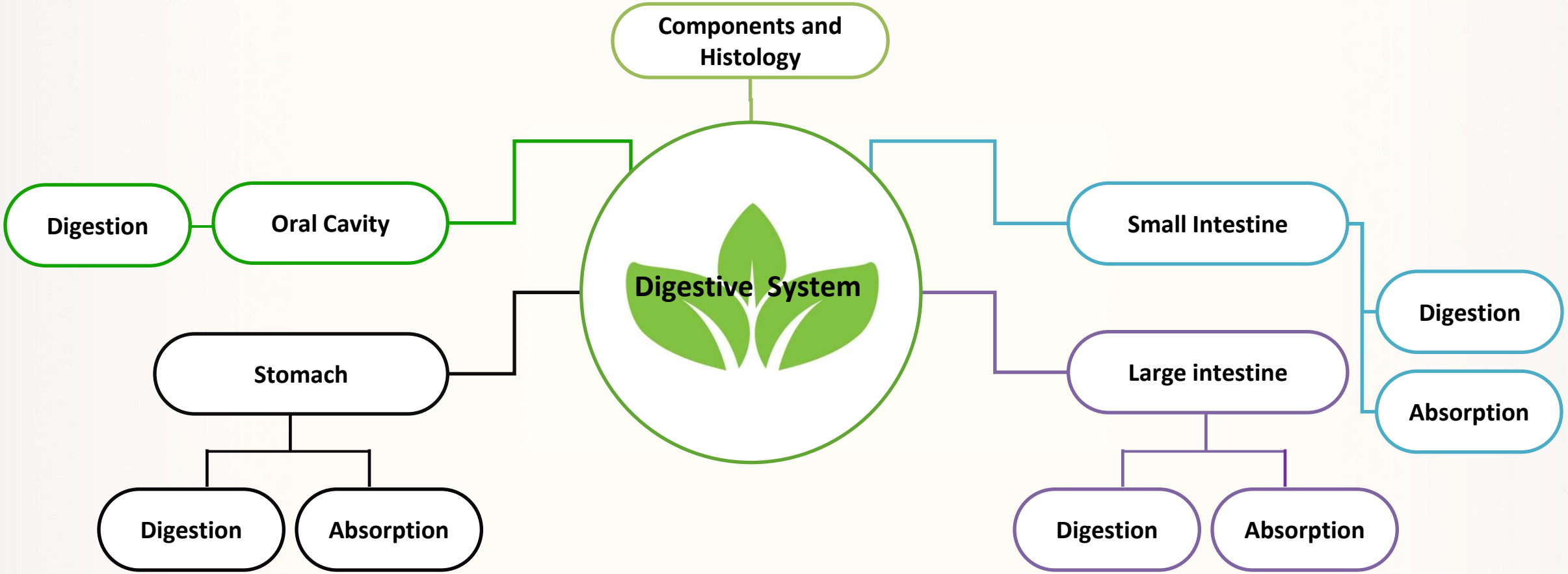
Unit 2 : The Digestive System

Mind Map


Components and Histology
Digestive System
Digestion
Oral Cavity
Stomach
Digestion
Absorption
Small Intestine
Digestion
Absorption
Large intestine
Digestion
Absorption

Preface

What is the function of the digestive system?

Anatomy of the digestive system

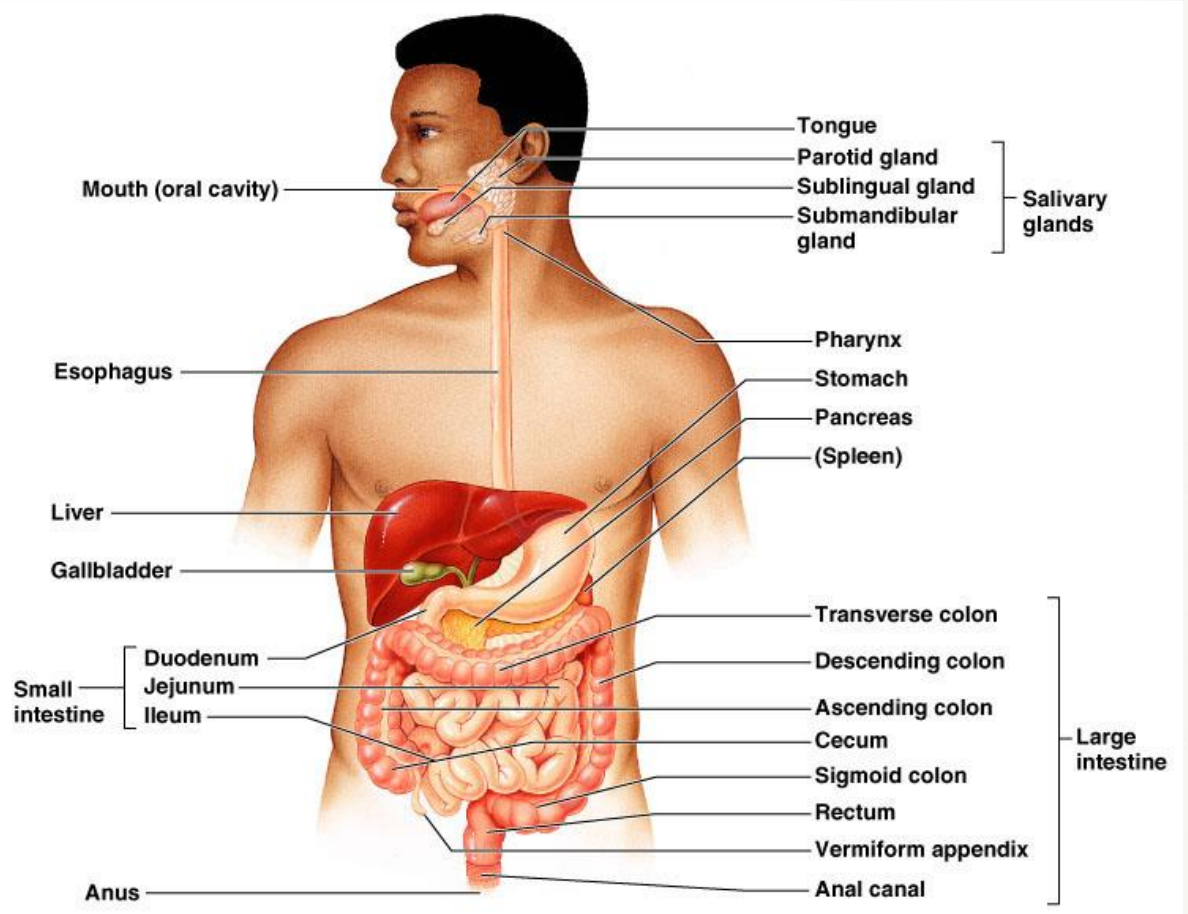
The digestive system organs are separated into two major groups:

- **The alimentary canal or gastrointestinal tract (G.I. tract)**

A hollow tube extending from the mouth to the anus. It consists of the mouth, pharynx, oesophagus, stomach, and small and large intestines.

- **The accessory digestive organs**

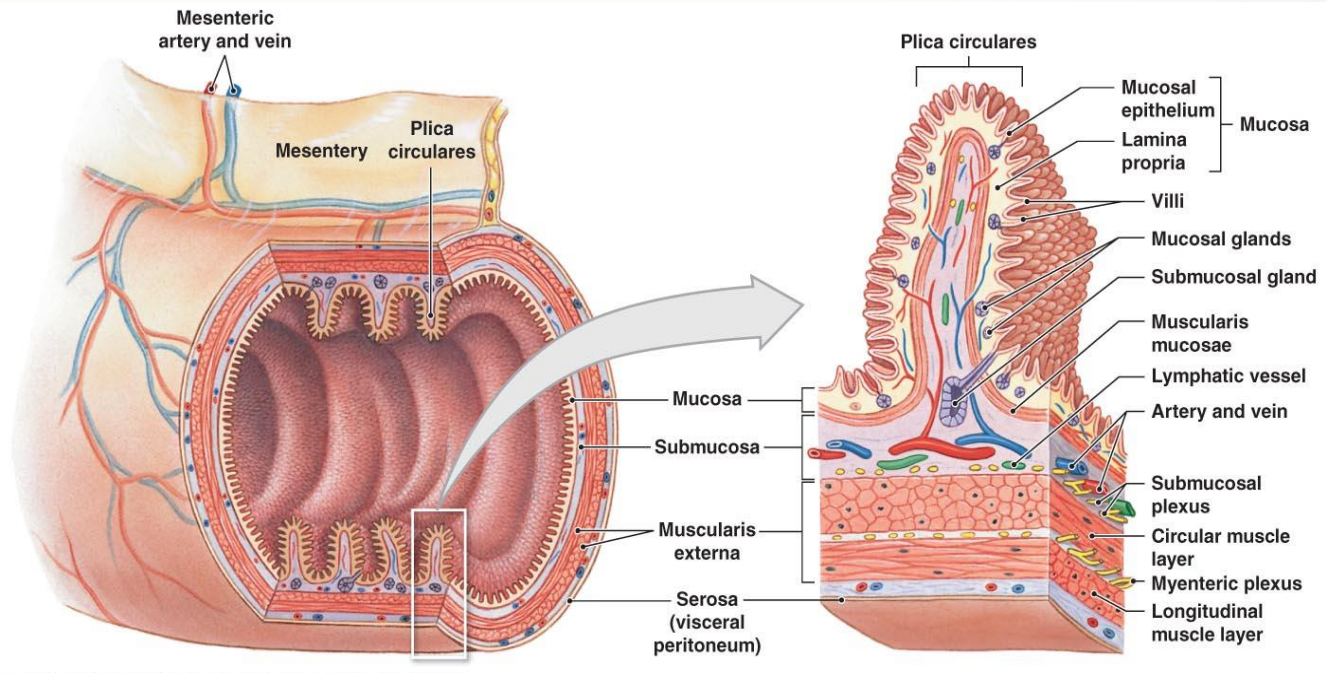
include the teeth, salivary glands, gallbladder, liver, and pancreas.



Histology of the digestive system

The digestive tract wall is made up of 4 layers (From inside to outside):

- **The Mucosa:** This is the inner layer of the tract that actually absorbs food and secretes mucus and digestive enzymes.
- **The Submucosa** is made up of loose connective tissue, blood vessels, glands, and nerves.
- **The Muscular Layer**: this layer is made up of 2 layers of smooth muscle, the inner layer of muscle is circular (I.C.) while the outer layer is longitudinal (O.L.).
- **The Serosa** is the outer most layer of the tube and is primarily composed of serous epithelium and some connective tissue.



The digestive system

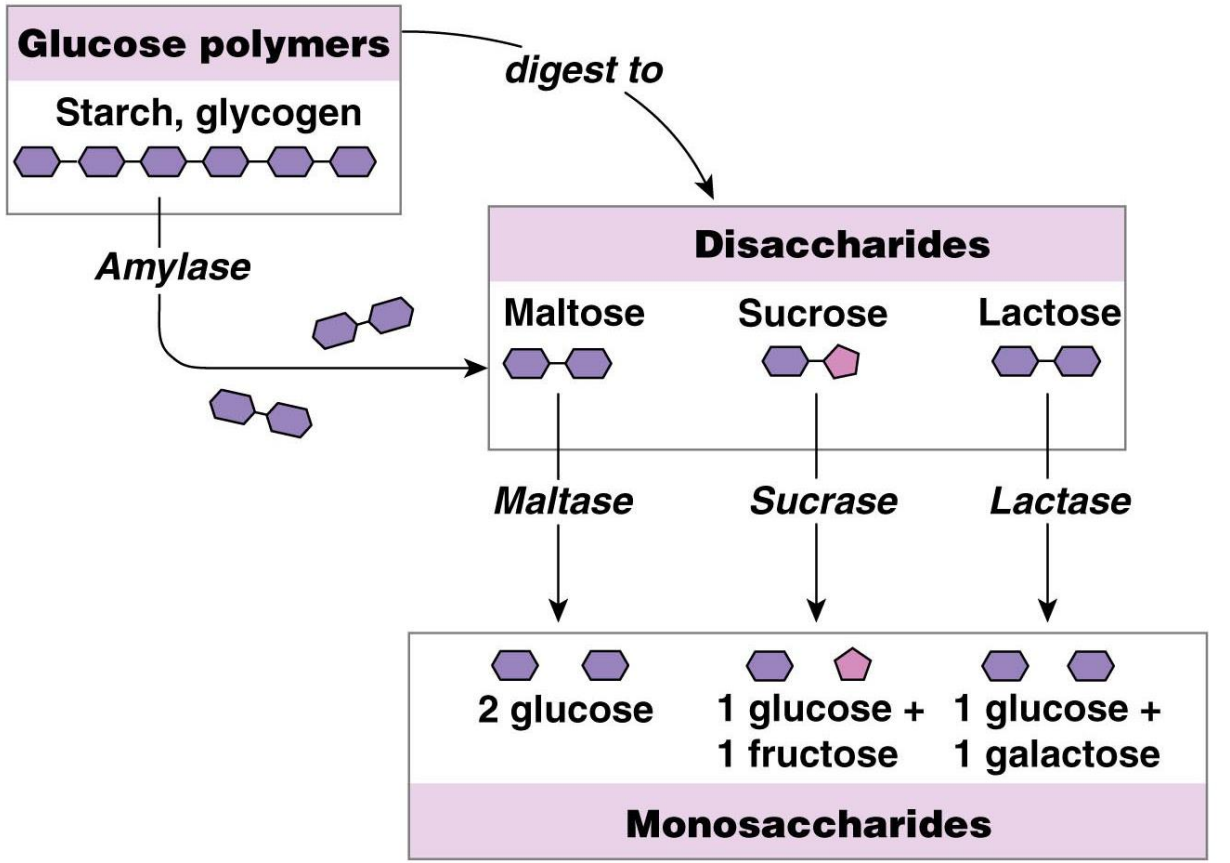
There are four (4) stages of food processing:

- **Food ingestion:** taking in food
- **Digestion:** breaking down food into nutrients
- **Absorption:** taking in nutrients by cells
- **Elimination (Defecation):** removing any leftover wastes.

Digestion of nutrients

Digestion of carbohydrates:

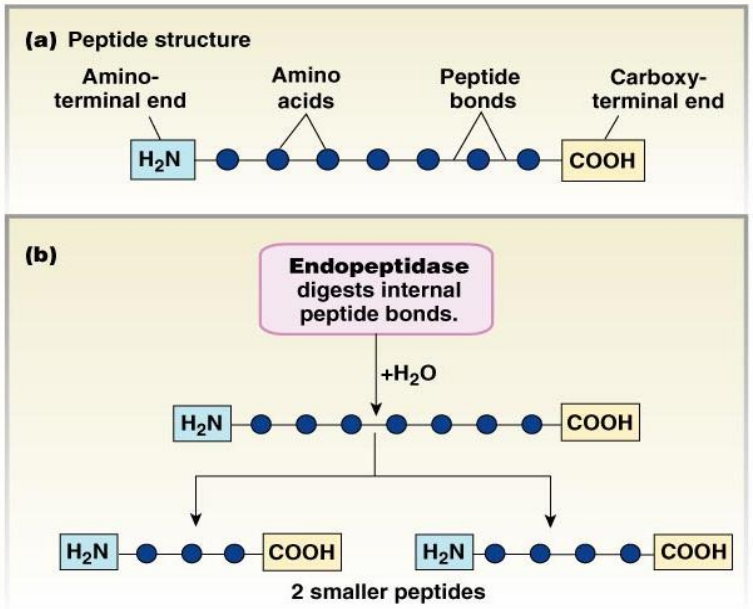
- Breakdown polysaccharides (polymers) into disaccharides (maltose, sucrose, lactose).
- Break off disaccharides into 2 monosaccharaides (mostly glucose)

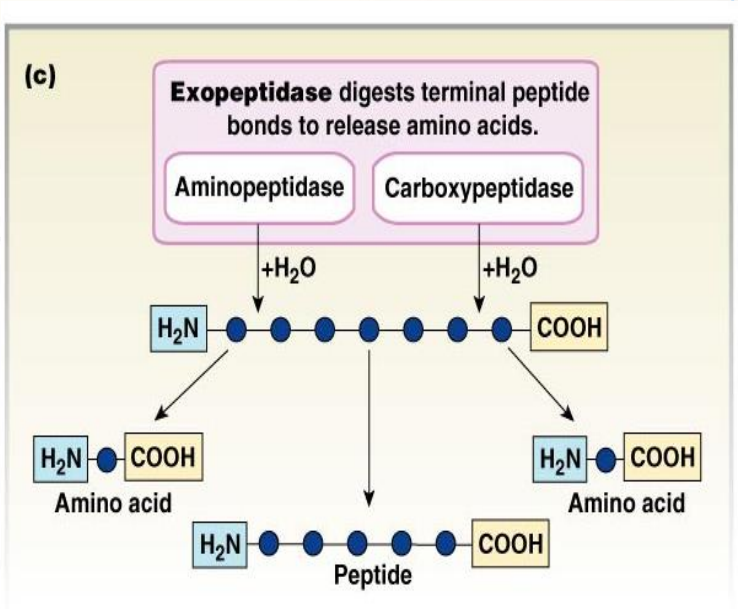


Digestion of nutrients

Digestion of proteins:

- The peptidases digest internal peptide bonds to free smaller peptides.
- The dipeptidases break off the bond between dipeptides to free 2 amino acids.

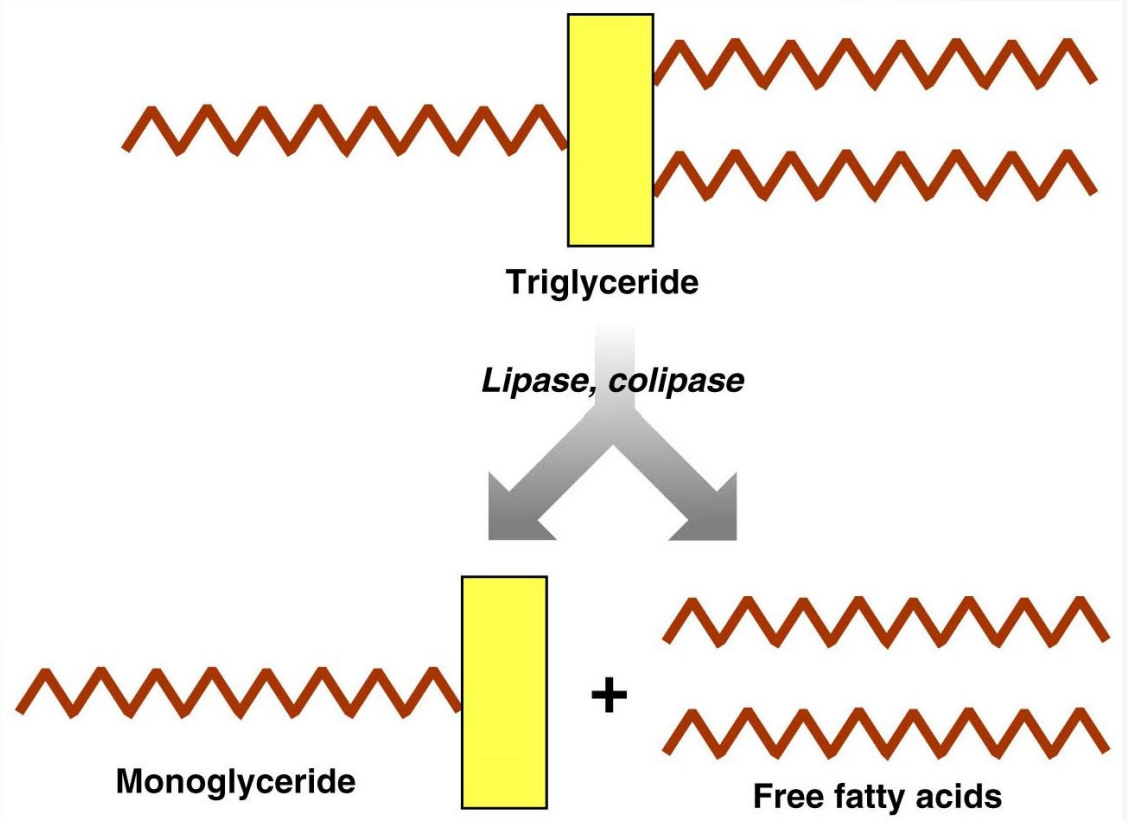




Digestion of nutrients

Digestion of fat:

- Triglycerides digested into monoglycerides and free fatty acids.
- Intestinal lipase breaks off diglycerides into monoglycerides and fatty acids and finally into free fatty acids and glycerol.



The oral cavity

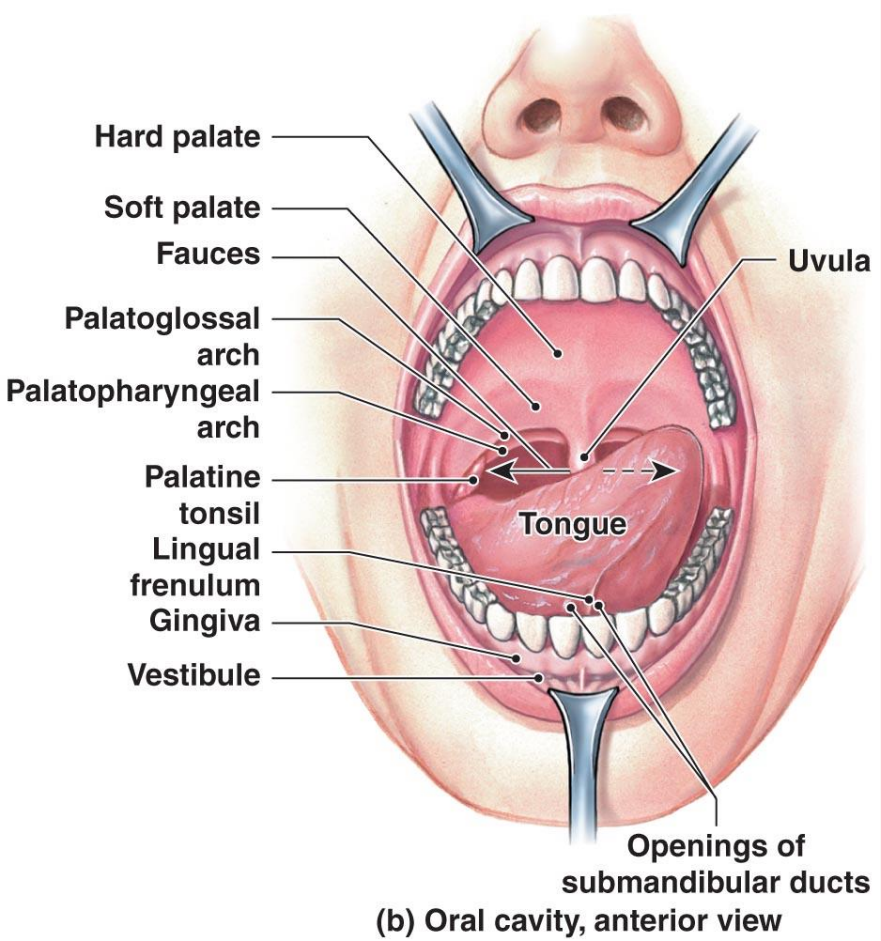
Functions

- **Sensory analysis**

The top of the tongue is covered with structures called papillae which help to handle food and provide the sense of taste of food before swallowing.

- **Lubrication**

Mixing food with mucus and salivary gland secretions.



(b) Oral cavity, anterior view

The oral cavity

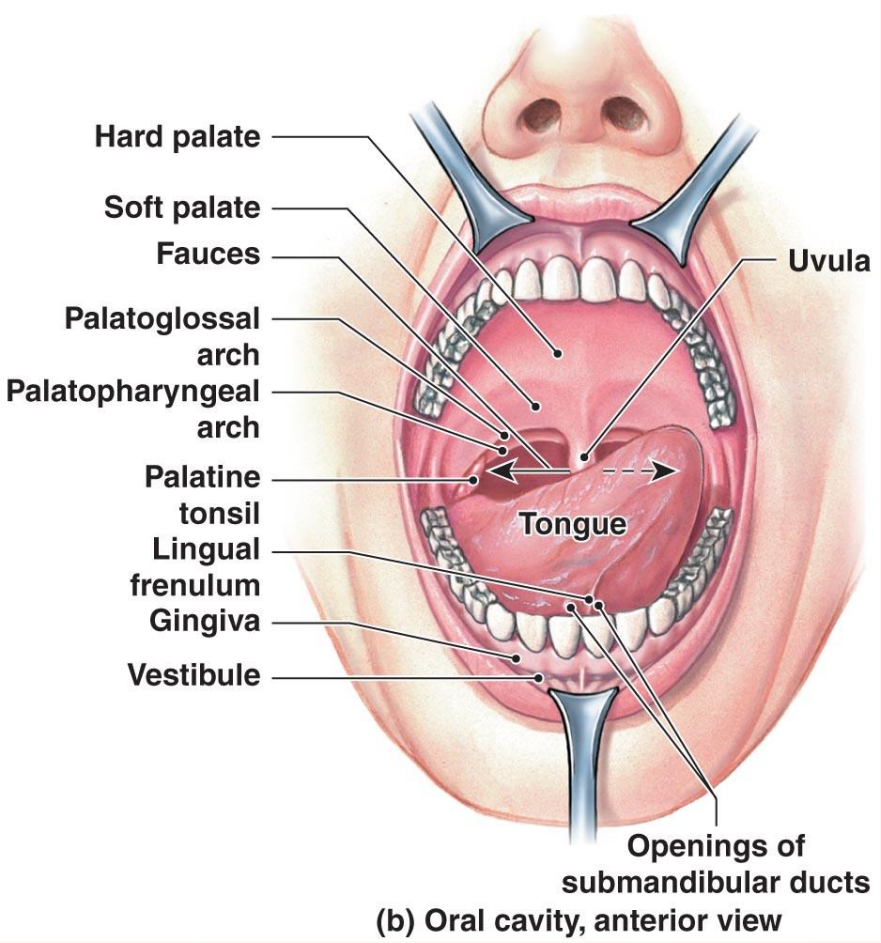
Digestion in the mouth

- **Mechanical processing**

Mechanical digestion begins here with mastication (chewing) through actions of teeth, tongue, and palatal surfaces

- **Chemical digestion**

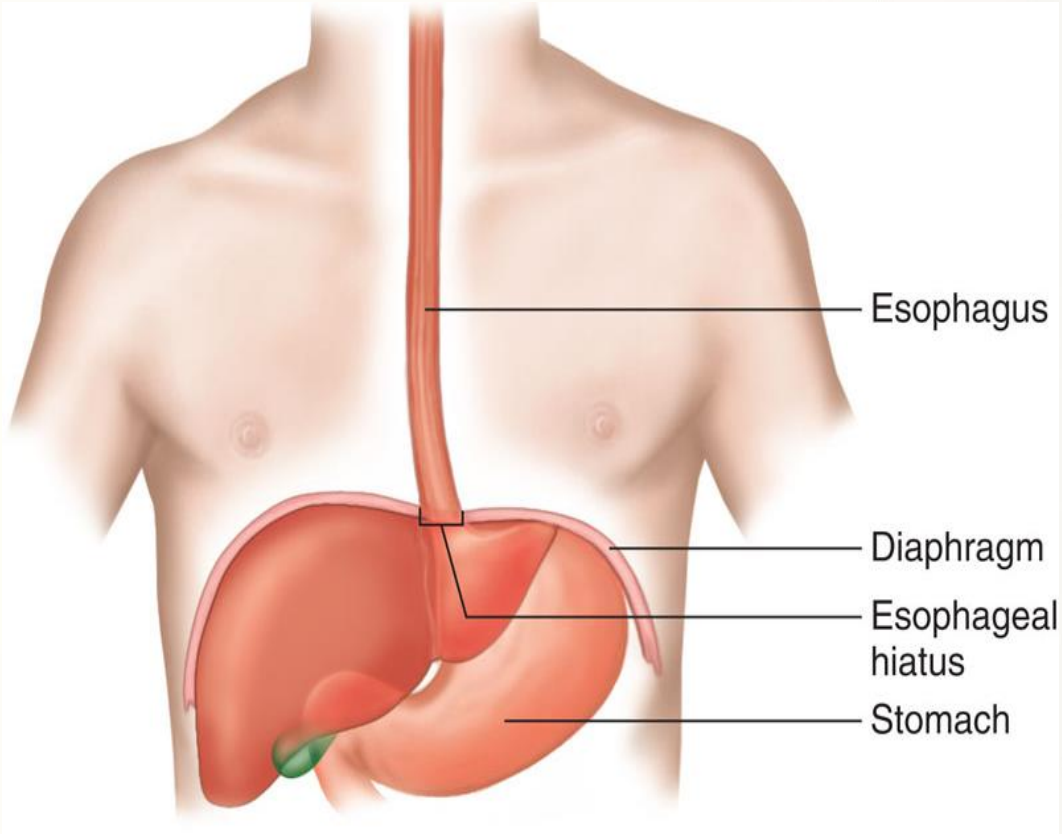
- Salivary amylase, an enzyme in saliva that breaks down carbohydrates (starch) into maltose, maltotriose and alpha dextrins.
- Lingual lipase an enzyme in saliva that breaks down dietary triglycerides.



(b) Oral cavity, anterior view

The esophagus

- A hollow muscular tube, about 25 cm long and 2 cm wide.
- Conveys solid food (bolus) and liquids from the mouth to the stomach
- Begins from the pharynx through the thoracic cavity to the stomach.

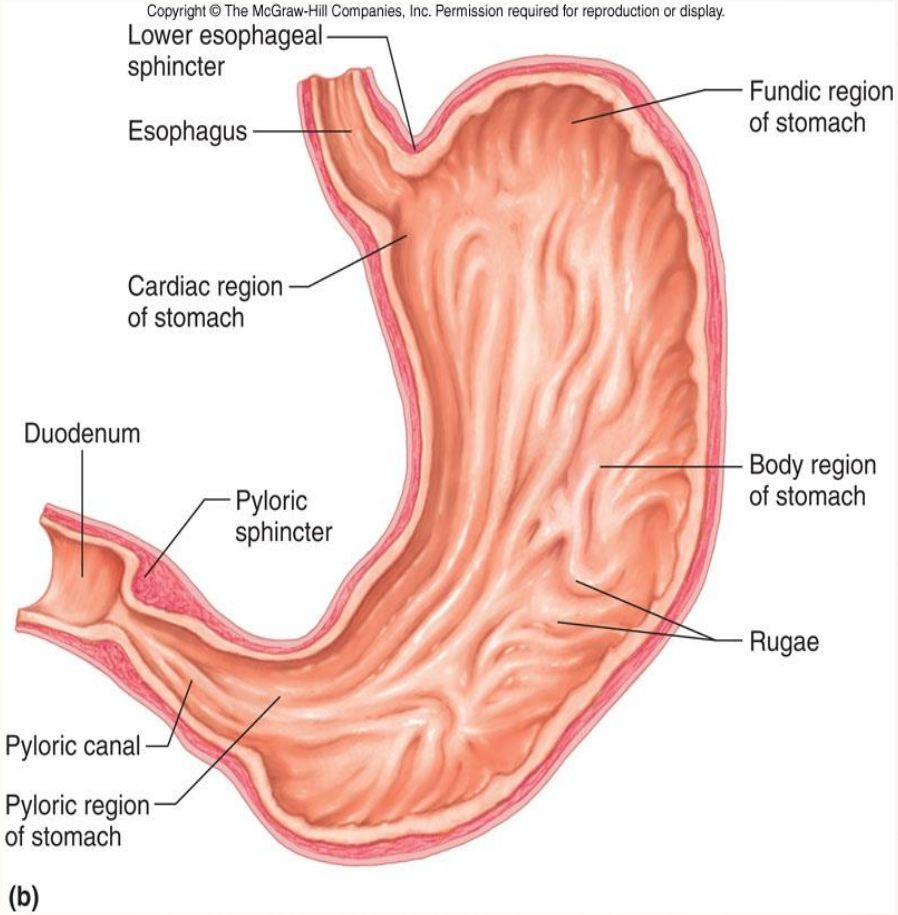


The stomach

Morphology

The Stomach is a curved pouch-like organ that is located in the upper left quadrant of the abdomen. It's divided into 4 regions:

- The **cardiac region** is located just inside the cardiac sphincter.
- The **fundus** is the superior most portion located above the cardiac sphincter.
- The **body region** makes up the bulk of the organ in the middle.
- The **pyloric region** is the inferior most area, just above the Pyloric Sphincter. It consists of antrum and pyloric canal.



The stomach

Functions

The major functions of the stomach are:

- Storage of ingested food
- Mechanical breakdown of ingested food
- Disruption of chemical bonds in food material by acid and enzymes
- Production of intrinsic factor, a glycoprotein required for absorption of vitamin B_{12} in small intestine. Vitamin B12 is necessary for RBCs formation.
- Carrying on a limited amount of absorption.
- Moving food into the small intestine.

Digestion in the stomach

Chemical digestion

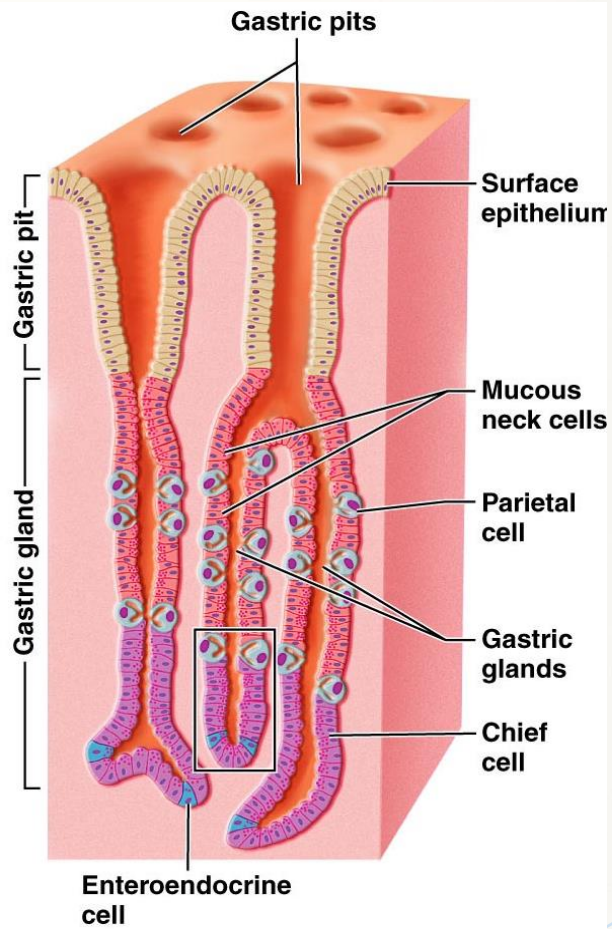
The stomach secretes gastric Juice that has a very low pH (2-3). This juice is the secretion of 3 types of exocrine gland cells:

- **Parietal cells** that secrete intrinsic factor for B12 absorption and secrete HCl that:
  - kills microbes, denatures proteins
  - causes some acid hydrolysis of food molecules
  - stimulates secretion of hormones for bile (CCK) & pancreatic juice flow (Secretin).
- **Chief cells** that produce:

-Pepsinogen (inactive form of pepsin, which becomes active in presence of HCl). The pepsin cleaves proteins into smaller peptides.

-Rennin an enzyme in neonates: curdles milk to increase time for gastric processing.

-Gastric lipase in neonates: splits short chain triglycerides common in milk

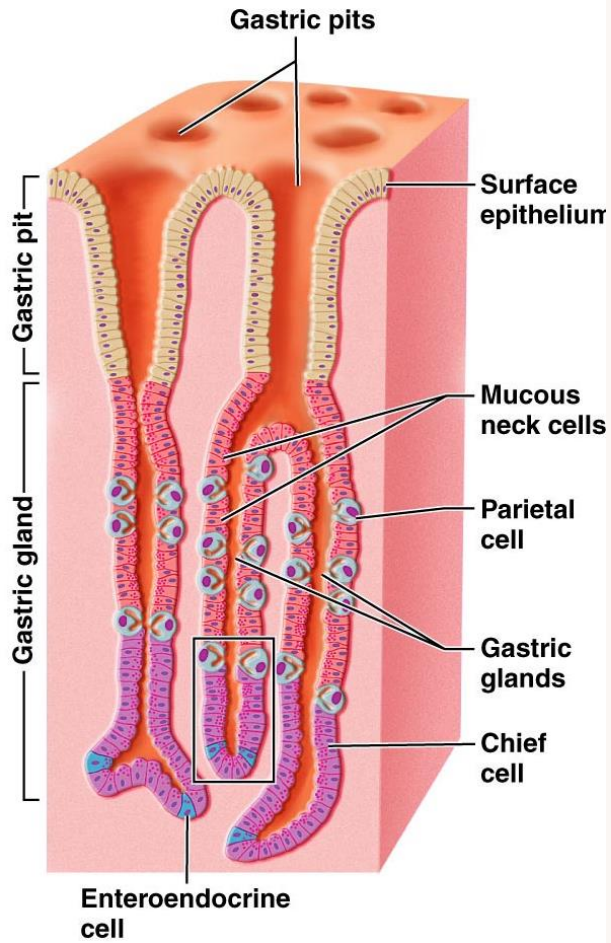


Digestion in the stomach

Hormone	Secreted By	Target	Effects on Motility	Stimulus for Release	Release Inhibited by
Gastrin	G cells in stomach (Pyloric region)	parietal cells	Enhance stomach motility	Peptides and amino acids in lumen; gastrin releasing peptide and Ach in nervous reflexes	pH<1.5; somatostatin
CCK	Endocrine cells of small intestine; neurons of brain and gut	Gallbladder, pancreas, gastric smooth muscle	Stimulates gallbladder contraction for bile release; inhibits gastric emptying; promotes intestinal motility	Fatty acids and some amino acids	Somatostatin
Secretin	Endocrine cells in small intestine	Pancreas, stomach	Inhibits gastric emptying	Acid in small intestine	Somatostatin
Gastric Inhibitory Peptide (GIP)	Endocrine cells in small intestine	Beta cells of endocrine pancreas	Mild effect in lowering stomach motility. Lowering emptying of food to duodenum.	Glucose, fatty acids, and amino acids in small intestine	NA
Motilin	Endocrine cells in small intestine	Smooth muscle of antrum and duodenum	Stimulates migrating motor complex	Fasting: periodic release every 1.5-2 hours by neural stimulus	NA

Absorption in the stomach

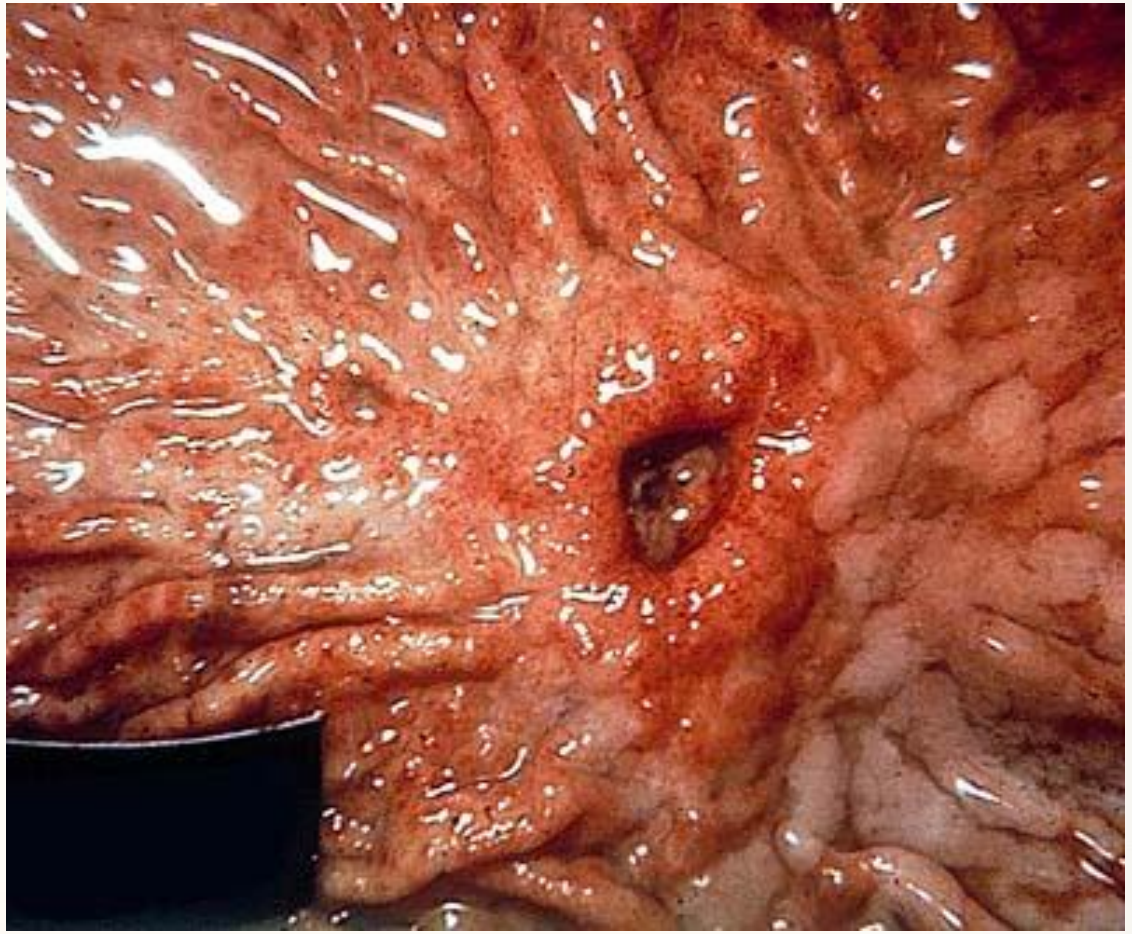
- Impermeable to diffusion of most molecules into the bloodstream.
- Absorbs a few lipid soluble compounds:
  - Certain drugs (e,g., aspirin)
  - Alcohol
  - Water, ions



Disorders of the stomach

Gastric ulcers: erosion of stomach wall.

- pain occurs 1-3 hrs after eating
- 90% of recurrent ulcers due to bacterial infection (*Helicobacter pylori*), which destroys mucous protective barrier; use antibiotic therapy to kill bacteria.



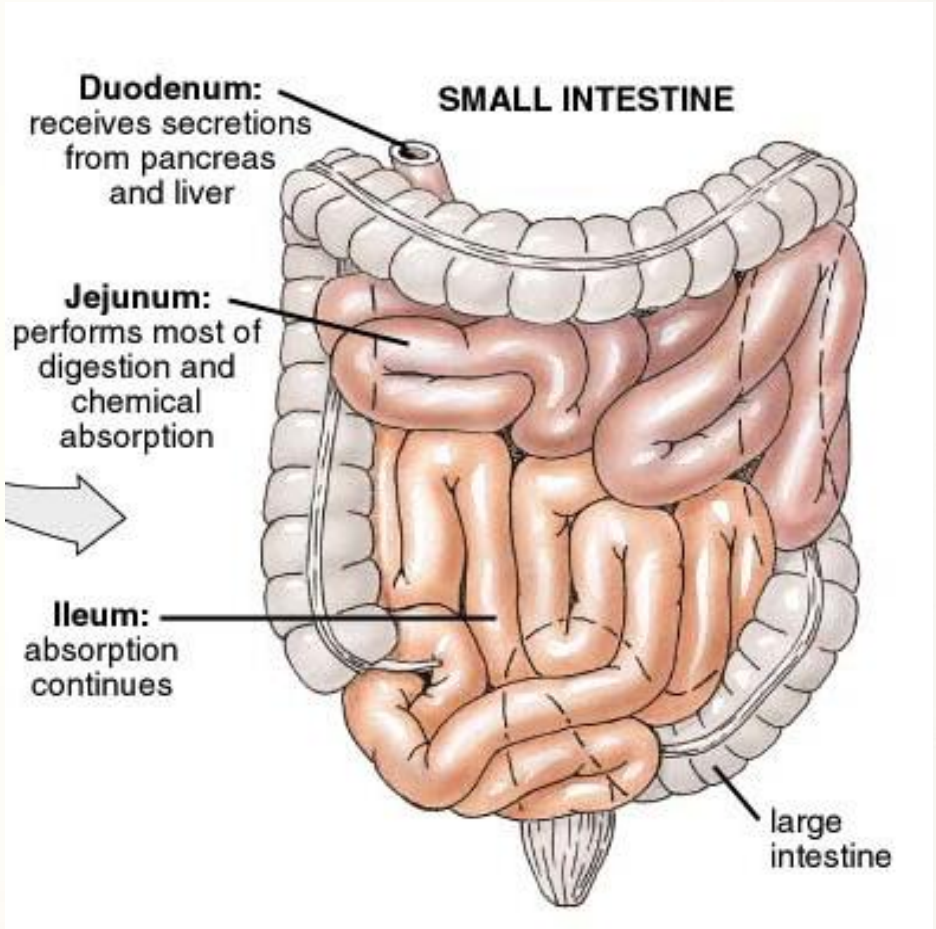
The small intestine

Anatomy

- The Small Intestine is a tubular organ that extends from the pyloric sphincter to the Large Intestine.
- The most active region for both digestion and absorption is the small intestine.

This organ is divided into three parts:

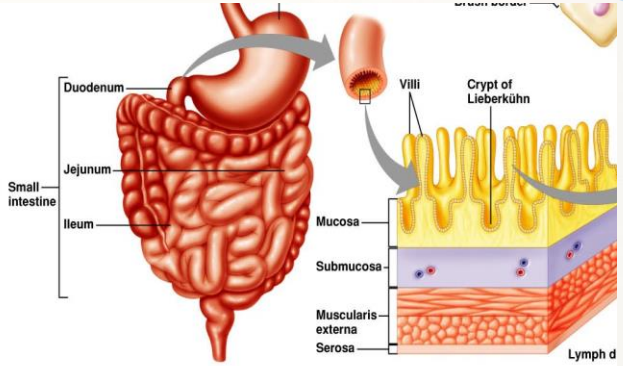
- **The duodenum** is the proximal most portion and receives secretions from both the pancreas and the liver.
- **The Jejunum** is usually larger in diameter than the ileum and more vascular.
- **The Ileum** is the longest distal portion of this organ and is usually less active than the jejunum.

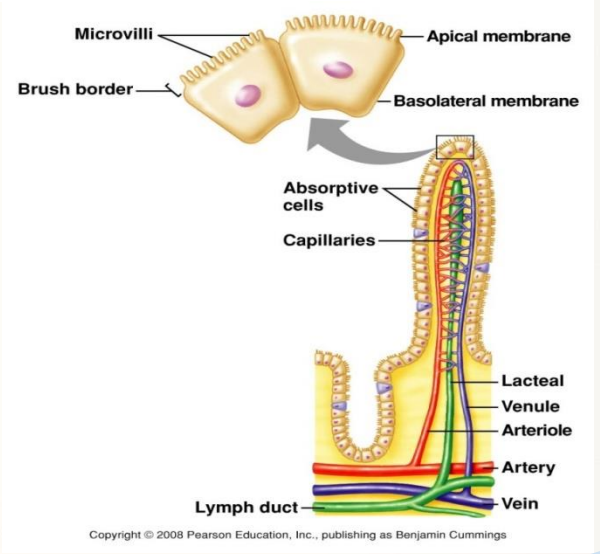


The small intestine

Histology

- The interior lining of the intestinal wall are covered by numerous Villi.
- These structures project into the lumen of the intestine and greatly increase the absorptive capacity of this organ (structure fits function).
- Each villus is made up of a layer of epithelium and a core of connective tissue containing blood capillaries, nerve fibers, and a lymphatic Lacteal.
- At their free surface the epithelial cells have many fine extensions called Microvilli that form what is known as the "Brush Border" that further enhances digestion and absorption.
- The capillaries (monosaccharaides and AAs) and lacteals (FAs and glycerol) carry absorbed nutrients into general circulation.

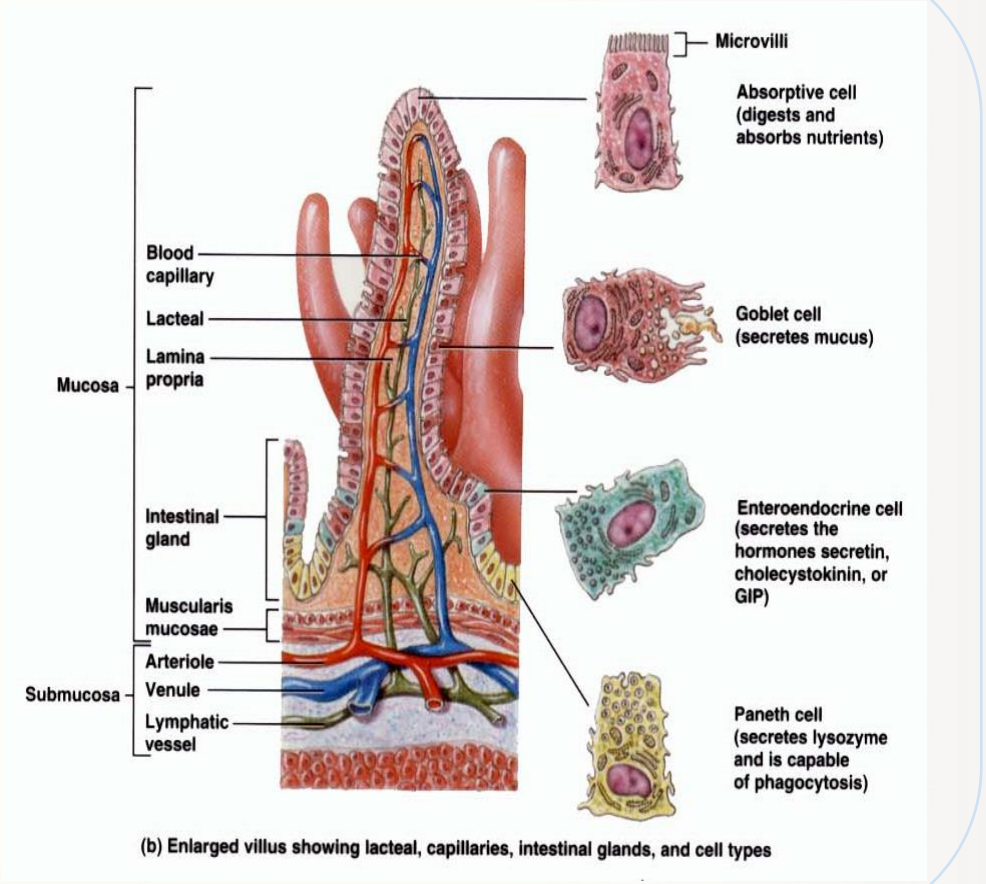




Digestion in the small intestine

The duodenum

- The duodenum is the first section of the small intestine and has a thicker layer of tissue than the other areas of the small intestine.
- It neutralizes stomach acids and breaks down carbohydrates and fats.
- Receive juices from pancreas, liver and its own wall:
  - Peptidases (or dipeptidases) break off the bond between dipeptides to free 2 amino acids
  - Disaccharides: break off disaccharides into 2 monosaccharides (mostly glucose)
  - Intestinal lipase breaks off diglycerides into monoglycerides and fatty acids.
  - Nutrients are completely degraded into forms that can be absorbed by cell

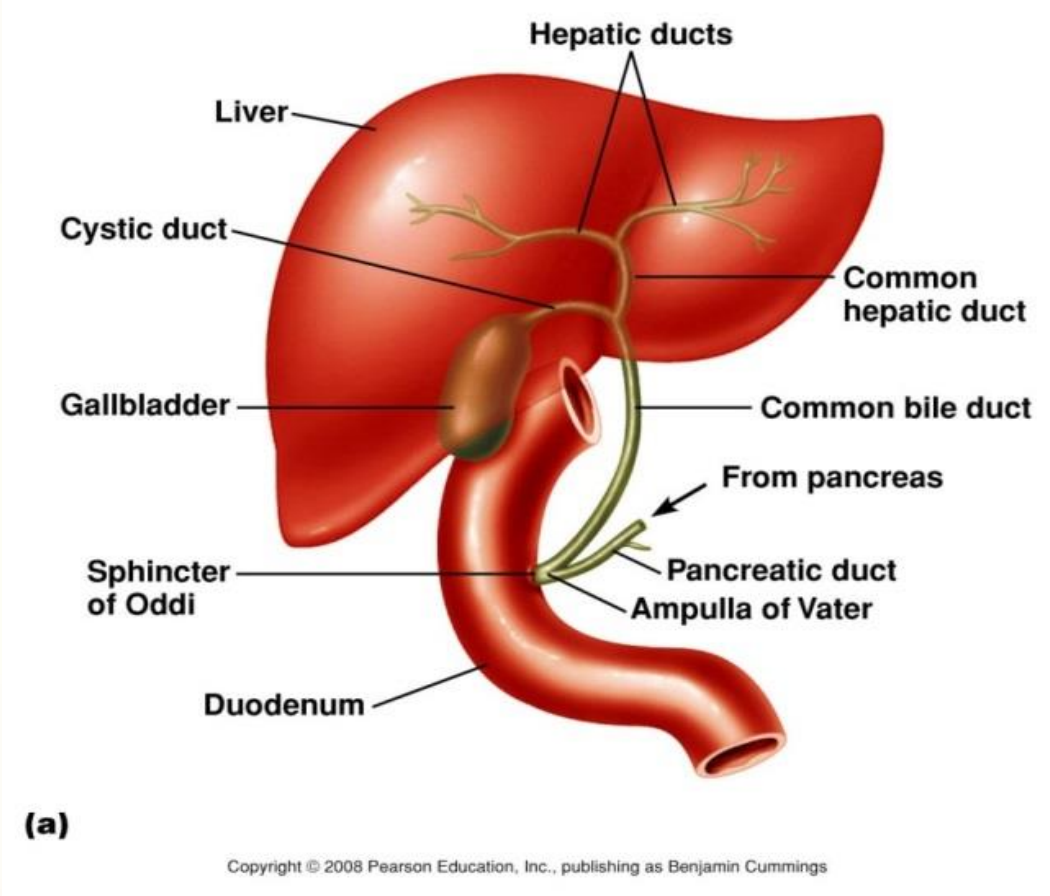


(b) Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types

Digestion in the small intestine

The liver

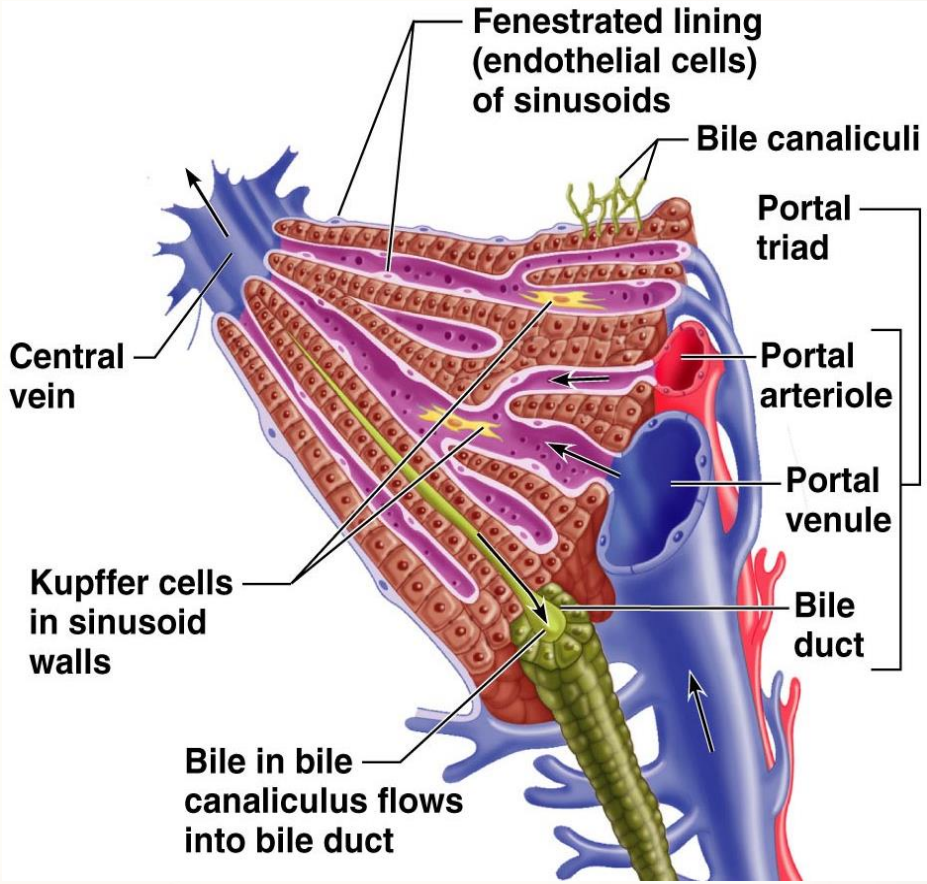
- The liver is the largest of all internal organs.
- is enclosed by a fibrous capsule and divided into a right and left lobe. Two minor lobes also exist. They are the caudate lobe and the quadrate lobe.
- Blood from digestive tract, carried in the portal vein brings newly absorbed nutrients into the sinusoids of the liver. Here blood is cleansed of impurities and microbes by Kupffer Cells (phagocytosis).



Digestion in the small intestine

The liver functions

- Storage – oil-soluble vitamins (A, D,E,K), B12, iron, other nutrients and minerals
- Remove wastes from the body, notably dietary toxins, hormones, drugs, old RBCs.
- Metabolize thyroid and steroid hormones
- Make bile (500-1000 ml/day)
- Activation of Vitamin D (?)
- Metabolism of CHO, protein and fat
- Pathologies of the liver: hepatitis (viral, toxic), cirrhosis, cancer



Digestion in the small intestine

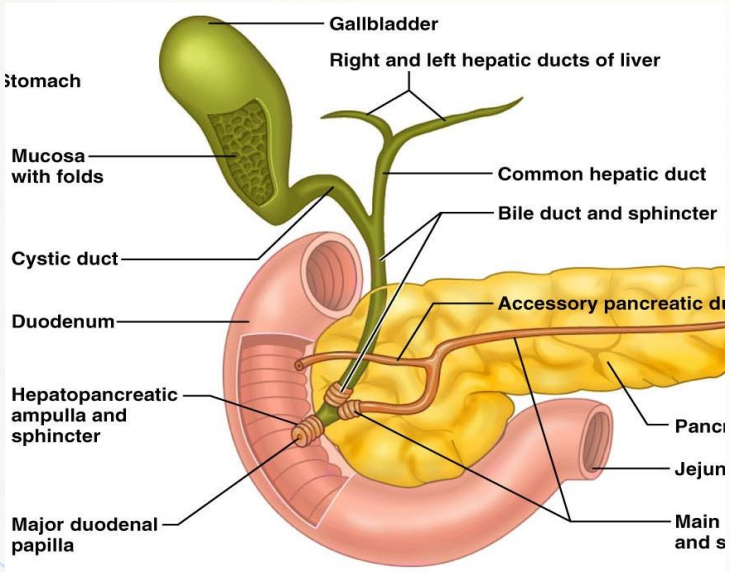
The liver functions

- **Carbohydrate metabolism**: regulates blood glucose levels
  - glycogenesis (insulin)
  - glycogenolysis (glucagon)
  - gluconeogenesis (glucagon): Formation of glucose from non-CHO sources during fasting.
- **Lipid metabolism**
  - stores, metabolizes some triglycerides
  - synthesizes new cholesterol
  - degrades excess cholesterol for bile salt production
- **Protein metabolism**
  - deaminates AA's by removing amino groups ($-NH_2$) from AA's (This is the first step of AA metabolism)
  - detoxifies ammonia (NH_3) by synthesizing urea (1 CO_2 + 2 NH_3 = urea)(This is called urea cycle)
  - can convert AA's from one to another (transamination)
  - synthesizes and secretes most plasma proteins (e.g. albumin, alpha and beta globulins, fibrinogen,.....etc).

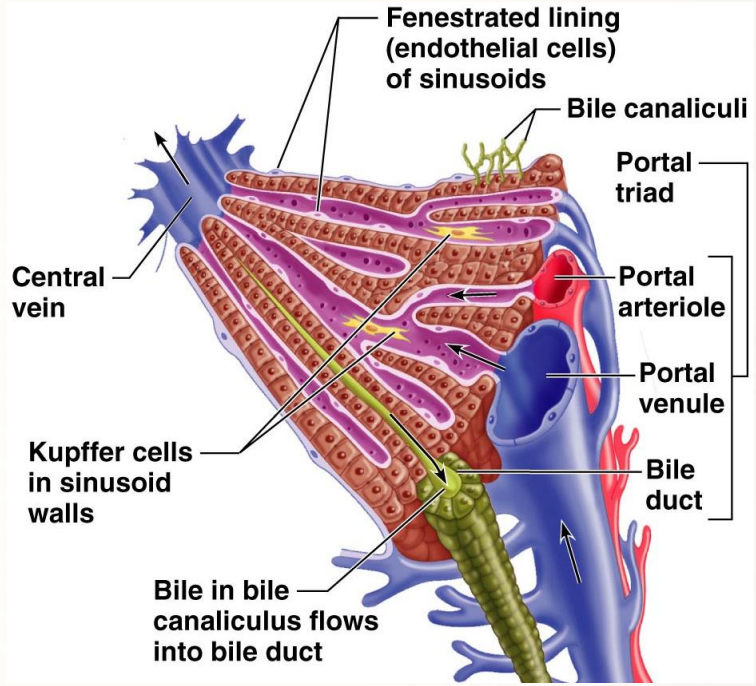
Digestion in the small intestine

Bile secretion by the liver

- Bile is a yellow-green liquid that is continuously secreted by the liver (hepatocytes). It is then stored in the gallbladder until needed.
- Bile from the hepatocytes enters bile (canaliculi) which empty into small bile ducts.



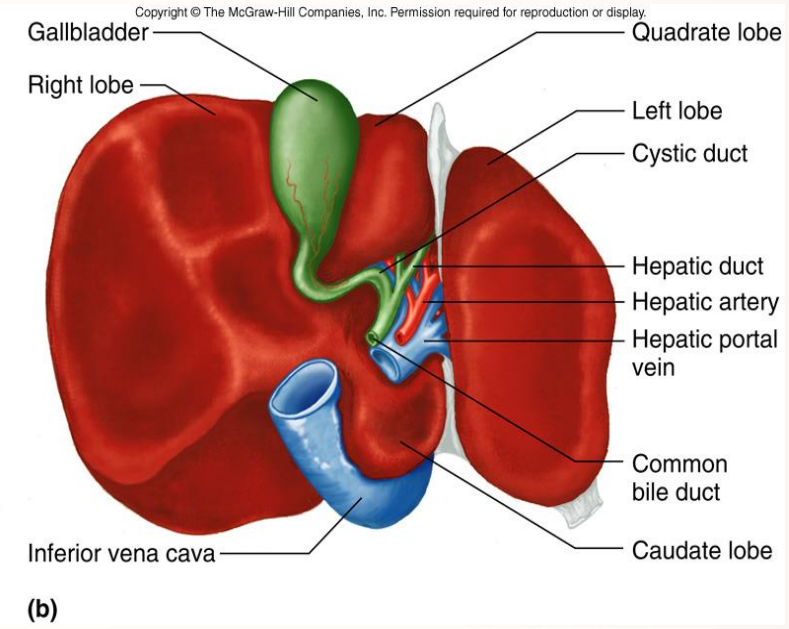
- Hepatic ducts join the cystic duct from the gallbladder to form the common bile duct.
- Common bile duct meets pancreatic duct at the hepatopancreatic ampulla (ampulla of Vater which ends with sphincter of Oddi).



Digestion in the small intestine

Bile secretion by the liver

- Gallbladder is found on the inferior side of the liver and stores bile until it is called for by the body.
- It concentrates the bile by dehydration (absorption of water) and keeps it in this form until release.
- Under certain abnormal conditions this liquid can form a crystal and an accumulation of these crystals is referred to as a gallstone. (due to increased cholesterol)This process is referred to as Choleolithiasis.
- Choleolithiasis can lead to Choleocystitis, which can lead to a medical emergency.

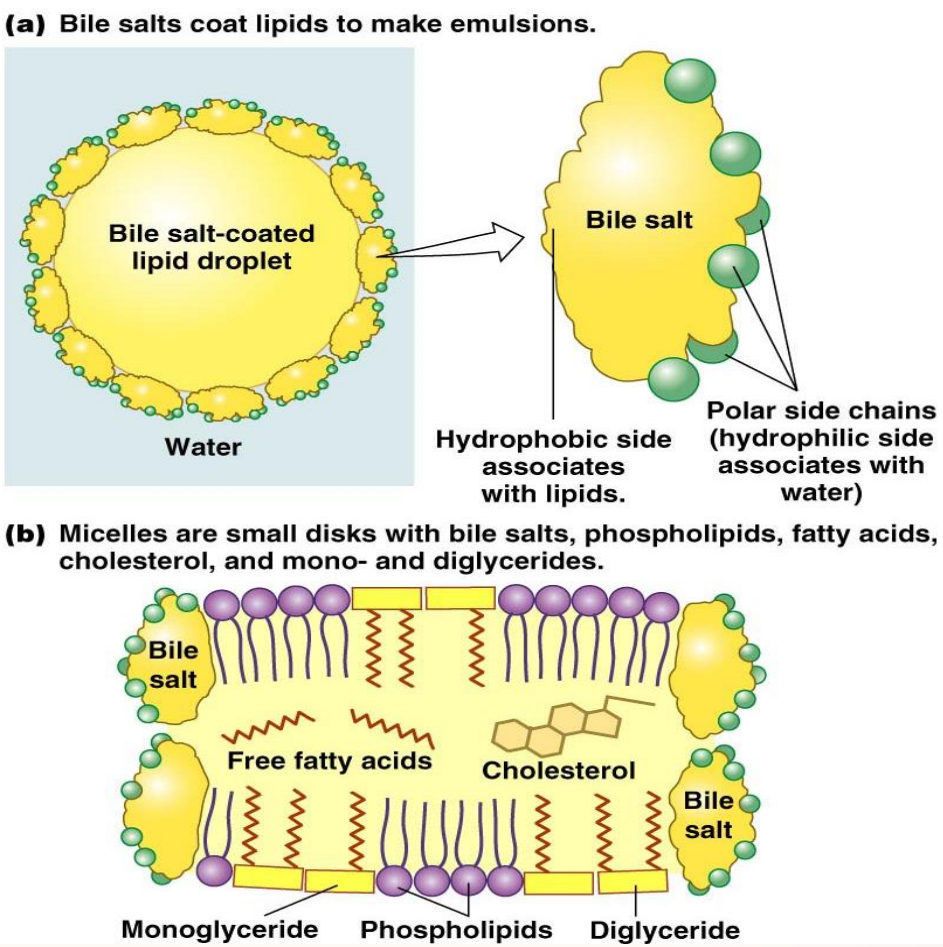


Digestion in the small intestine

The Bile

The role of bile salts are fat emulsification and formation of micelles and a route of waste removal.

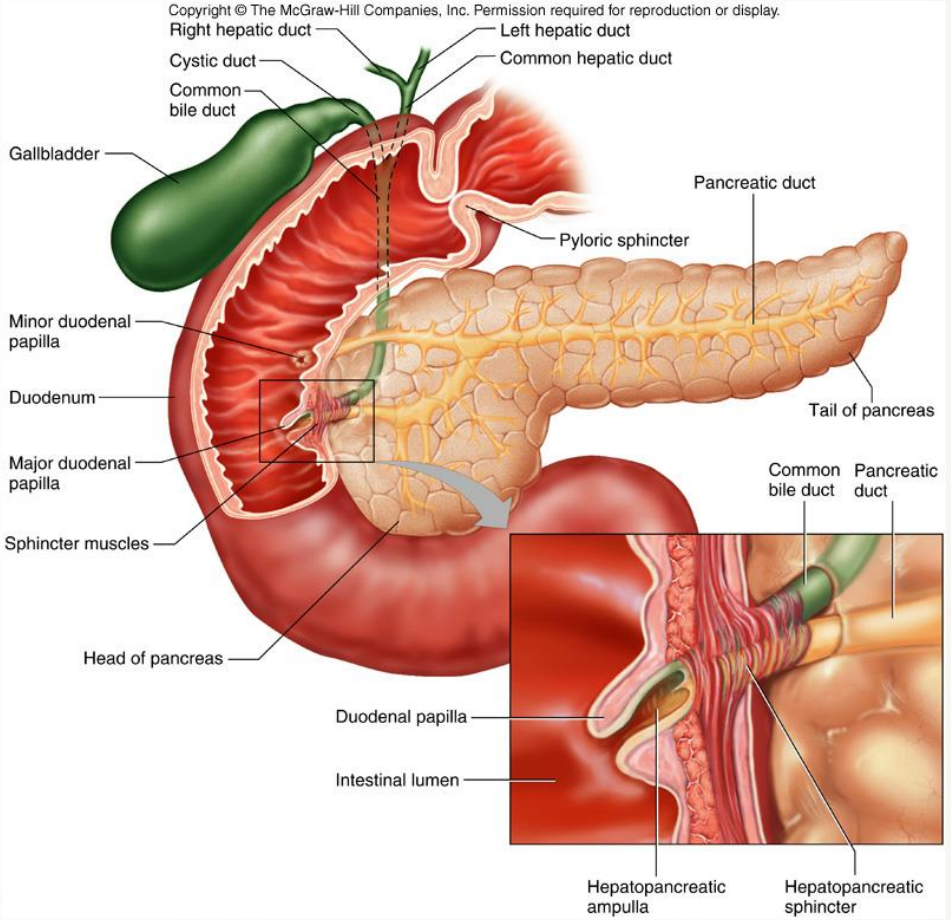
- Bile composition: water, mucus, bile salts (emulsify lipids), bile pigments (biliverdin and bilirubin), cholesterol (No enzymes).
- Secreted 800-1000 ml/day
- Yellow, brownish, or olive-green liquid
- Bile salts help in emulsification of ingested fats (breaking down large fat molecules into smaller ones).
- Bilirubin and other bile pigments are wastes from lipid catabolism
- CCK stimulates bile release for fatty meals.
- when the small intestine is empty, the hepatopancreatic sphincter closes, forcing bile into the gallbladder for storage



Digestion in the small intestine

The pancreas

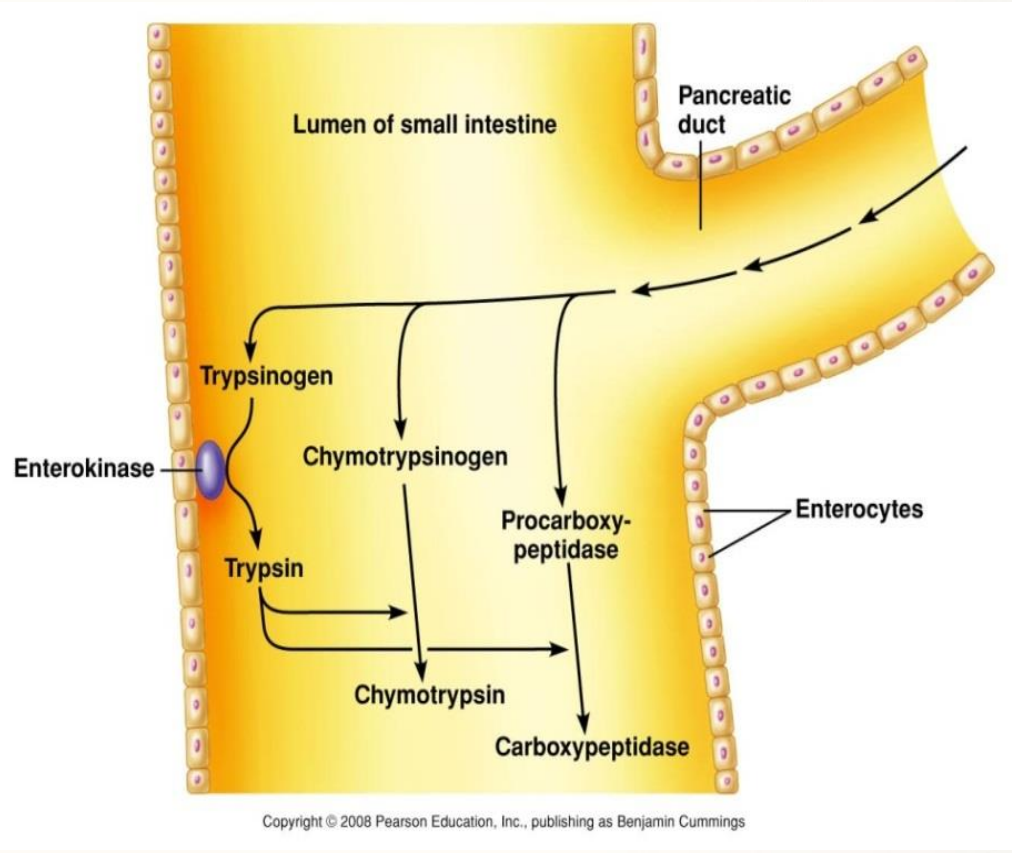
- Is located primarily in the upper left quadrant of the abdomen, and has both endocrine (insulin, glucagon and somatostatin) and exocrine (pancreatic juice) functions.
- In addition to insulin and glucagon secretion, it secretes many digestive enzymes.
- These secretions, called pancreatic juice join bile secreted by the liver and enter the small intestines through the Ampulla of Vater (Hepatopancreatic Ampulla).



Digestion in the small intestine

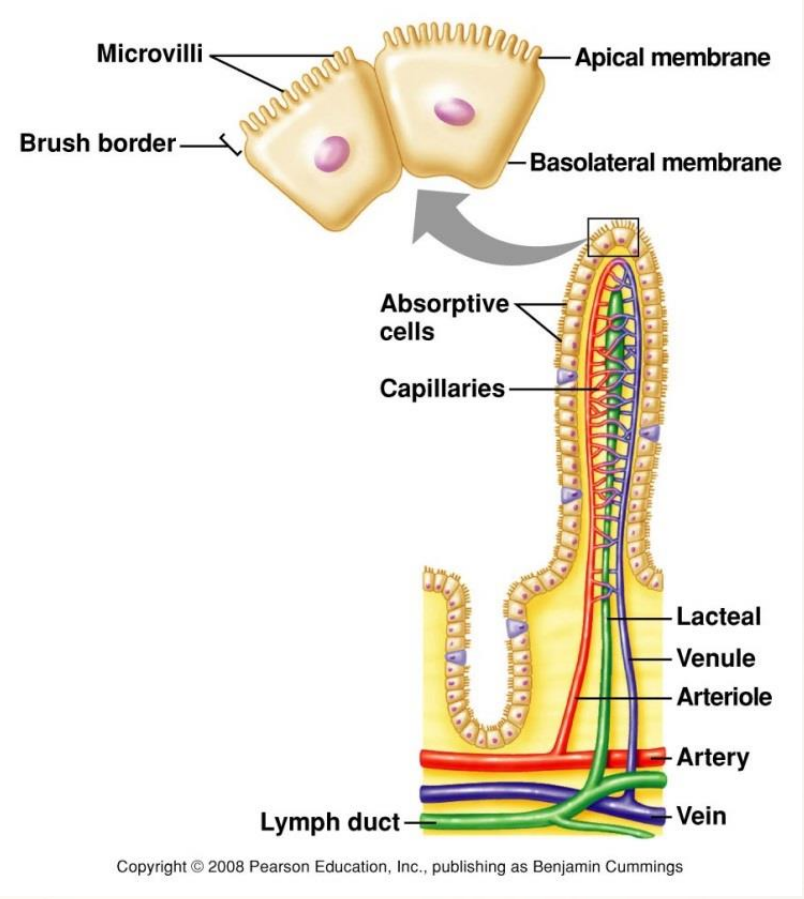
Pancreatic juice

- Secreted 1.2-1.5 L/day
- Composition: Mostly water, some salts, bicarbonate and enzymes
- Alkaline: pH 7.1-8.2
- Enzymes include:
  - Pancreatic amylase: carbohydrate digestion
  - Zymogens: inactive zymogens
    - *Trypsinogen → trypsin* (under effect of interokinase and trypsin)
    - *Chymotrypsinogen → Chymotrypsinogen (under effect of trypsin)*
    - *Procarboxypeptidase → Carboxypeptidase (under effect of trypsin)*
  - Pancreatic lipase: lipid digestion
  - Ribonuclease and deoxyribonuclease
  - Phospholipase



Absorption in the small intestine

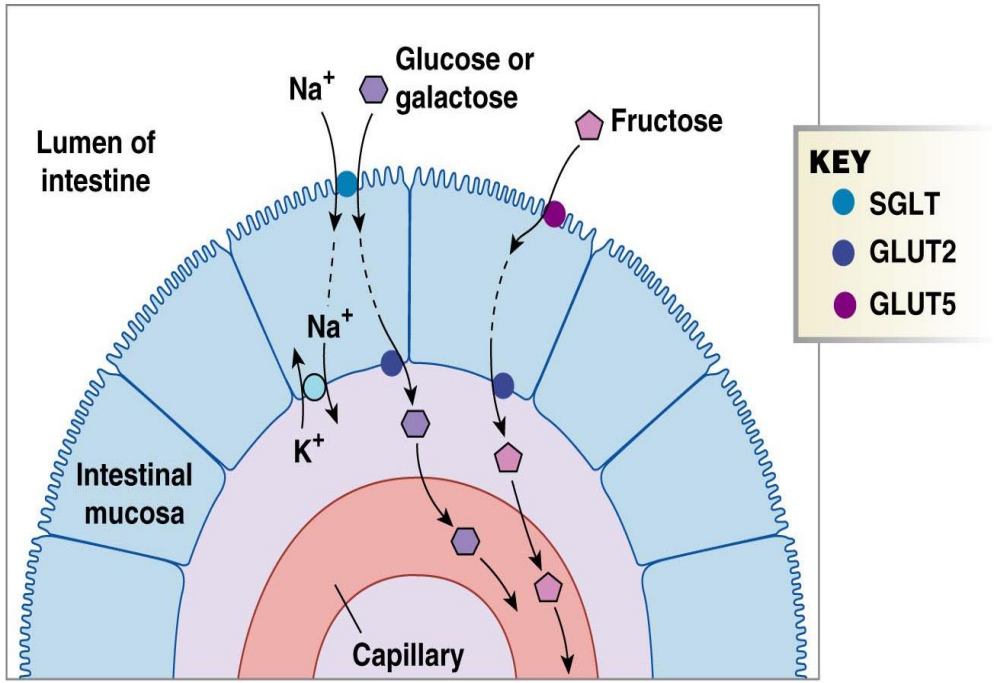
- The most active region for both digestion and absorption is the small intestine.
- The barrier through which materials must pass during absorption from the gut is formed by a single layer of epithelial cells on the surface of the villi, the *finger-like projections*.
- The area of the apical luminal surface of each epithelial cell is greatly increased by the presence of the *brush-border*.
- Below the villi in the mucosal membrane is a *thick network of blood capillaries* and small *lymphatics*.
- The basal side of the cell rests on a very thin basement membrane, which is close to the basement membrane of the underlying capillary.



Absorption in the small intestine

Absorption of carbohydrates

- Carbohydrate is absorbed as monosaccharides (mainly glucose, galactose and fructose-) these being formed from the disaccharides maltose, lactose and sucrose by enzymes on the brush-border of the intestinal villi.
- There is a specific protein carrier molecule for glucose and galactose; the affinity of glucose for this molecule is high, so this sugar is absorbed especially rapidly.
- One suggestion is that Na+ may modify the structure of the carrier to give it a greater affinity for glucose; then the complex (carrier, Na+ and glucose) moves in such a way that the Na+ and glucose are offloaded into the cytoplasm, and the carrier returns to the external cell surface and picks up another Na+ ion and another glucose molecule.

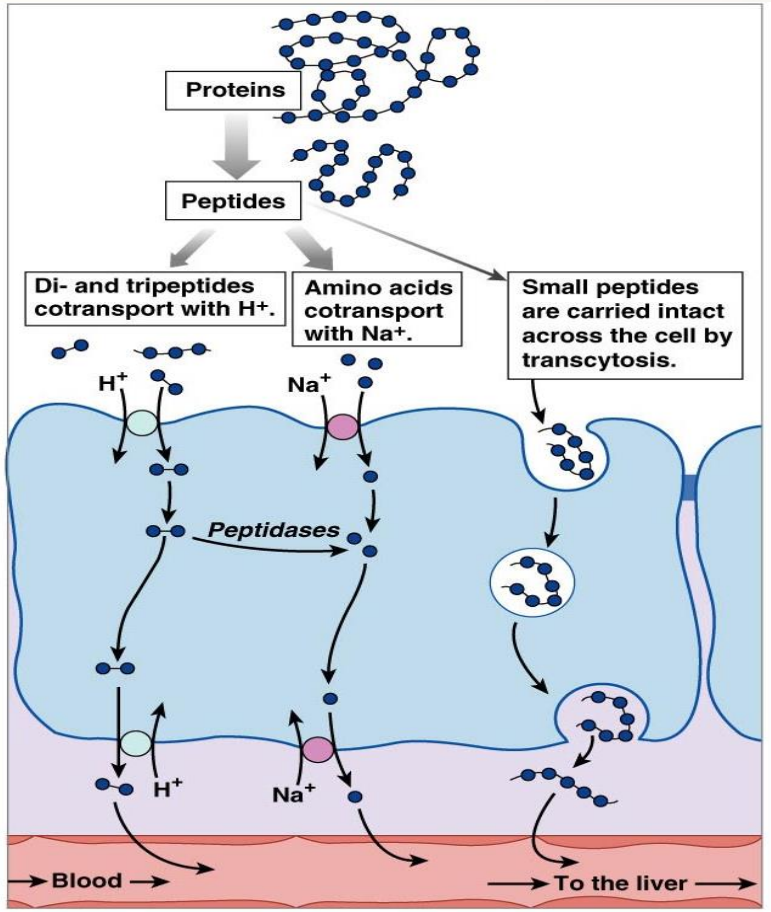


Glucose enters the cell with Na^+ on the SGLT symporter and exits on GLUT2. Fructose enters on GLUT5 and exits on GLUT 2.

Absorption in the small intestine

Absorption of peptides

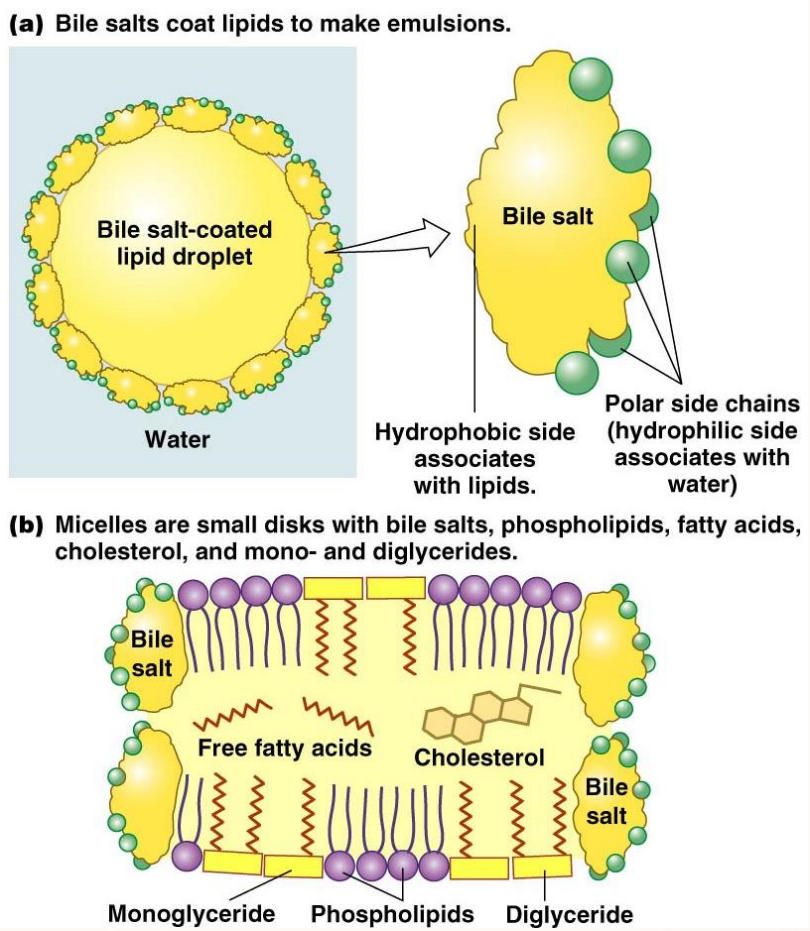
- There are dipeptidases in the cells of the villi, so most of the luminal dipeptides are hydrolysed at the moment of absorption.
- There are four different carrier molecules:
  - One for the neutral amino acids
  - One for the basic amino acids
  - One for the dicarboxylic amino acids (glutamic and aspartic)
  - and the fourth for proline, hydroxyproline and glycine.
- The presence of the Na+ ion speeds the carrier-mediated movement of amino acids into the intestinal cell. The role of sodium here may be similar its role in glucose absorption.



Absorption in the small intestine

Absorption of fats

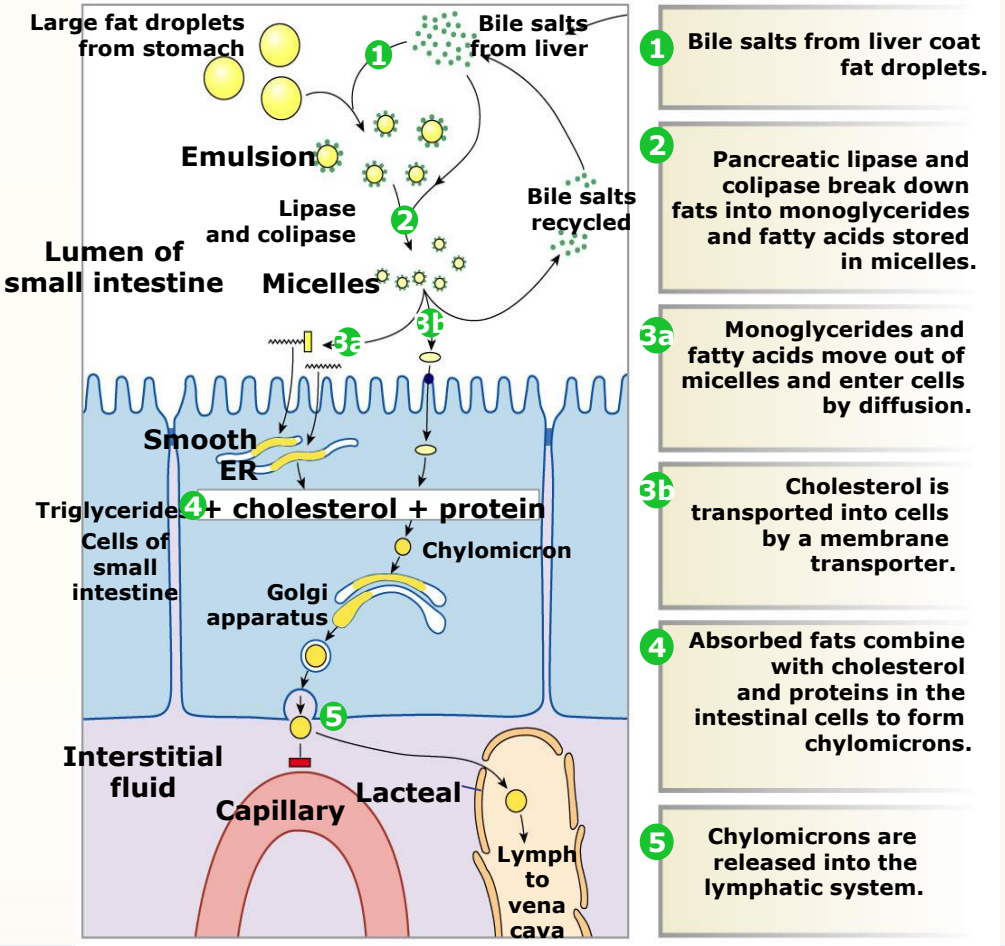
The role of bile salts is emulsification of fat and formation of micelles.



Absorption in the small intestine

Absorption of fats

- Fat may be absorbed in the form of extremely small particles. These may be droplets of an emulsion of monoglyceride, free fatty acids and bile salts.
- If these particles are less than 5000 nm in diameter, they could pass down between the threads of the microvilli forming the brush-border, and enter by pinocytosis.
- Most fat absorption, however, involves the micelles.

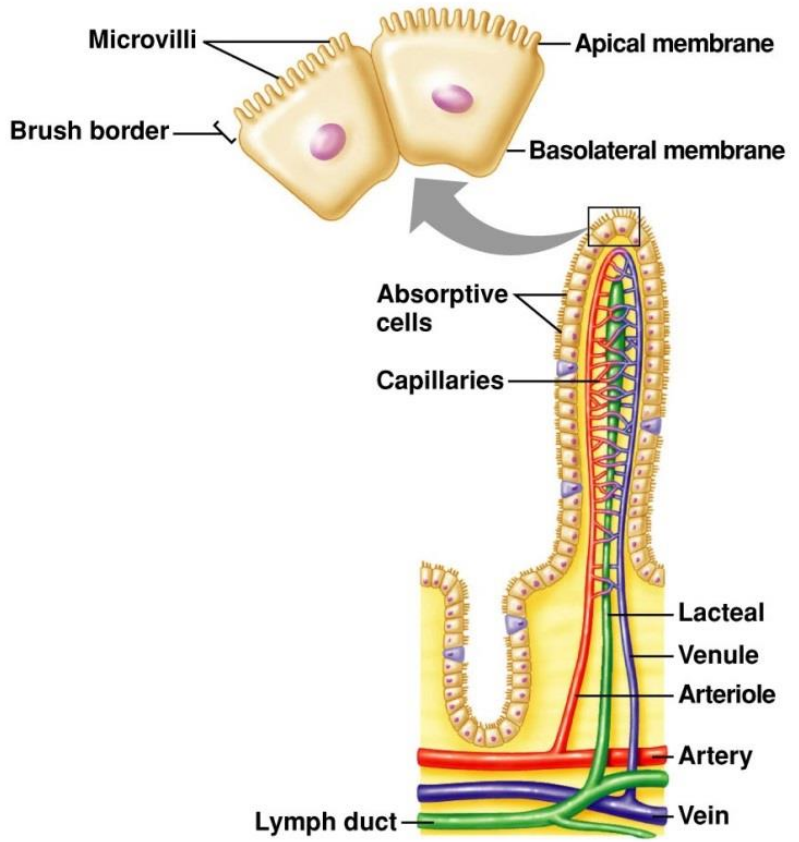


Absorption in the small intestine

- Intestine absorbs vitamins and minerals
- Fat-soluble vitamins (A, D, E, K) absorbed with fats in small intestines
- Water-soluble vitamins (C, B vitamins) absorbed by mediated transport except vitamin B12 which absorbed by active transport.
- Minerals absorbed by active transport

Absorption of fats in the Jejunum-Ileum

- Nutrients will be reabsorbed along the jejunum-ileum.
- Vitamin B_{12} when complexed to intrinsic factor, secreted in the stomach, and actively absorbed in ileum.



The large intestine

Anatomy

- The Large Intestine is so named because of its diameter.
- It also forms and stores **Feaces**. It also has a limited amount of absorption (water and electrolytes).

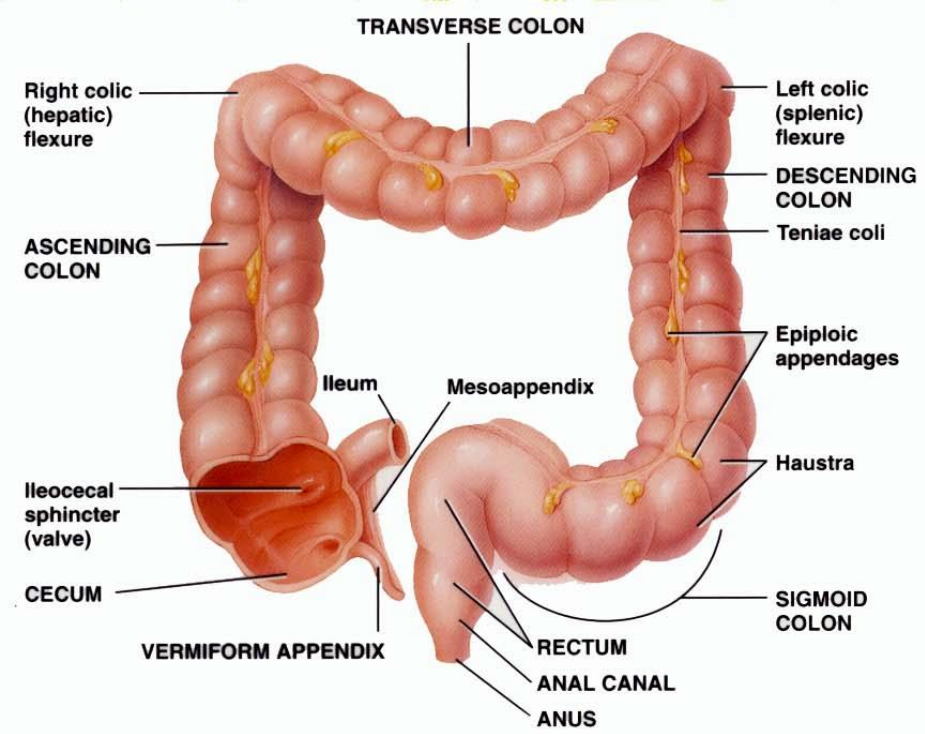
Parts include:

- **Ascending portion**

- The Cecum is the pouch like end of the ascending portion

- The Veriform Appendix is the terminal portion of the cecum.

- **Transverse portion**
- **Descending portion**



(a) Anterior view of large intestine showing major regions

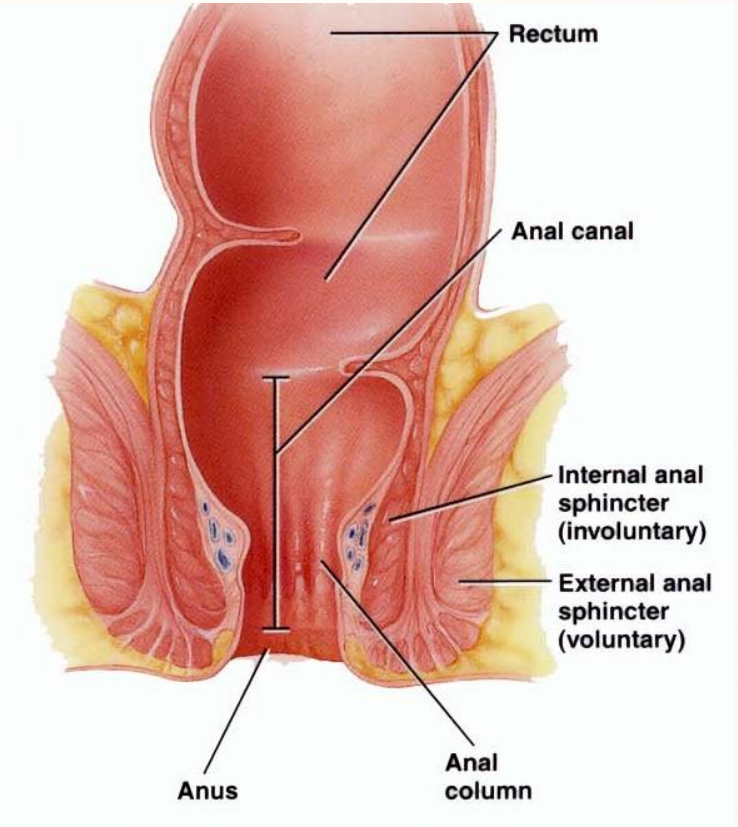
The large intestine

Anatomy

- **The Sigmoid Colon** is the final portion of the .
- **The Anal Canal** is made up two sets of sphincter muscles that are under voluntary control. :

-The internal anal sphincter is made of smooth muscle.

- The external anal sphincter is made up of skeletal muscle.



The large intestine

Functions

- The large intestine has little or no digestive function, other than to eliminate an unneeded waste product. Its epithelial lining has many goblet cells in it and thus mucus is the only significant secretion of this organ.

- Many bacteria inhibit the large intestine and make up the Intestinal Flora. Many of these bacteria synthesize vitamins such as **K** and **B12** which are then absorbed by the mucosa.

- Movement through the large intestine are caused by peristalsis, but these movements are usually less prevalent here than in the small intestine.

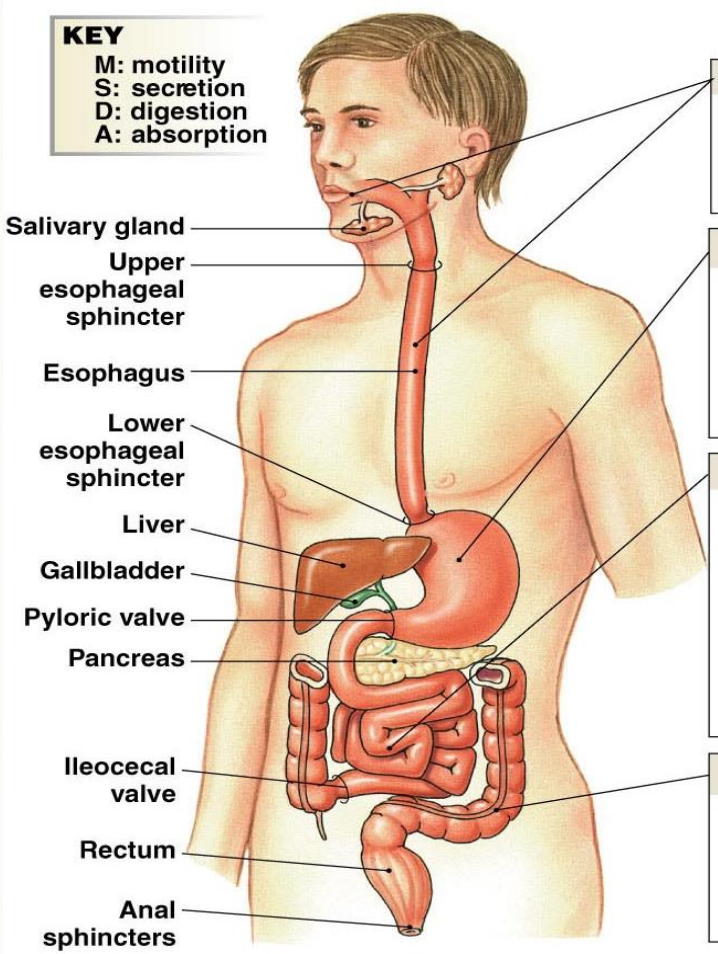
- Feces are composed of materials that were not digested (such as cellulose), or not absorbed, some water and electrolytes, mucus, and bacteria.

The large intestine

Absorption

- The large intestine absorbs water, electrolytes, and remnants of the digestive secretions remaining in the left over waste product that was once food.

Summary



ORAL CAVITY AND ESOPHAGUS

M: swallowing, chewing
S: saliva (salivary glands), lipase
D: carbohydrates, fats (minimal)
A: none

STOMACH

M: peristaltic mixing and propulsion
S: HCl (parietal cells); pepsinogen and gastric lipase (chief cells); mucus and HCO_3^- (surface mucous cells); gastrin (G cells); histamine (ECL cells)
D: proteins, fats
A: lipid-soluble substances such as alcohol and aspirin

SMALL INTESTINE

M: mixing and propulsion primarily by segmentation;
S: enzymes; HCO_3^- and enzymes (pancreas); bile (liver); mucus (goblet cells); hormones: CCK, secretin, GIP, and other hormones
D: carbohydrates, fats, polypeptides, nucleic acids
A: peptides by active transport; amino acids, glucose, and fructose by secondary active transport; fats by simple diffusion; water by osmosis; ions minerals, and vitamins by active transport

LARGE INTESTINE

M: segmental mixing; mass movement for propulsion
S: mucus (goblet cells)
D: none (except by bacteria)
A: ions, water, minerals, vitamins, and small organic molecles produced by bacteria