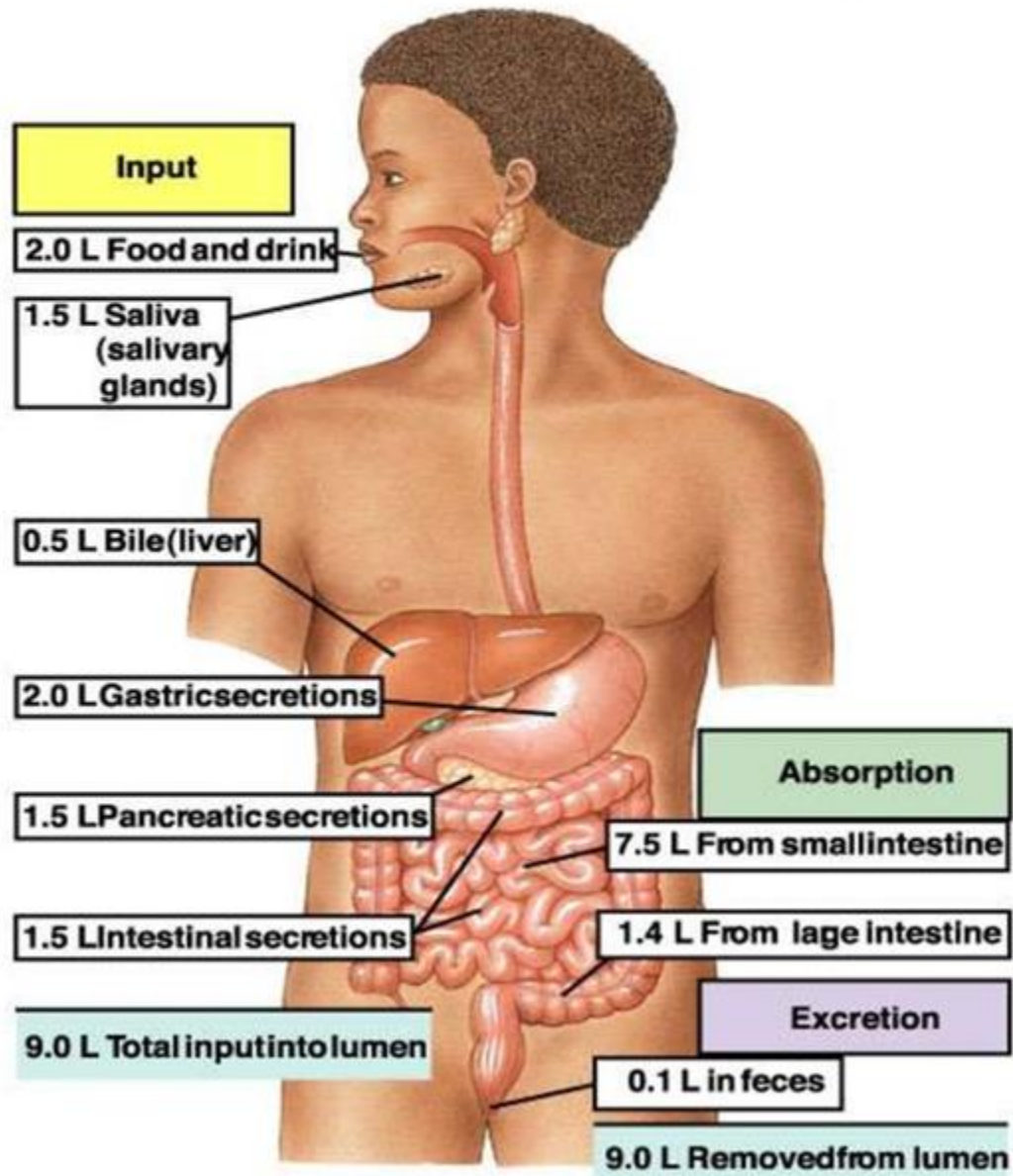
Digestion and Absorption

- **Small intestine** is primary site for **digestion** and **absorption** of food.
- **Digestion** occurs in the GI lumen by **secreted enzymes** and on surface of enterocytes by **membrane-bound enzymes**.
- Absorption occurs by **simple diffusion**, **facilitated diffusion**, **active transport**, **endocytosis**, and **paracellular transport**.
- **Surface area** of small intestine is greatly increased by extensive **folding** and the projection of **fingerlike villi** covered with **microvilli**.

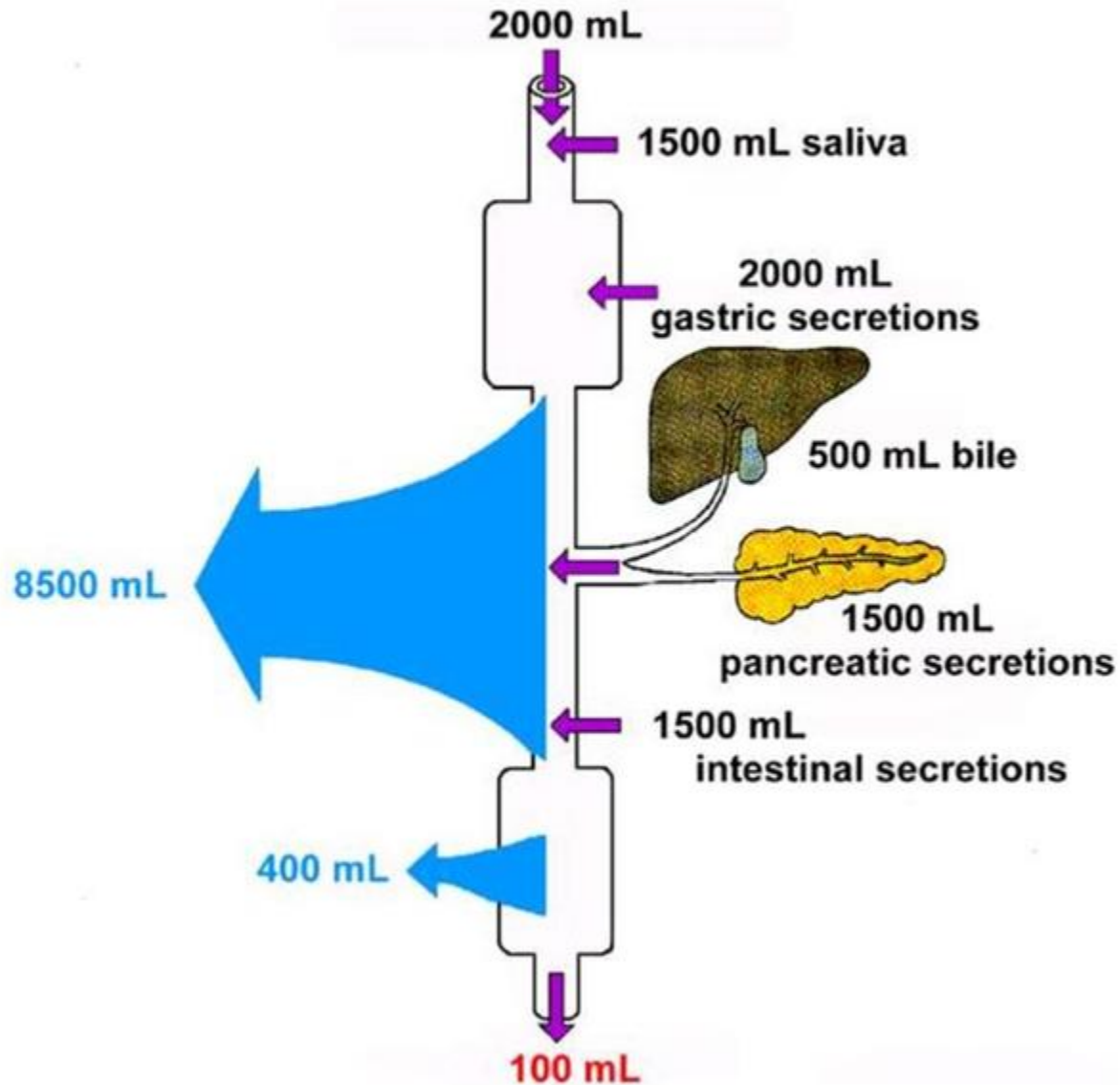
Intestinal Mucosa



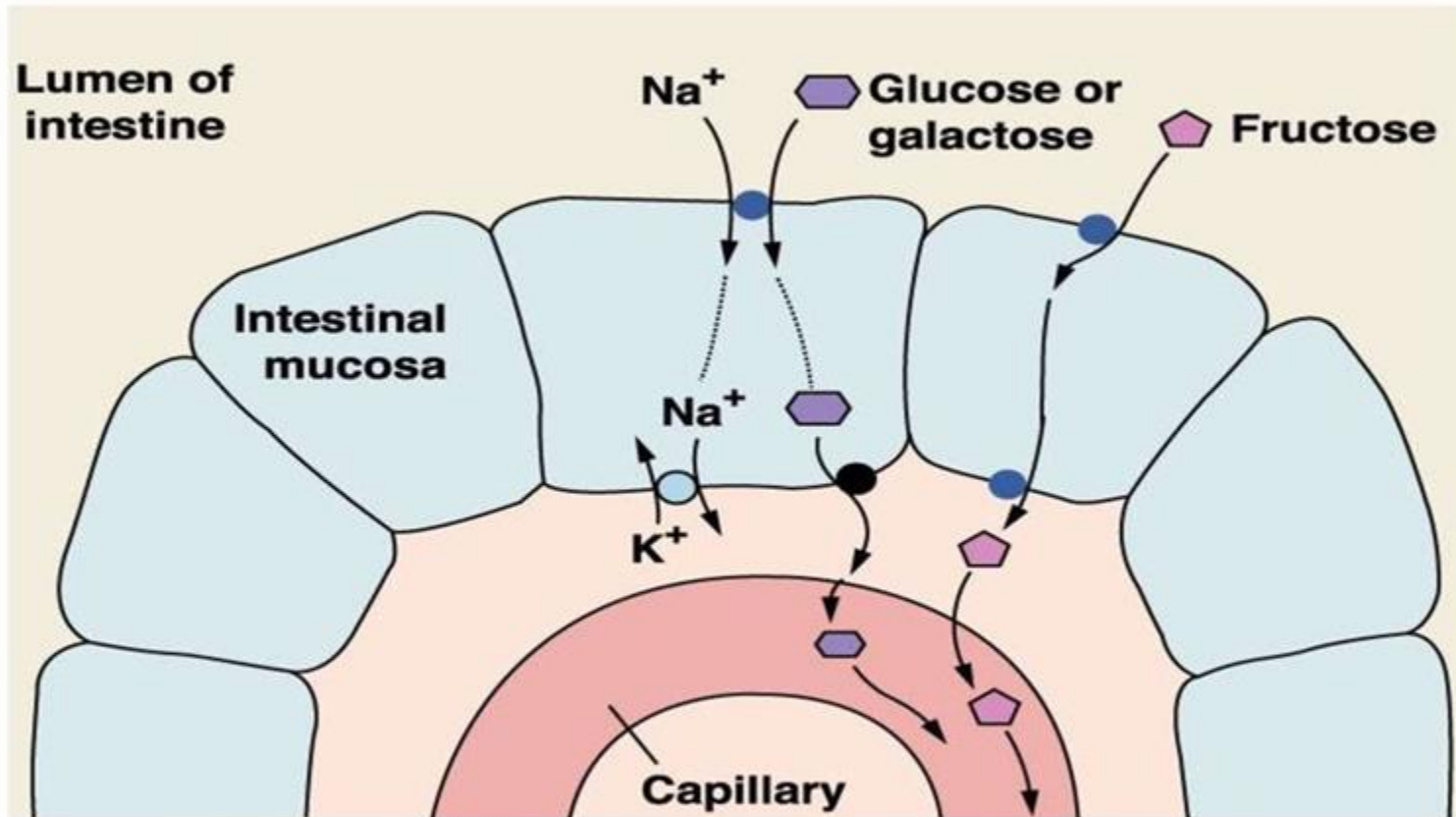
Absorption of Water



Absorption of Water



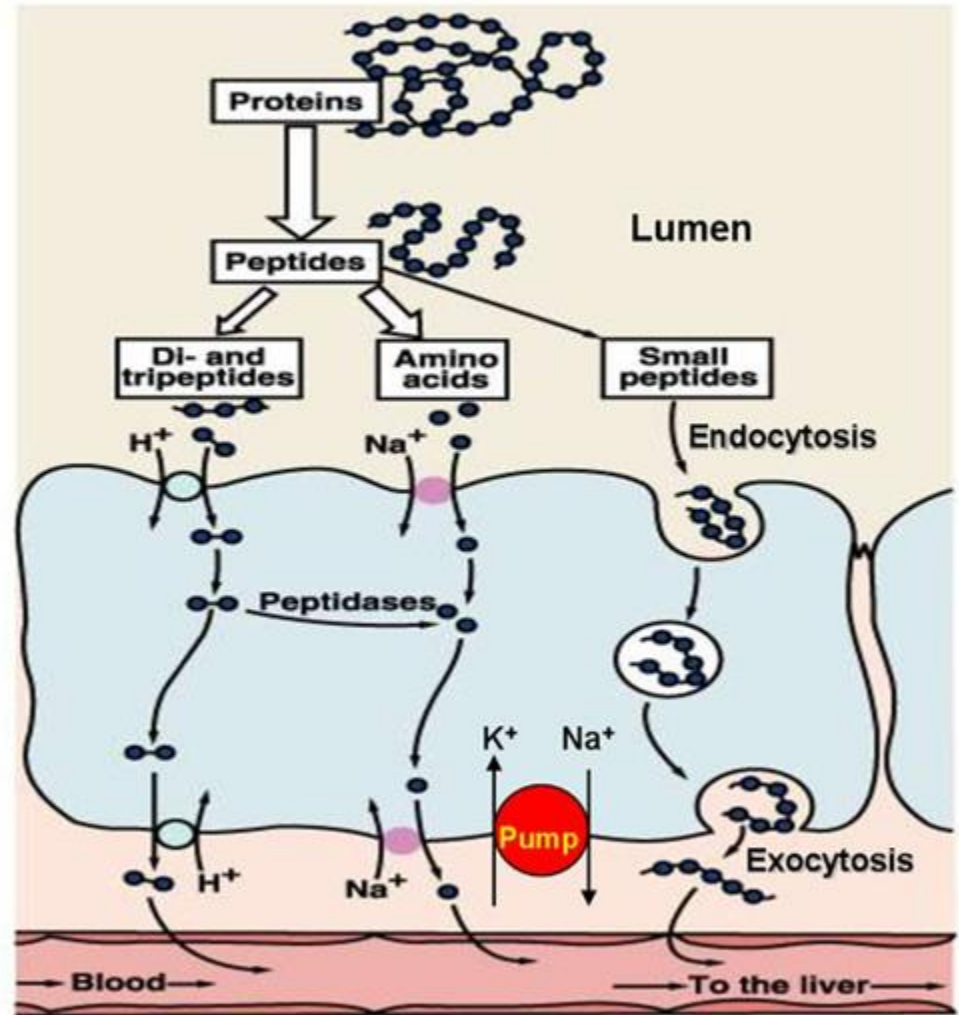
Absorption of CHO



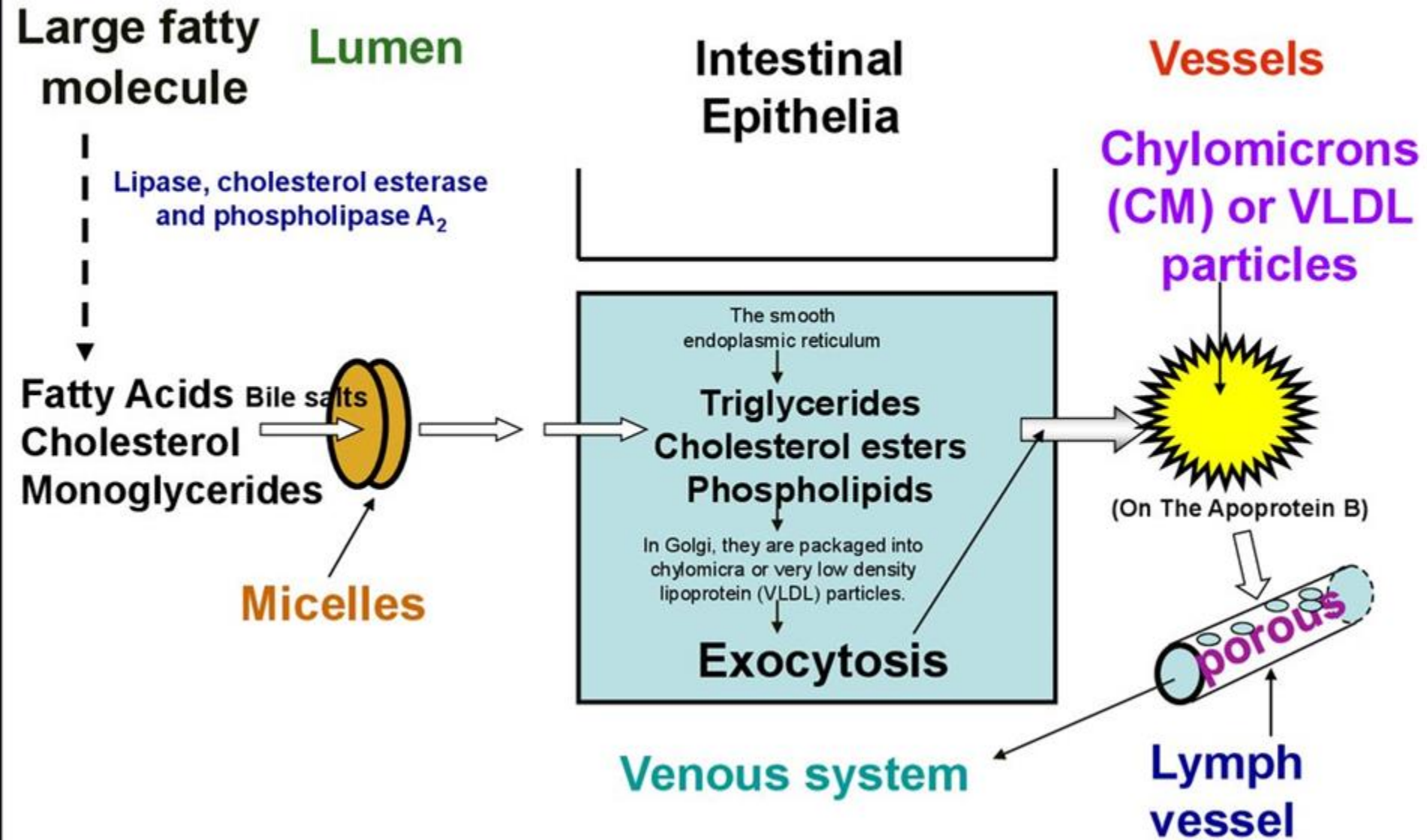
Enterocytes absorb **glucose and galactose** through an **Na-dependent secondary active transport process**, while **fructose** is absorbed by **facilitated transport**.

Absorption of proteins

- The whole proteins by **endocytosis**
- Amino acids and di and tripeptides by **Na-dependent 2ry active transport**

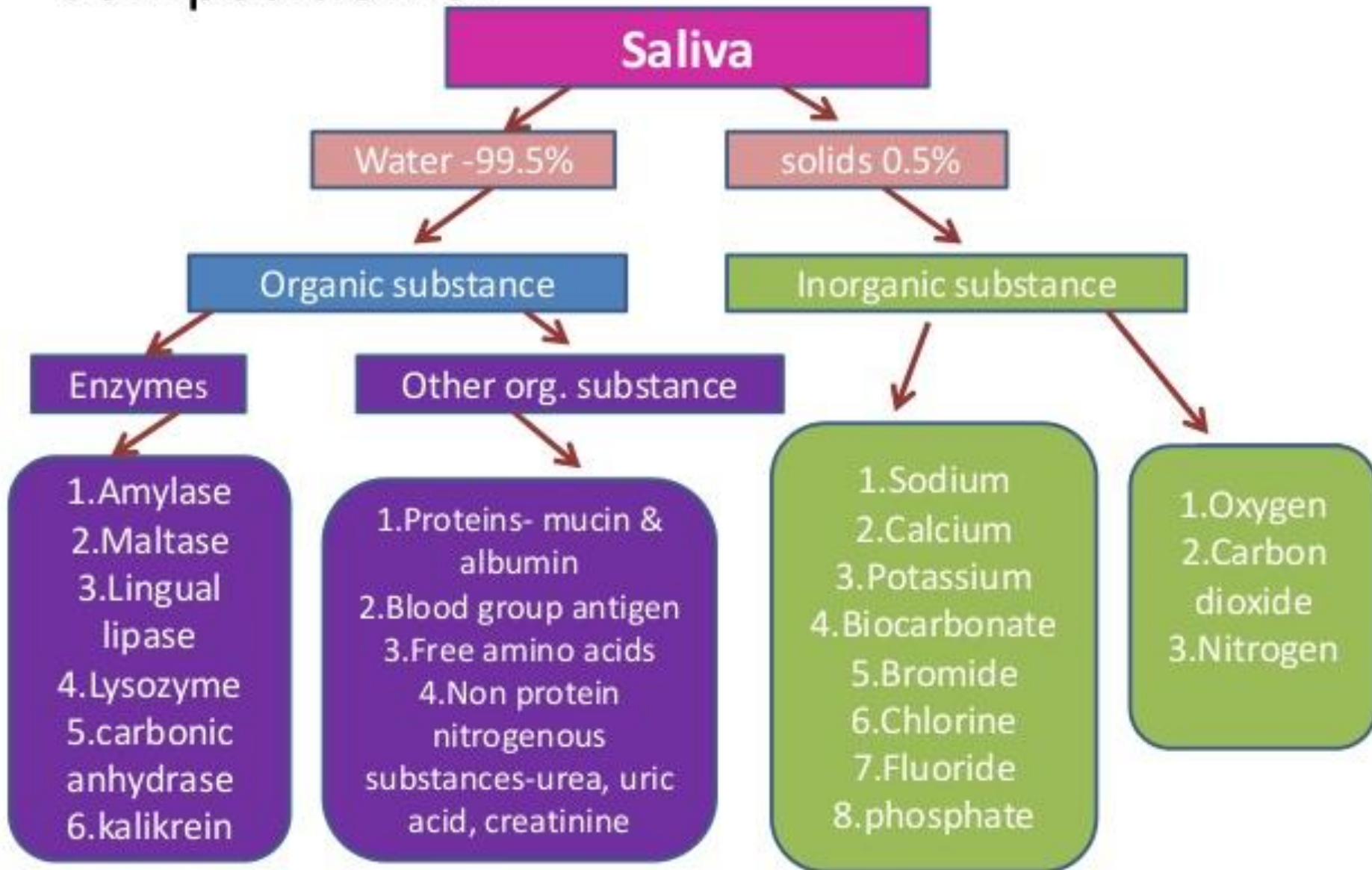


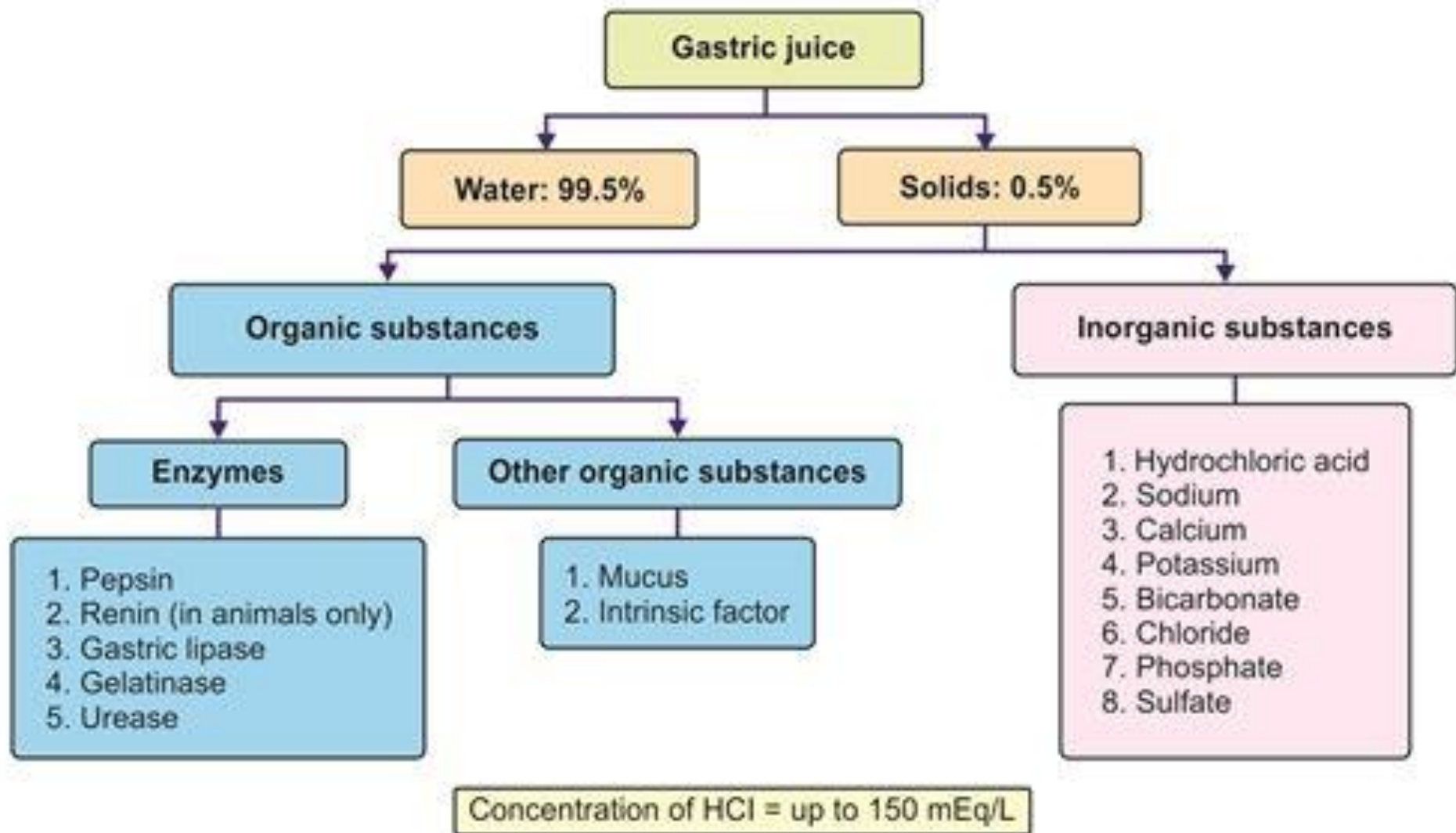
Absorption of Lipids

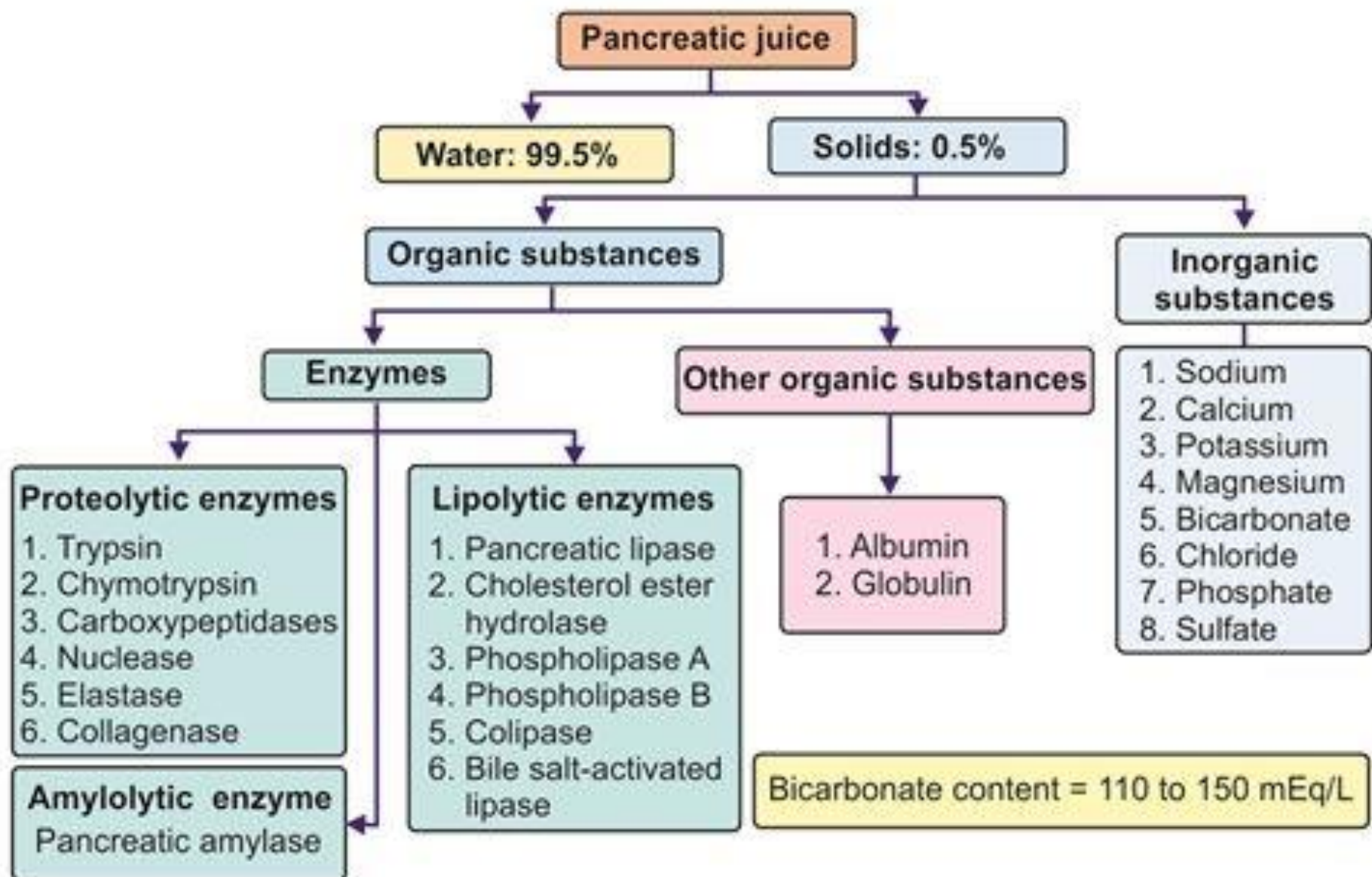


Absorption of Fats in the Small Intestine

Composition of







Bile

Water: 97.6%

Solids: 2.4%

Organic substances

1. Bile salts
2. Bile pigments
3. Cholesterol
4. Fatty acids
5. Lecithin
6. Mucin

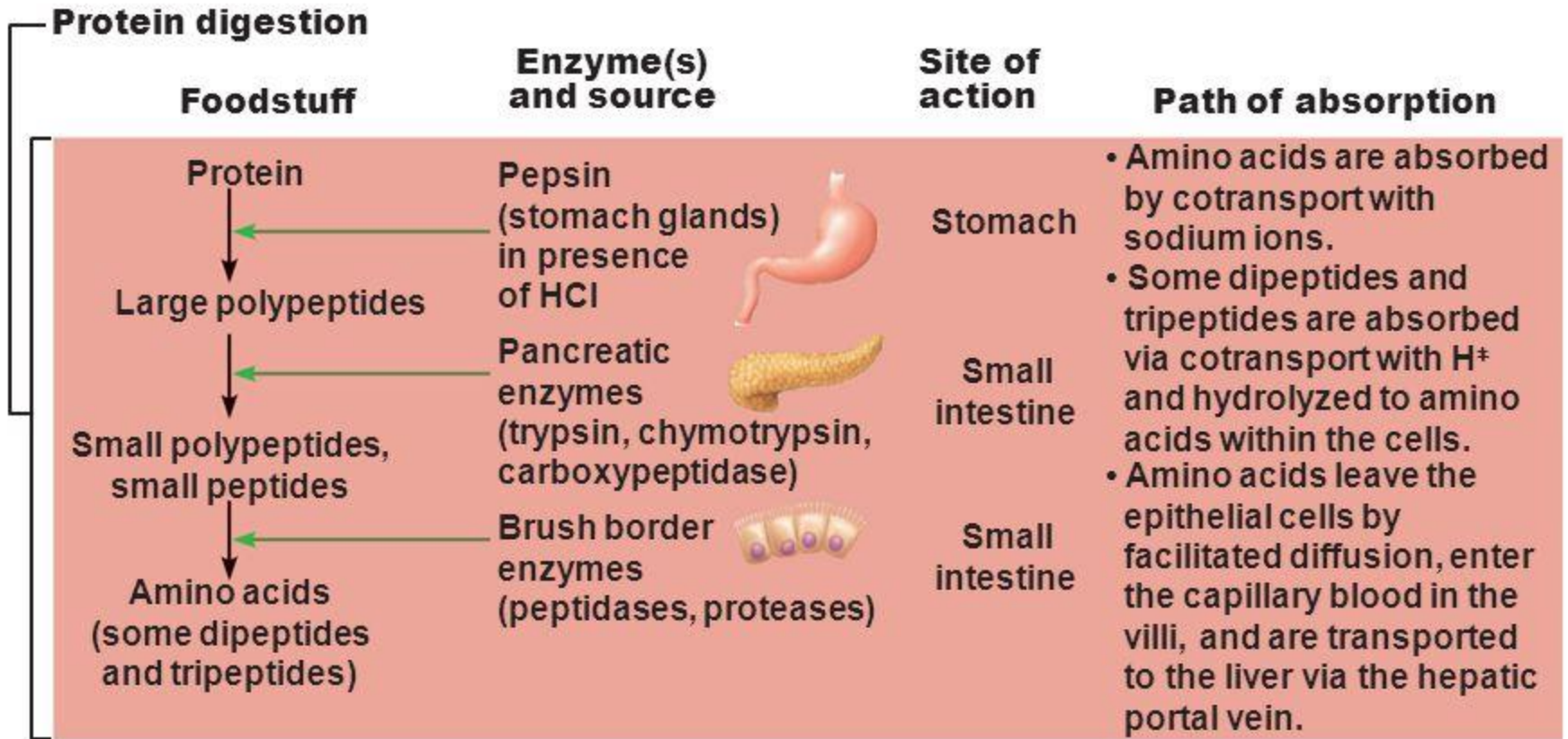
Inorganic substances

1. Sodium
2. Calcium
3. Potassium
4. Chloride
5. Bicarbonate

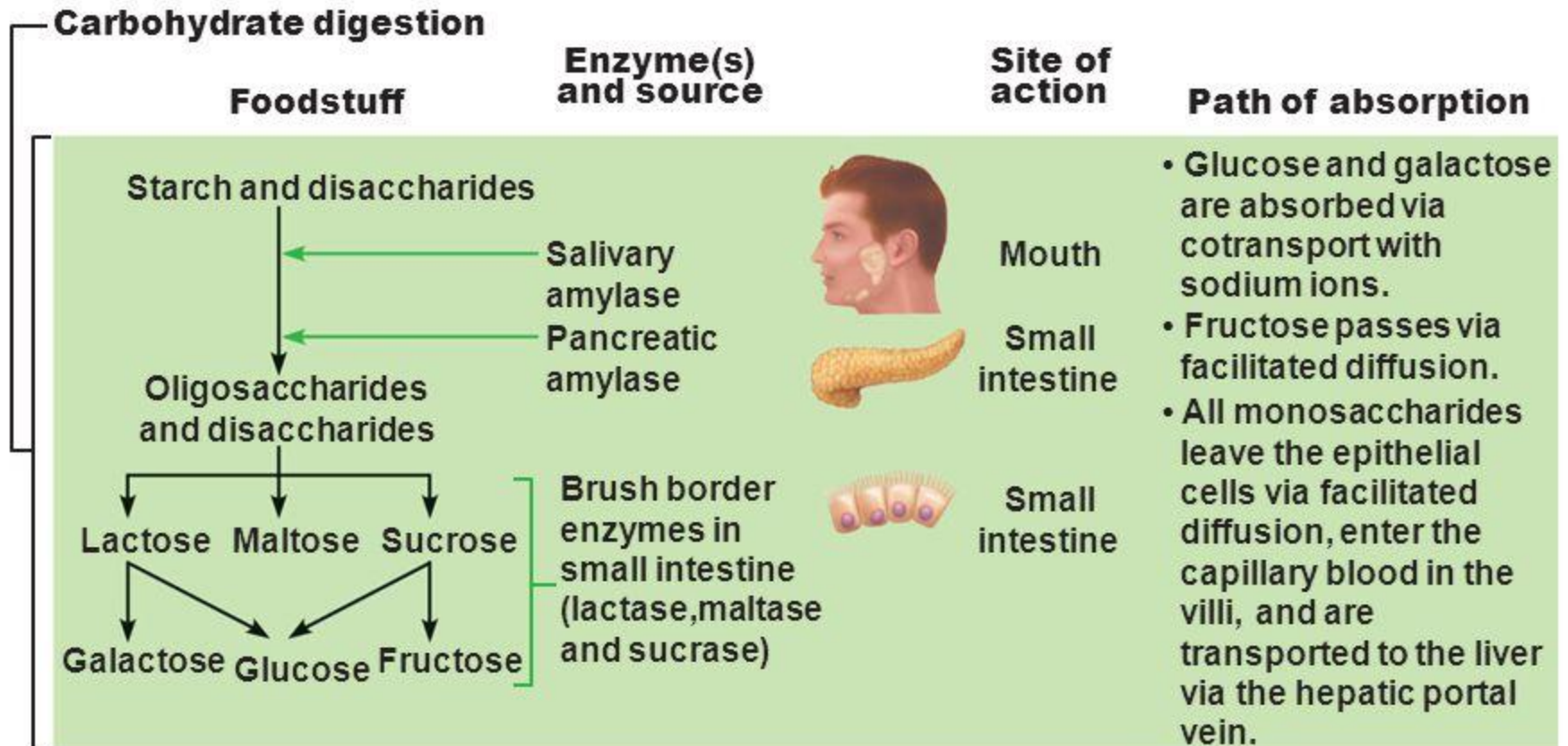
Composition of intestinal juice

- **Organic substances** - more than 20 enzymes.
 1. **Proteases:** enterokinase, polypeptidase,
 2. aminopeptidases, nuclease.Erepsin – A mixture of enzymes, containing dipeptidases.
 2. **Carbohydrate-splitting enzymes:** Hydrolysis of disaccharides is realized by: **maltase, lactase, sucrase** (only in small intestine).
 3. **Lipase**, phospholipase, phosphatase.
 4. Mucin.
- **Inorganic substances:** 1% of mineral salts K^+ , Na^+ , Ca^{2+} , Mg, chlorides, bicarbonates.

Chemical Digestion and Absorption of Proteins

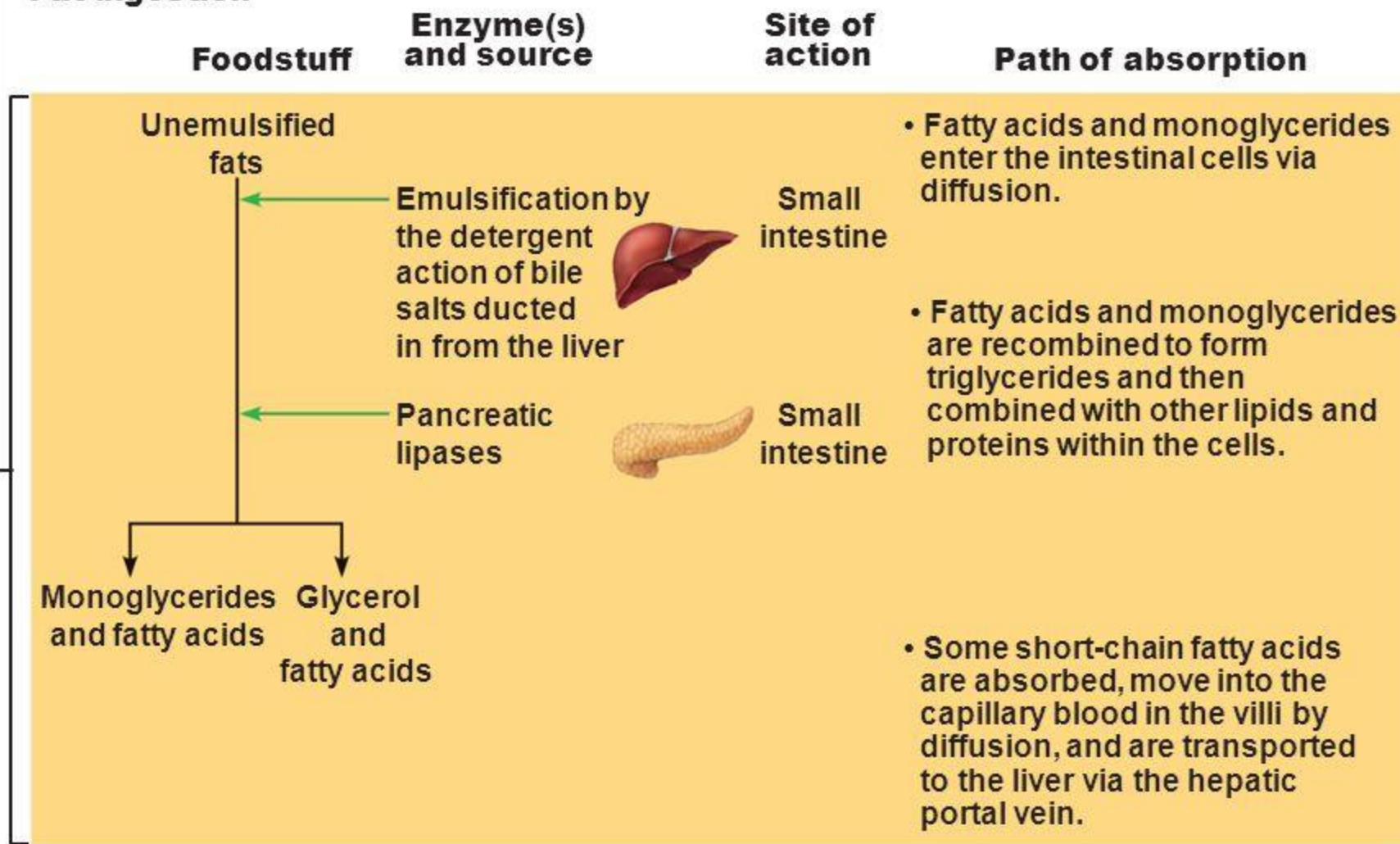


Chemical Digestion and Absorption of Carbohydrates



Chemical Digestion and Absorption of Fats

Fat digestion



Chemical Digestion Lipids & Nucleic acids

Path of absorption

Fat digestion

Absorption: Fatty acids and monoglycerides enter the intestinal cells via diffusion. They are combined with proteins within the cells, and the resulting chylomicrons are extruded. They enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct. (Glycerol and short-chain fatty acids are absorbed into the capillary blood in the villi and transported to the liver via the hepatic portal vein.)

Nucleic acid digestion

Absorption: Active transport via membrane carriers; absorbed into capillary blood in the villi and transported to the liver via the hepatic portal vein.

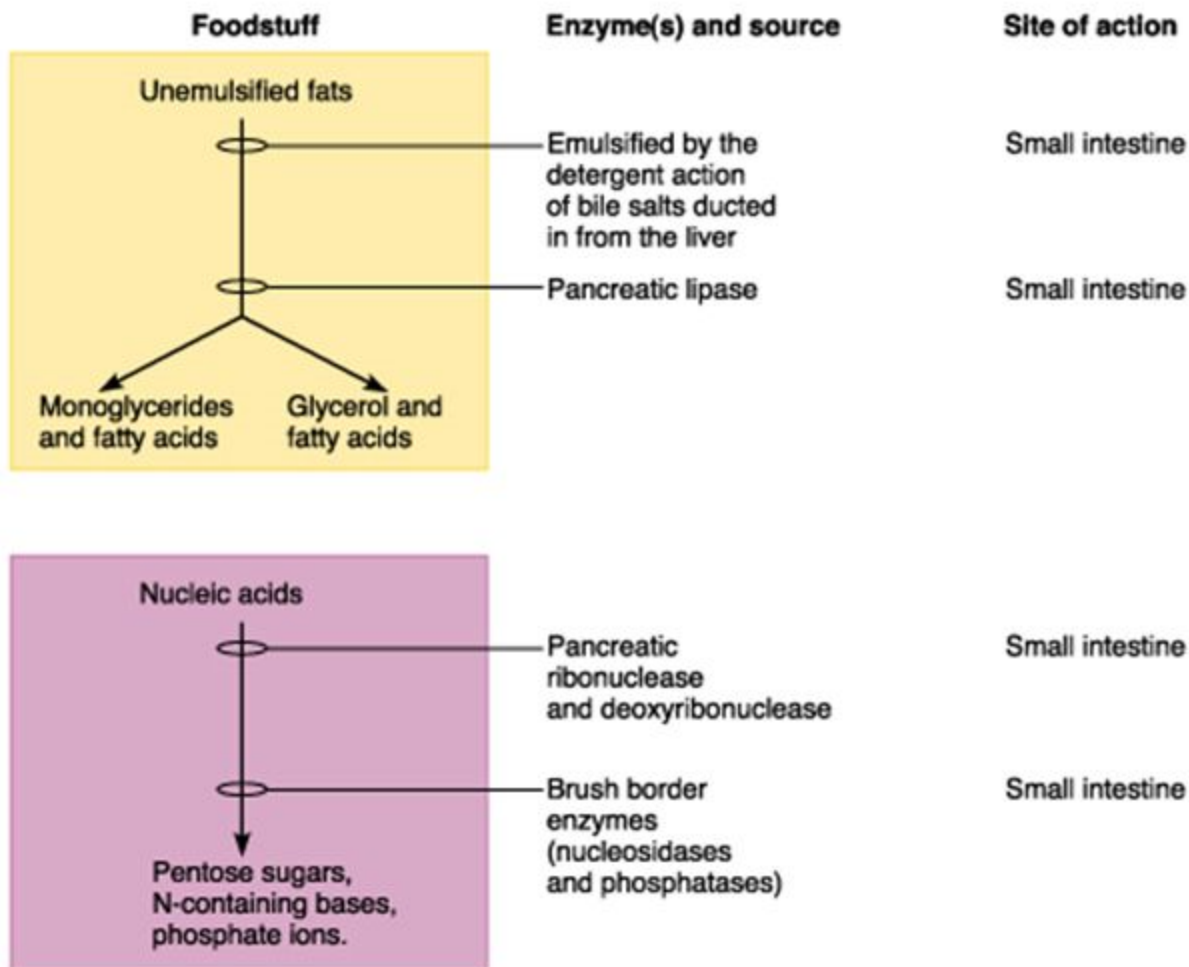


Table : Glands of small intestine

Brunner's glands	Payer's patches	Crypts of Leiberkuhn
<ul style="list-style-type: none">• Found in duodenum only.• Mucus secreting gland (known as mucus gland.)	<ul style="list-style-type: none">• These are lymph nodules.• They produce lymphocytes.• Lymphocytes are phagocytic in nature which destroy harmful bacteria.	<ul style="list-style-type: none">• Known as intestinal gland.• Found in duodenum and ileum only.• Secrete succus entericus <i>i.e.</i> intestinal juice.• Formed by folding of lamina propia.