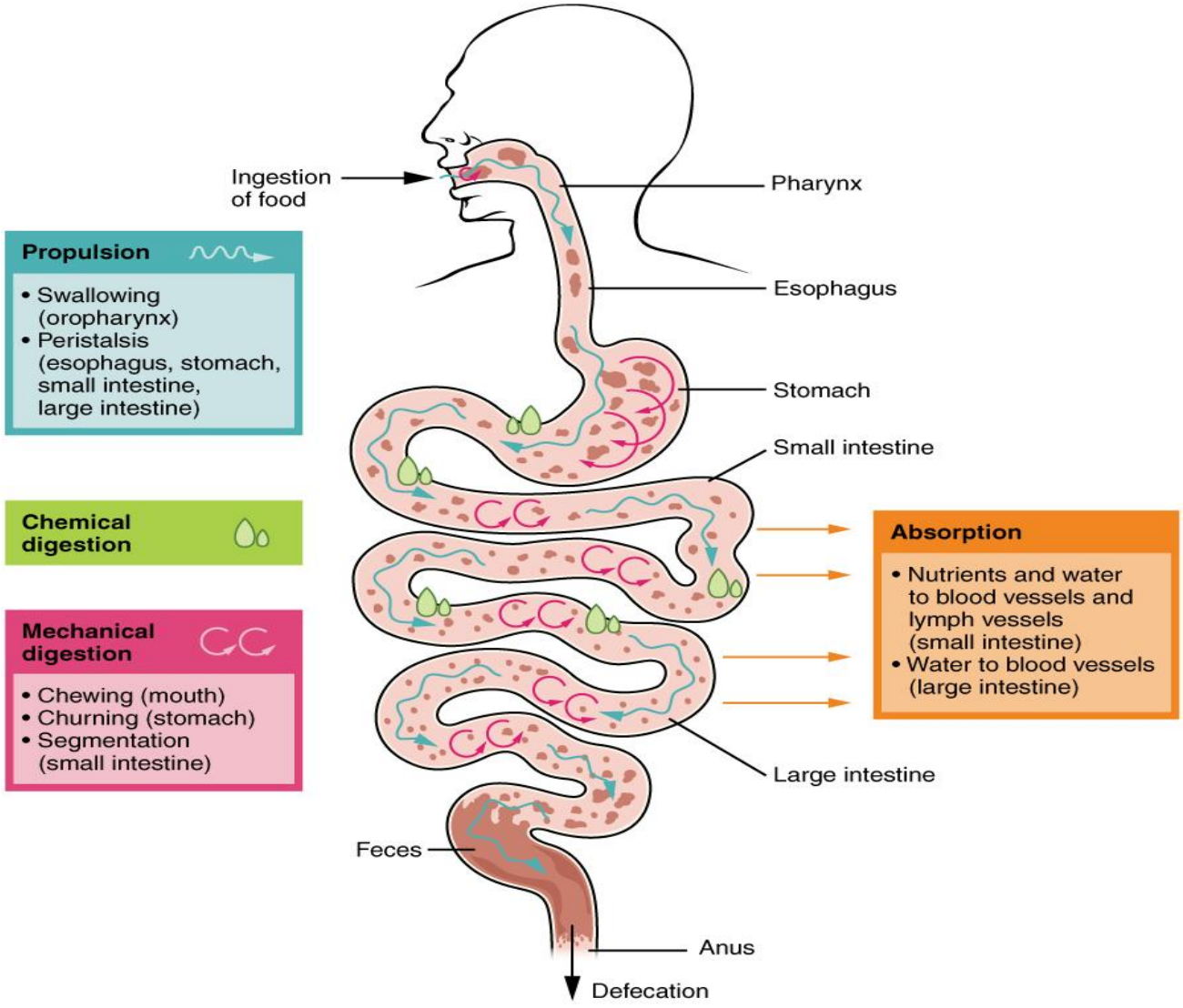
Alimentary system or digestive system

Digestive system

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube, known as the alimentary canal or the gastrointestinal tract (GI tract). The alimentary canal is made up of the oral cavity, pharynx, esophagus, stomach, small intestines, and large intestines. In addition to the alimentary canal, there are several important accessory organs, include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

Digestion

Digestion is the physiological breakdown of large insoluble food molecules into small water soluble food molecules so that they can be absorbed into the watery blood plasma. It is the process of breaking down of food by mechanical and enzymatic action in the alimentary canal into substances that can be absorbed and used by the body.



 # Functions of digestive system

1. Receive food
2. Break down food into absorbable nutrients
3. Move food through the digestive system
4. Secrete hydrochloric acid, mucus, digestive enzymes, bile and pepsin
5. Absorb nutrients
6. Elimination of toxic waste products and unabsorbed food

 # Parts of alimentary system:

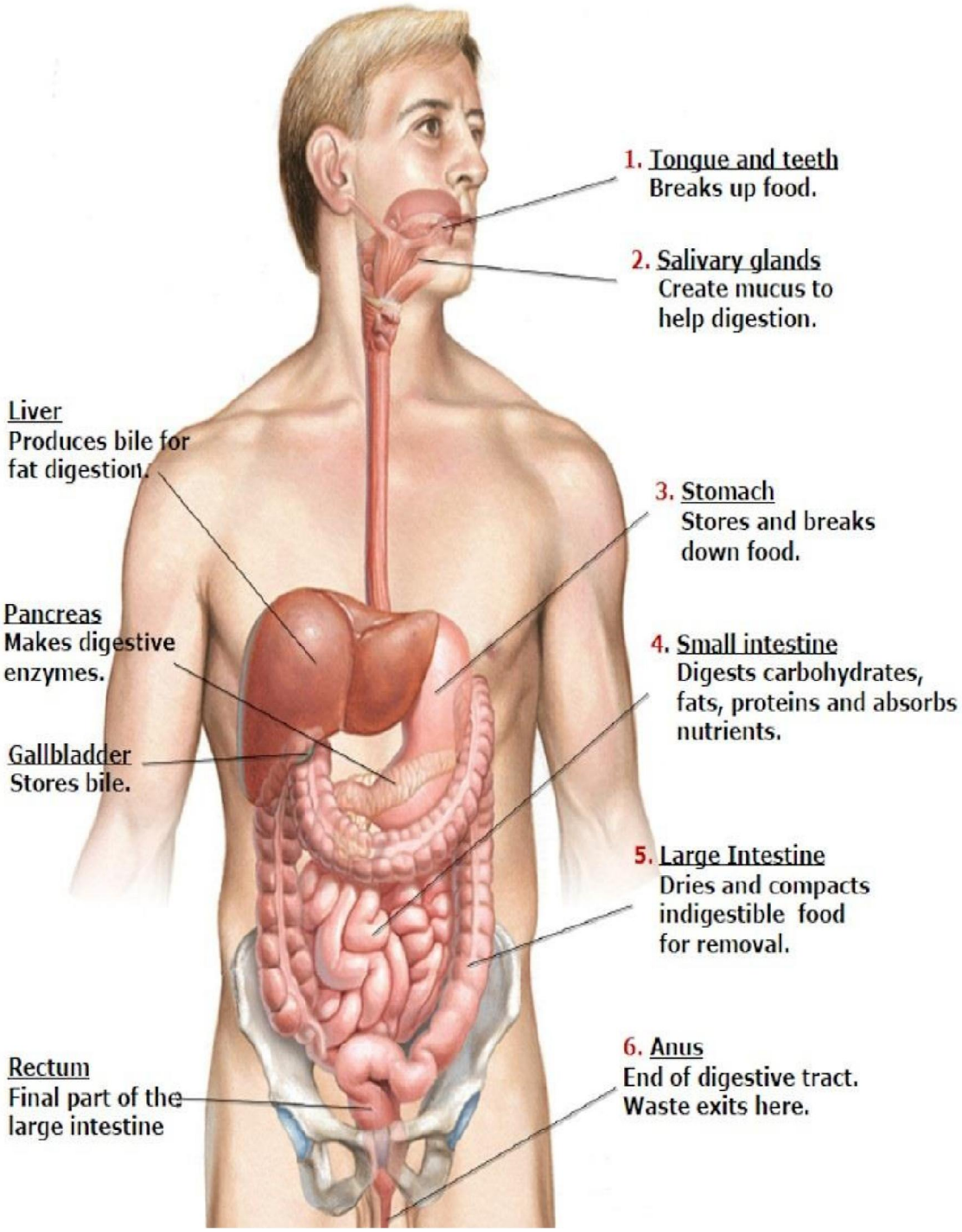
1. Mouth a.Teeth b.Tongue c.Salivary glands
2. Pharynx
3. Esophagus
4. Stomach
5. Small intestine a.Duodenum b.Jejunum c.Ileum
6. Liver
7. Gallbladder
8. Pancreas
9. Large intestine
    a. Cecum
    b.Ascending colon
    c.Transverse colon
    d.Descending colon
    e.Sigmoid colon
    f.Rectum
    g.Anal canal

 # Hormones of GIT

- Villikinin
- Enterocrinin
- Enterogastrone
- Motiline
- Somatostatin
- Bombesin

- Gastrin
- Secretin
- Cholecystokinin
- Pancreozymine
- Gastric inhibitory peptide
- Vaso-active intestinal peptid

Hormones	Site of production	Stimuli	Site of action	Functions
Gastrin	Mucosal layer of Stomach **G cells**	Protein and protein digestion products in stomach.	Stomach, small intestine, lower esophageal sphincter and gallbladder.	Stimulates gastric acid, pepsinogen. Increase stomach motility. Stimulates the movement of colon.
Secretin	**S cells** located in the mucosal gland of Duodenum and jejunum.	Acid in duodenum.	Pancreas	Stimulate pancreatic bicarbonate secretion. Inhibit gastric secretion and motility. Stimulate bile secretion and potentiate action of CCK.
Cholecystokinin (CCK)	**I cells in** Duodenum and jejunum.	Fat or protein digestion product in duodenum.	Pancreas and gallbladder.	Potentiates the secretion of pancreatic amylase. Inhibit gastric acid secretion and motility. Stimulate bile secretion by liver. Stimulate gallbladder secretion.
Gastric inhibitory peptide (GIP)	**K cells** in Duodenal and jejununal mucosa	Intestinal cell in response to fat, glucose or acid.	Stomach, gallbladder.	Insulin secretion. Inhibit gastric secretion and motility.
Glucagon like peptide1 (GLP1)	**L cells** in Ilium, colon and pancreatic alpha cell	Nutrient ingestion that induce insulin secretion	Stomach and Pancreas	Promote insulin secretion in glucose-dependent manner. Inhibits gastric emptying, acid secretion and motility collectively decreasing appetite.
Motilin	**M cells in** Duodenum and jejunum	Fat in duodenum	Intestine and stomach.	Increase small bowel motility and gastric emptying.
Somatostatin	**Delta cells** Stomach, small intestine and pancreas.	In response of acid.	stomach	Decrease the stomach acid.
Vasoactive Intestinal peptides (VIP)	Enteric nerves of intestine.	Intestinal cell in response to glucose.	Intestine	Increase water and electrolyte secretion. Relaxes smooth muscles from gut.



 # Enzymes of GIT

- Alpha amylase — Maltase
- Trypsin — Chymotrypsin
- Pepsin — Pancreatic lipase
- Lingual lipase — Gastric lipase

 # Saliva

Saliva is a viscous, colorless, oplacent fluid which is secreted by the three pairs of salivary glands.

Composition:

a. Water: 99.5%
b. Solid: 0.5%
    i. Organic: 0.3%
        - Enzymes: salivary alpha amylase, Lingual lipase, Lysozymes
        - Other organic: Mucin, urea, cholesterol, amino acids
        - Blood group substances: Antigen of ABO blood groups.
    ii. Inorganic (0.2%): NaCl, KCl, acid and alkaline sodium phosphate, calcium phosphate, $CaCO_3$.
    iii. Cellular constitutions: yeast cell, bacteria, protozoa.
    iv. Gases: O_2, N_2, CO_2.

Functions:

Mechanical functions:

a. It keeps the mouth moist and helps in speech.
b. It facilitates swallowing.
c. It helps the food to prepare for digestion
d. It dilutes hot and irritated food stuff.
e. By dissolving food stuff saliva helps in taking the sensation of taste.

- Digestive functions: It breaks down starch into maltose by the presence of ptyaline enzyme.
- Excretory functions: It excretes urea, heavy metal, certain drugs and antibiotics.
- Helps in water balance: Reduction of saliva on mouth stimulates the desire of thirst.
- Buffering functions: Due to the presence of bicarbonate and phosphate ion, it acts as a buffering agent.
- Bacteriolytic functions: Enzymes present in saliva act as a bacteriolytic agents.

 # Pancreatic juice

Composition:

a. Water: 98.5%
b. Solid: 1.5%

Functions:

a. Digestive action
    1. Proteolytic activity: Trypsin, chymotrypsin like proteolytic enzymes split down the protein into small amino acids.
    2. Amylolytic activity: Pancreatic amylase convert both boiled and unboiled starch, glucagon into disaccharides.
    3. Lipolytic activity: Pancreatic lipase hydrolyses neutral fat, Cholesterol esterase hydrolyses cholesterol ester and phospholipase A2 split down the phospholipid.
b. Neutralizing action

Pancreatic juice containing HCO3-, neutralize the acid chyme into the duodenum.

 # Bile

- Bile acid are the derivative end product of cholesterol.
- Bile is made up of the bile salts, bile pigments and other substances dissolved in an alkaline electrolyte solution.
- It is about to 500 ml secreted by liver every day.
- Bilirubin and biliverdin are the bile pigments and their glucuronides are responsible for the yellow color of bile.
- The four bile acids are: taurocholic acid and glycocholic acid (derivatives of cholic acid) and taurochenodeoxycholic acid and glycochenodeoxycholic acid (derivatives of chenodeoxycholic acid).

Composition:

1. Water
2. Bile salts
3. Bilirubin
4. Cholesterol
5. Fatty acid
6. Lecithin

Functions:

1. It is a means for the body to excrete waste products from the blood.
2. Emulsify fats and break it down into small particles. This is a detergent-like action of bile.
3. Helps the body absorb the breakdown products of fat in the gut.
4. Bile salts bind with lipids to form micelles. This is then absorbed through the intestinal mucosa.
5. The other important function of bile is that it contains waste products from hemoglobin break down. This is known as bilirubin.
6. Bile also carries excess cholesterol out of the body and 'dumps' it into the gastrointestinal tract where it can be passed out with other waste matter.

 # Gastric juice

It is a digestive fluid, formed in the stomach. Composed of hydrochloric acid (HCl) .05–0.1 M, potassium chloride (KCl) and sodium chloride (NaCl). Gastric acid is produced by gastric parietal cells in the lining of the stomach. These cells also produce mucus, which forms a viscous physical barrier to prevent gastric acid from damaging the stomach.

Composition:

a. Water: 99.5%
b. Solid: 0.5%

Functions:

i. Digestive functions
    a. Pepsinogen, with gastric HCl digest the protein.
    b. Gastric lipase digests the fat.
    c. Renin helps to digest milk into insoluble calcium caseinate.
ii. Toxins, heavy metals and certain alkaloids are excreted through gastric juice.
iii. Functions of HCl
    a. It converts inactive pepsinogen into active pepsin.
    b. It acts as antiseptic agents against bacteria.
    c. It causes hydrolysis of all food stuff.
    d. It keeps iron in ferrous state for absorption.
    e. It gives optimum environment for pepsin, renin and lipase enzymes.

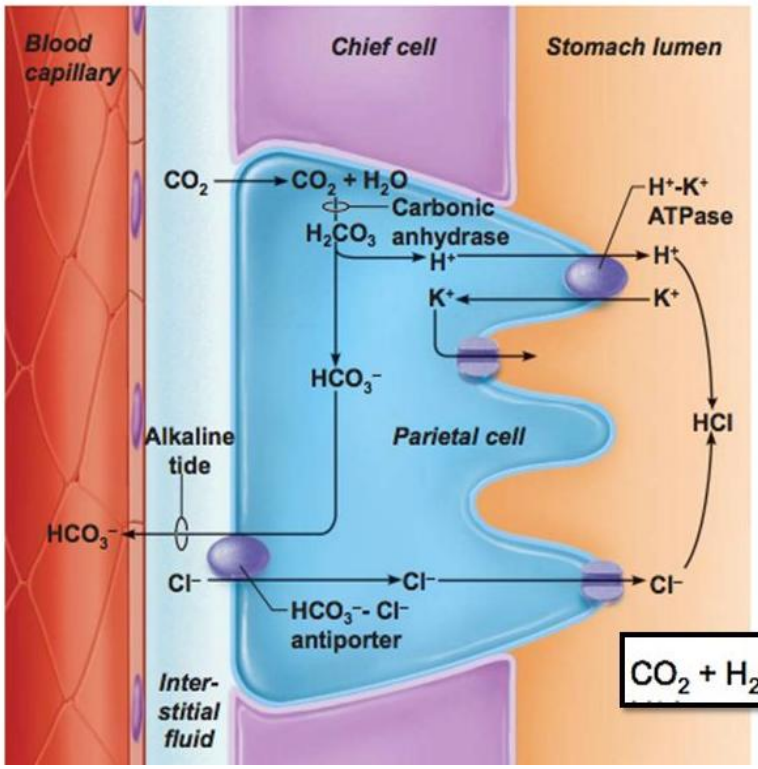
iv. The intrinsic factors of gastric juice help in absorption of Vit-B12, that is essential for maturation of RBC.

v. Lubricating functions: Mucin of gastric juice lubricates any irritant in stomach.

vi. Protective functions: Mucin is also responsible for protecting gastric mucosa.

vii. Acid base regulation: It is responsible for the alkaline tide of blood.

Mechanism of gastric HCL secretion:



Key Info to Note:

- Parietal cells contain Carbonic Anhydrase (CAH)
- H+ pumped into stomach lumen by H-K ATPase
- HCO3- exchanged for Cl- (chloride shift)
- Alkaline tide in blood due to increase HCO3- (Increase pH)

$$CO_2 + H_2O \xrightarrow{CAH} H_2CO_3 \rightarrow HCO_3^- + H^+$$

1. Carbonic anhydrase helps in formation of H_2CO_3 from CO_2 & H_2O within the parietal cell
2. H_2CO_3 disassociates to form H^+ and HCO_3^-
3. H^+ is secreted into the lumen of canaliculi of parietal cell in exchange for K^+ by H^+-K^+ ATPase pump
4. HCO_3^- produced are transported out through antiport in exchange with Cl^- at basolateral membrane into

Carbohydrate {$C_m (H_2O)_n$} Digestion:

Monosaccharides: Glucose, Galactose, Fructose
Disaccharides: Sucrose, Lactose, Maltose
Oligosaccharides (3-9): Raffinose
Polysaccharides (>9): Starch, Amylose, Cellulose, Pectin, Glycogen

1. Digestion

Three major sources of carbohydrates are existing in usual diet: Sucrose, lactose and starches. Besides these amylose, glycogen and cellulose are also present. Their digestion in different part of GIT occurs as below:

a. **In the mouth:**
   i. Saliva contain an alpha amylase: ptyalin secreted by parotid glands.
   ii. It converts starch into disaccharide maltose and other small polymer of glucose.

$$\text{Starch} \xrightarrow{\text{Ptyalin}} \text{Maltose and other glucose polymers.}$$

b. **In the stomach**
   i. Here the pH of the secretion is falls and activity of salivary amylase enzymes is blocked.
   ii. However, the starch digestion is still continuing for around 1 hr before the food become mixed with stomach secretion.

c. **In the small intestine**
   i. At this stage, almost all starches are converted into maltose and small glucose polymers.
   ii. In duodenum, they are mixed with pancreatic alpha amylase, which digest the rest of the carbohydrates.

d. **Membrane digestion**

Here, enzymes hydrolyze all the disaccharides into glucose and other basic elements.

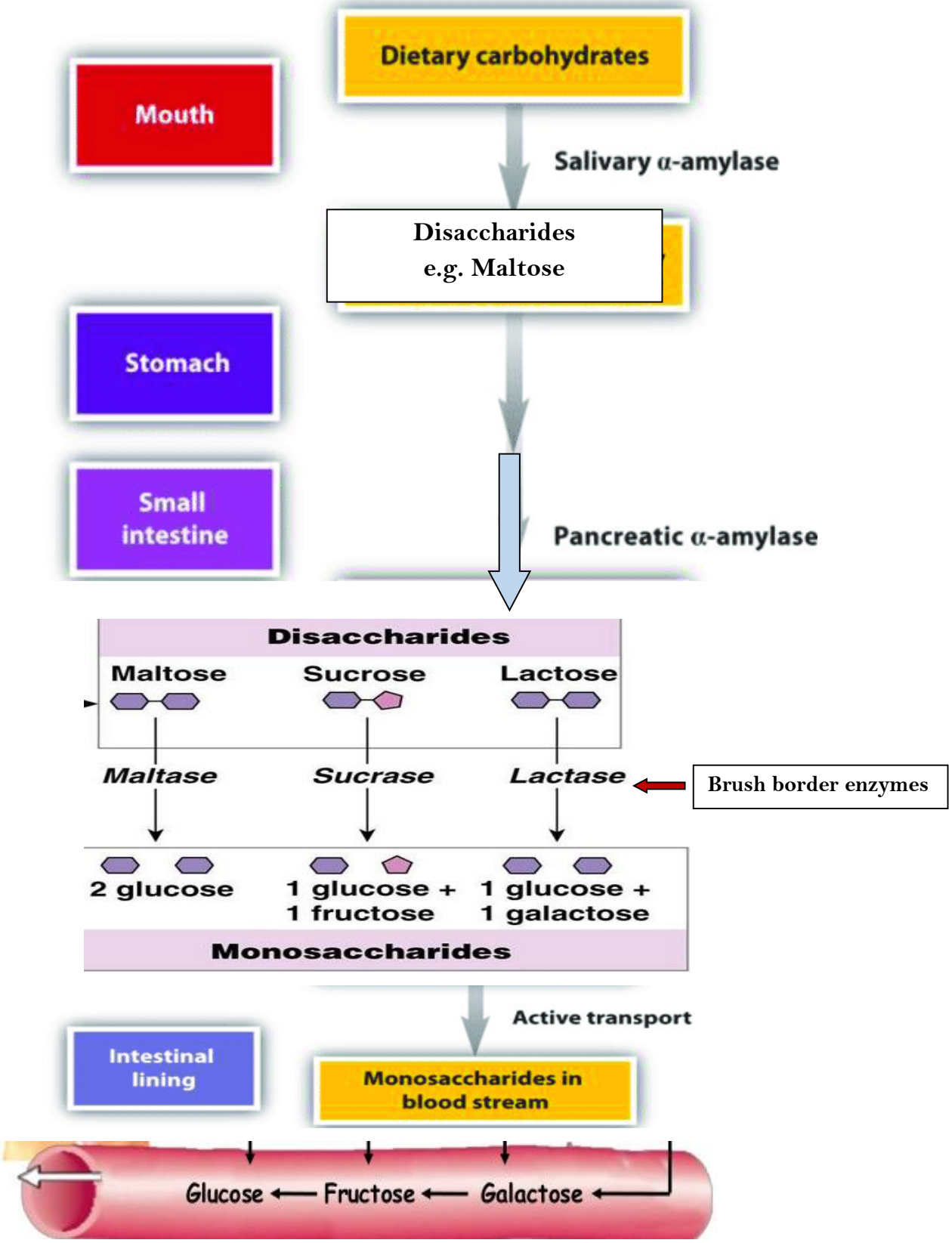
2. Absorption

a. Absorption of Glucose and galactose

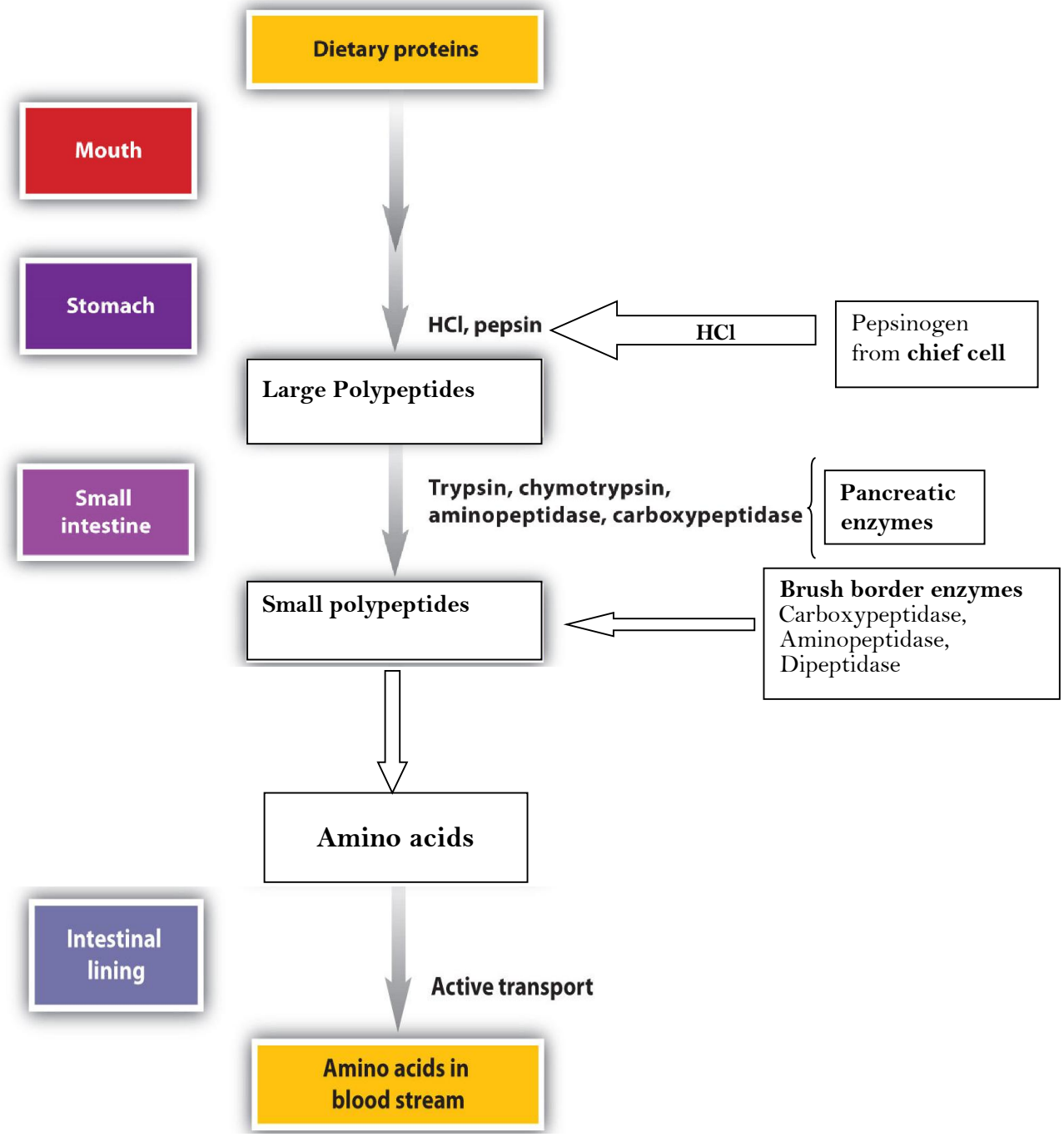
Glucose and galactose are absorbed at intestine with the help of Na-co transport carrier. They are found at the brush border of intestinal epithelial cells. Na+ ion is attached with the receptor site of transporter and along with glucose they are transported out of the intestine. From there, glucose is transported into blood stream by facilitated diffusion.

b. Absorption of fructose

Fructose does not couple with the Na transport. On entering into cell, it is phosphorylated and converted into glucose. Finally, it is absorbed by the same Na transporter system.


Dietary carbohydrates
Mouth
Salivary α-amylase
Disaccharides
e.g. Maltose
Stomach
Small intestine
Pancreatic α-amylase
Disaccharides
Maltose
Sucrose
Lactose
Maltase
Sucrase
Lactase
Brush border enzymes
2 glucose
1 glucose + 1 fructose
1 glucose + 1 galactose
Monosaccharides
Active transport
Intestinal lining
Monosaccharides in blood stream
Glucose
Fructose
Galactose

Protein Digestion



Absorption of proteins Amino acids enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.

The dietary proteins are found of long chains of amino acids bound together by peptide linkages. The digestion of protein at different part of GIT is described below:

i. In the mouth

No protein is digested in mouth.

ii. In the stomach

In the presence of pepsin and gastric HCl only 10-20% proteins are digested into proteoses, peptones and few polypeptides.

iii. In the duodenum

Here, through the pancreatic juice, trypsin and chymotrypsin digest broken and unbroken proteins into amino acid polypeptides. Finally, the aminopolypeptidase and several dipeptidase digest the rest of the amino acid polypeptide into small amino acids.

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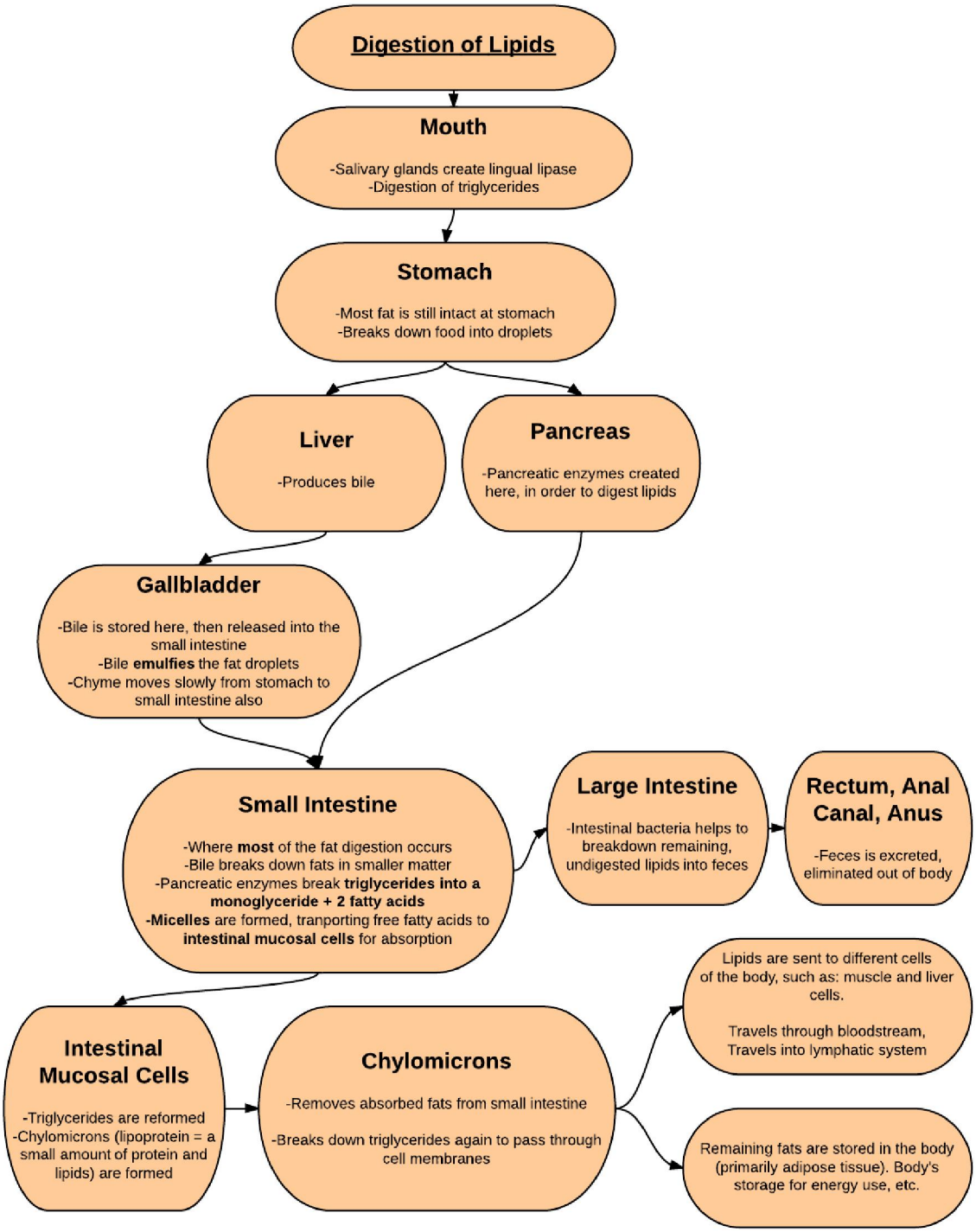
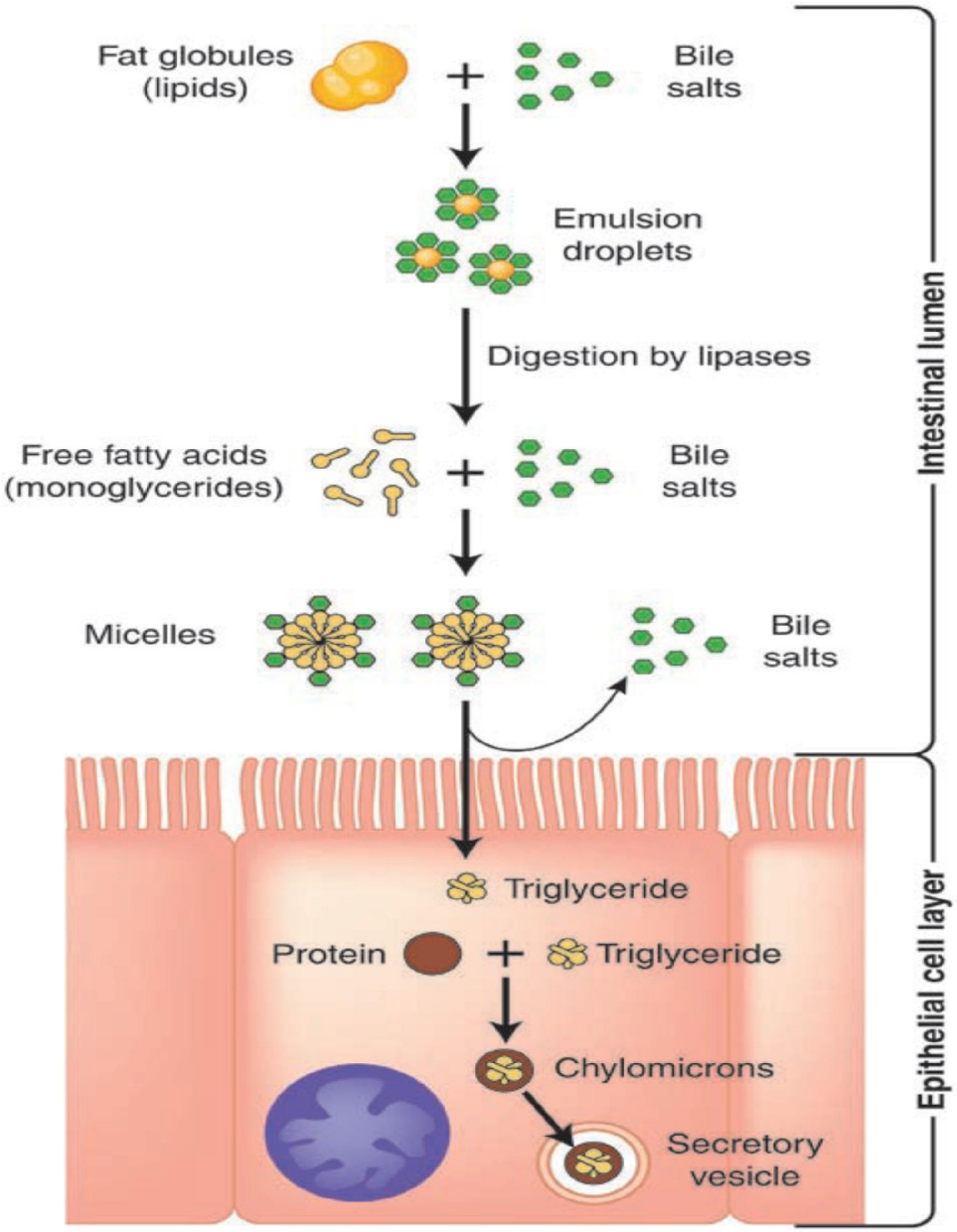
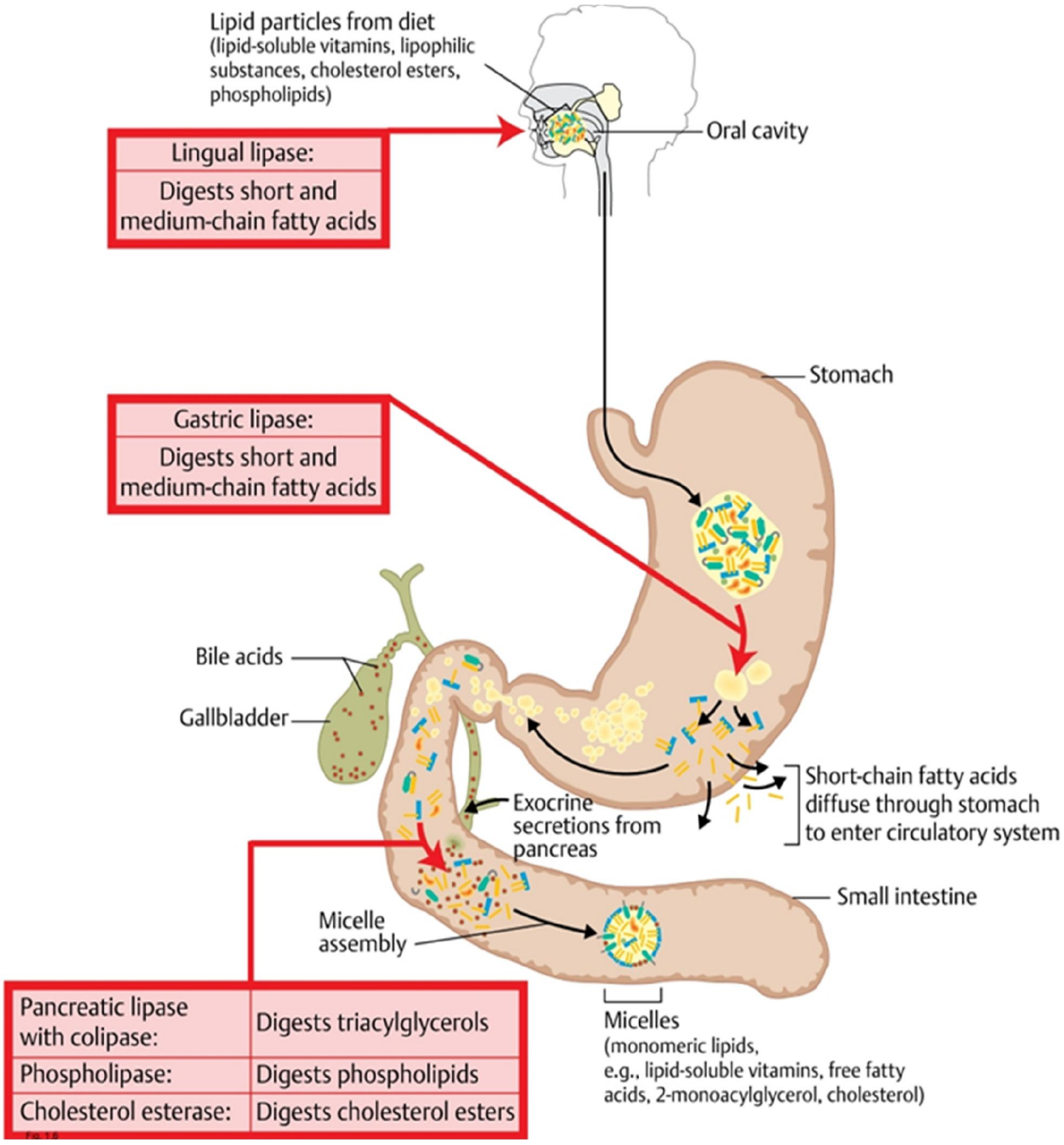
 # Fat Digestion:

Triglycerides are the most abundant fats of the diet. Besides this, phospholipids, cholesterol and cholesterol esters are also present.

1. In the mouth: No digestion of fat occurs in mouth.
2. In the stomach: With the help of gastric lipase (fat splitting enzyme), fat may be digested at stomach but at the condition of basic media. Besides this, fat may be also digested by lingual lipase at stomach but with less than 10% in amount.
3. In the intestine: The main digestion of fat occurs in the duodenum and small intestine by pancreatic lipase with the help of bile salts. Bile salts at first emulsified the fat globules and broken them into simple form and increases the surface area of fat globules. Then enzyme lipase act on the surface of fat globules and splits into free fatty acids and monoglycerides.


Digestion of Lipids
Mouth
-Salivary glands create lingual lipase
-Digestion of triglycerides
Stomach
-Most fat is still intact at stomach
-Breaks down food into droplets
Liver
-Produces bile
Pancreas
-Pancreatic enzymes created here, in order to digest lipids
Gallbladder
-Bile is stored here, then released into the small intestine
-Bile emulfies the fat droplets
-Chyme moves slowly from stomach to small intestine also
Small Intestine
-Where most of the fat digestion occurs
-Bile breaks down fats in smaller matter
-Pancreatic enzymes break triglycerides into a monoglyceride + 2 fatty acids
-Micelles are formed, tranporting free fatty acids to intestinal mucosal cells for absorption
Large Intestine
-Intestinal bacteria helps to breakdown remaining, undigested lipids into feces
Rectum, Anal Canal, Anus
-Feces is excreted, eliminated out of body
Intestinal Mucosal Cells
-Triglycerides are reformed
-Chylomicrons (lipoprotein = a small amount of protein and lipids) are formed
Chylomicrons
-Removes absorbed fats from small intestine
-Breaks down triglycerides again to pass through cell membranes
Lipids are sent to different cells of the body, such as: muscle and liver cells.
Travels through bloodstream, Travels into lymphatic system
Remaining fats are stored in the body (primarily adipose tissue). Body's storage for energy use, etc.


Fat globules
(lipids)
Bile
salts
Emulsion
droplets
Digestion by lipases
Free fatty acids
(monoglycerides)
Bile
salts
Micelles
Bile
salts
Intestinal lumen
Triglyceride
Protein
Triglyceride
Chylomicrons
Secretory
vesicle
Epithelial cell layer


Lipid particles from diet
(lipid-soluble vitamins, lipophilic substances, cholesterol esters, phospholipids)
Oral cavity
Lingual lipase:
Digests short and medium-chain fatty acids
Stomach
Gastric lipase:
Digests short and medium-chain fatty acids
Bile acids
Gallbladder
Short-chain fatty acids diffuse through stomach to enter circulatory system
Exocrine secretions from pancreas
Small intestine
Micelle assembly
Micelles
(monomeric lipids, e.g., lipid-soluble vitamins, free fatty acids, 2-monoacylglycerol, cholesterol)
Pancreatic lipase with colipase: Digests triacylglycerols
Phospholipase: Digests phospholipids
Cholesterol esterase: Digests cholesterol esters

Comparison Chart:

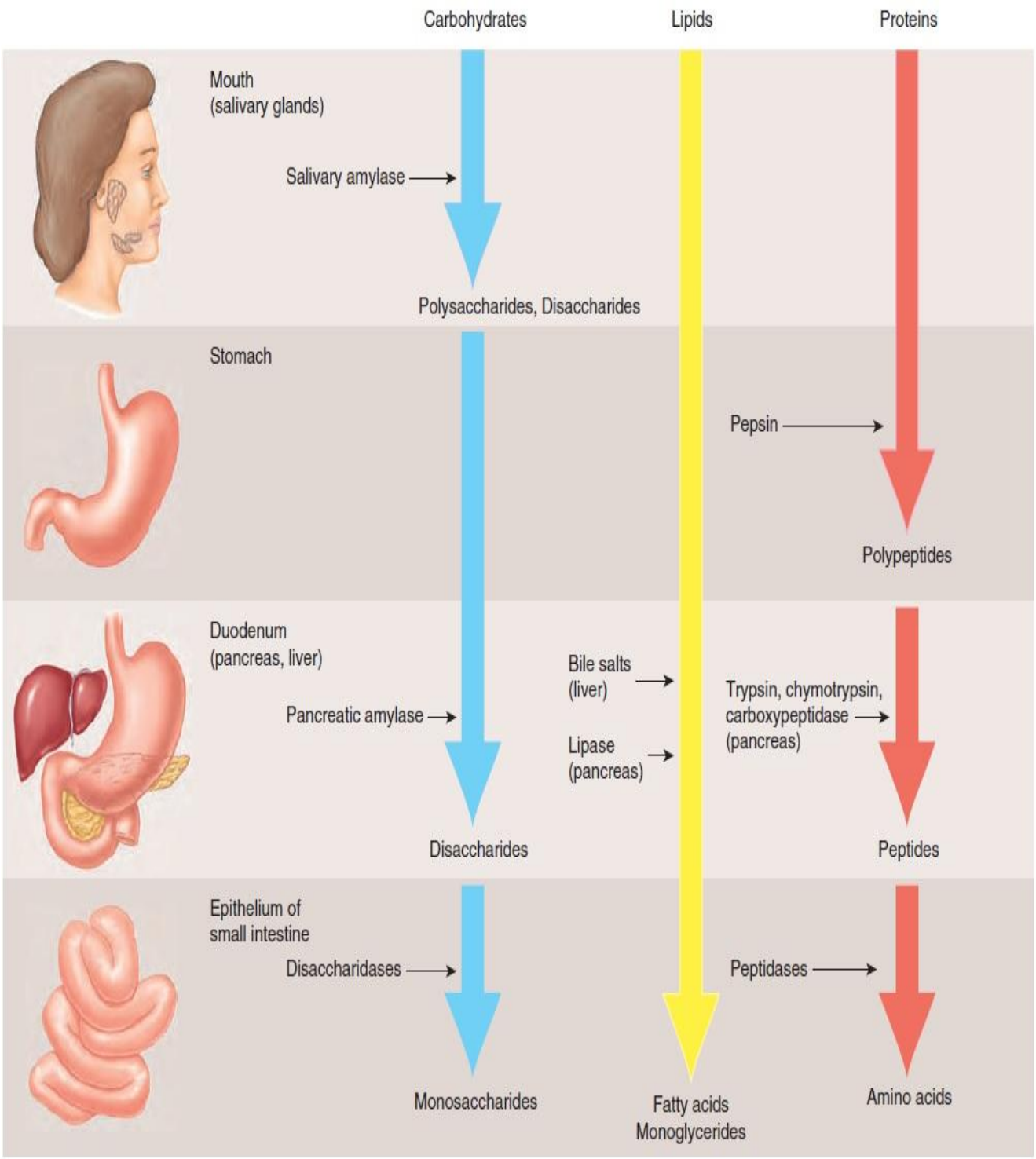
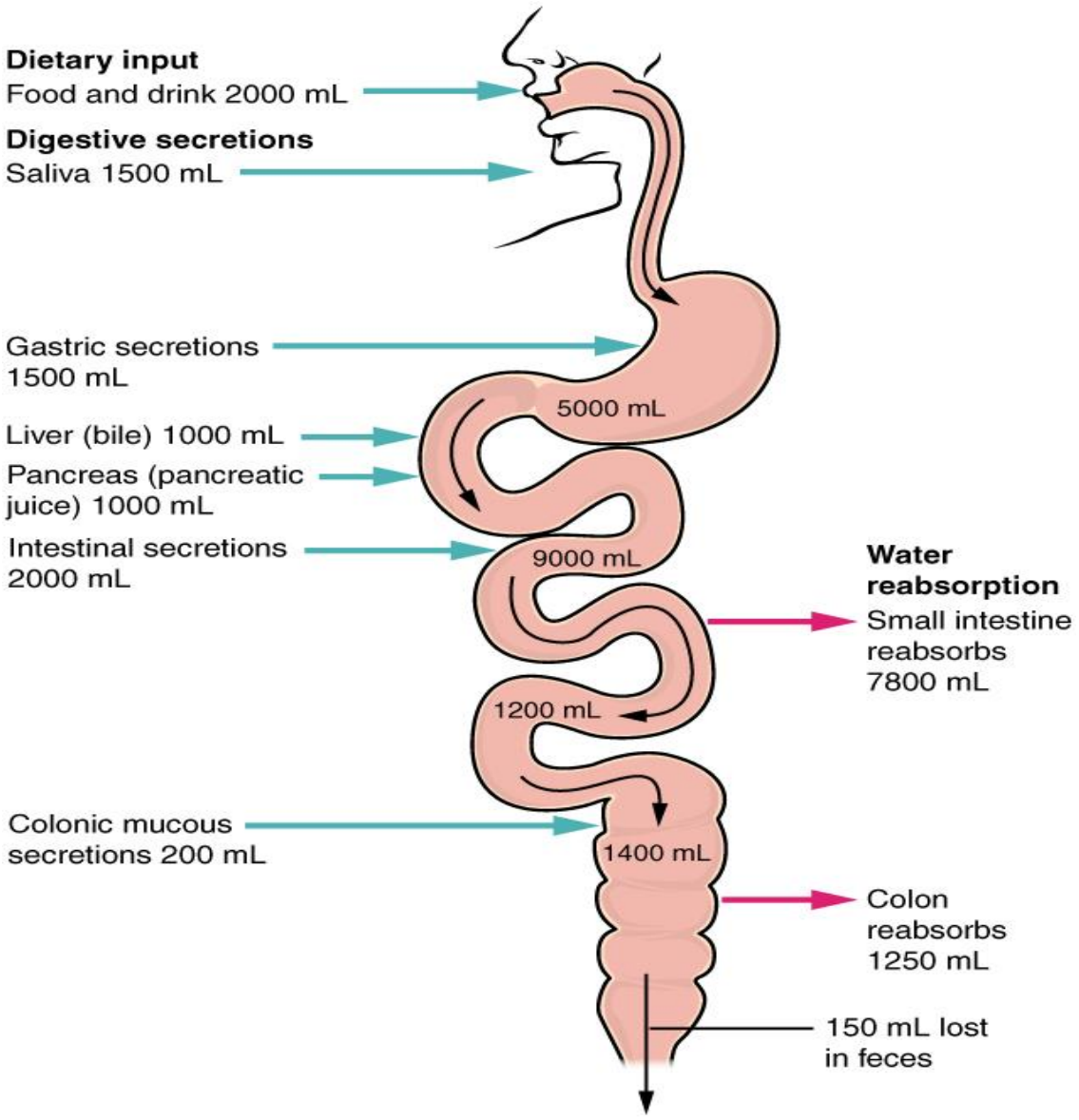


Figure 16.23 Digestion of Carbohydrates, Lipids, and Proteins

The enzymes involved in digesting carbohydrates, lipids, and proteins are depicted in relation to the region of the digestive tract where each functions.



All Birds find shelter
during a rain.
But Eagle avoids rain by
flying above the Clouds.
**Problems are common,
but attitude makes the
difference!**