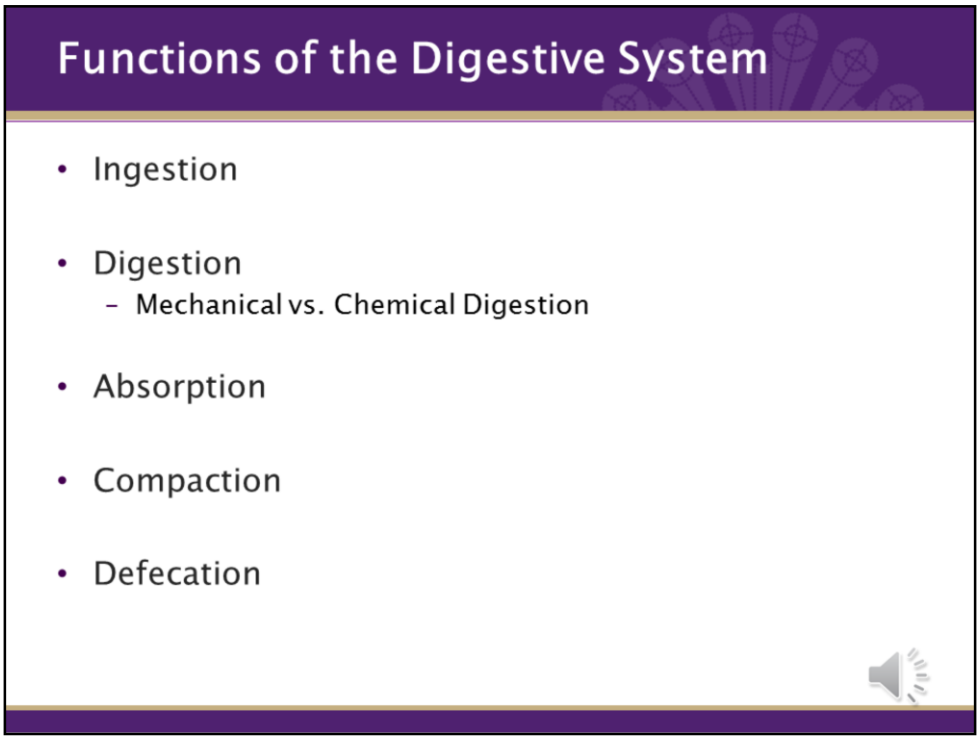
ST. CATHERINE UNIVERSITY

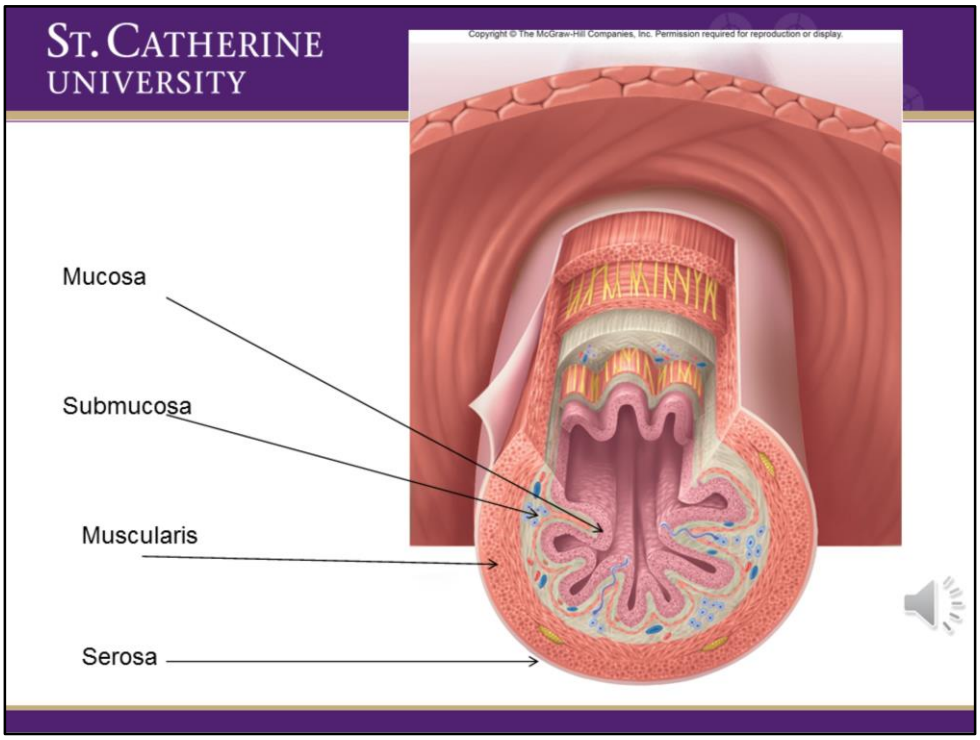
Digestive System



The digestive system functions in
1. Ingestion (taking in of food),
2. Digestion (the breaking down of food)

Digestion can occur through two methods: mechanical and chemical digestion
Mechanical is the physical break down of food such as chewing, grinding, churning, etc.
Chemical digestion uses digestive chemicals such as enzymes to break down food.

3. Absorption (the uptake of nutrients into the blood supply),
4. Compaction (absorbing water and consolidating the indigestible residue into feces
5. Defecation (the removal of remaining substances that cannot be digested).



The digestive tract (alimentary canal) is a tube that begins from the mouth and extends to the anus. Food moves through the space (lumen) of this tube. There are four basic layers: mucosa, submucosa, muscularis, and serosa.

Let's begin with the mucosa. The mucosa is the inner layer which consists of epithelium, connective tissue and smooth muscle. This is the layer that will have direct contact with food and will contain cells that secrete some of the enzymes for chemical digestion.

The submucosa layer is made of connective tissue and contains blood vessels, lymphatic vessels, and nerves.

As in its name, the muscularis layer is made up of muscle. Along most of the digestive tract, it consist of two layers of muscle. The inner muscle layer contain muscle fibers that run around the lumen, where the outer muscle layer runs longitudinally to the lumen. This layer is responsible for moving the food through the digestive tract and mechanical digestion.

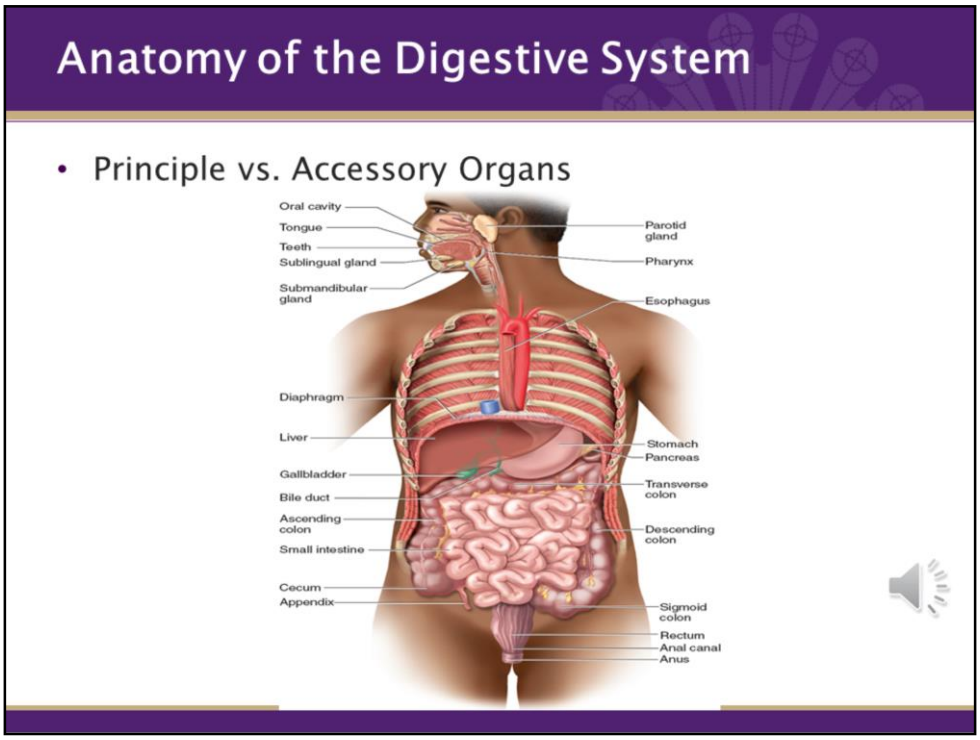
The outer layer is called the serosa, it acts as a covering and is made of epithelium and connective tissue.

Variations of these layers can be found, depending on the specific organ along the digestive tract.

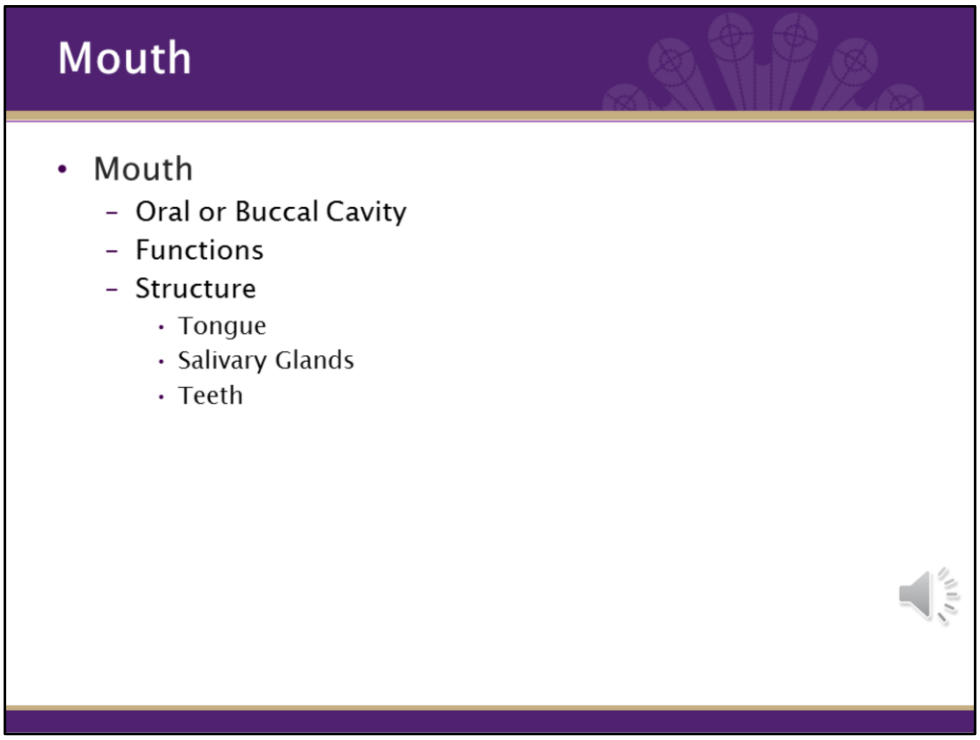
General Histology Continued

Name	Tissue Type	Function	Additional Comment
Mucosa			
Submucosa			
Muscularis Externa			
Serosa			

Use your notes and textbook to fill in this cognitive chart on the histology of the digestive tract. This type of active learning is very helpful in seeing the big picture and how everything fits in with each other. I encourage you to make several of these cognitive maps throughout this course.



The principle organs that food move through – and is referred to as the gastrointestinal tract/alimentary canal, These organs include the mouth, esophagus, stomach, small intestines, and large intestines. The accessory organs aid in digestion, usually by producing enzymes or some form of mechanical digestion. They include the teeth, tongue, salivary glands, liver, gall bladder, and pancreas.

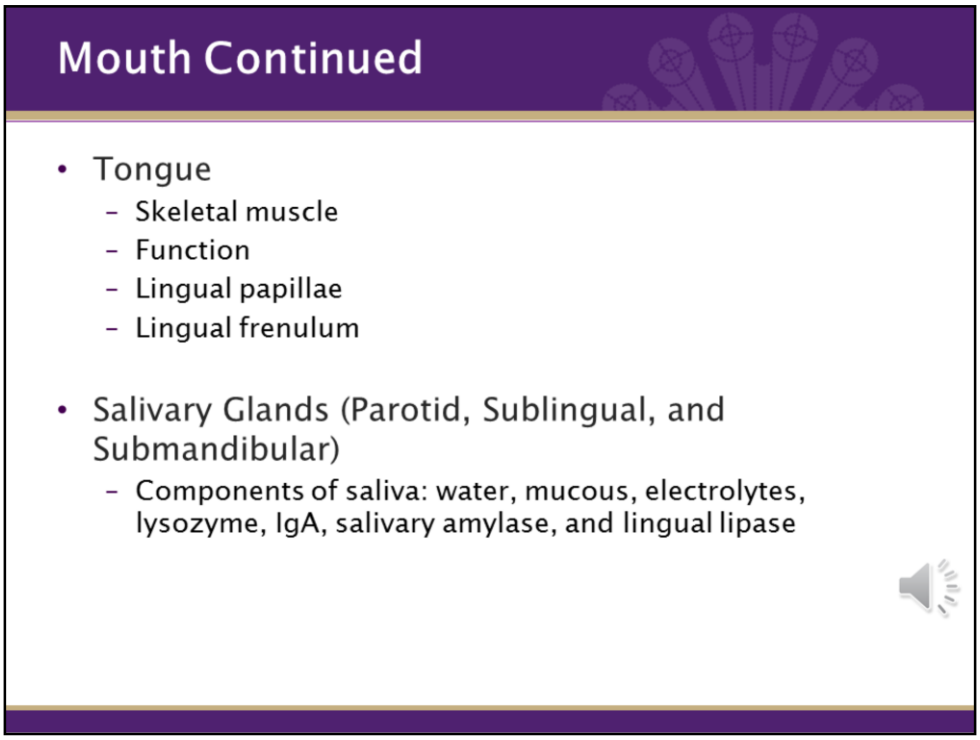


The mouth is also known as the oral or buccal cavity. It functions in ingestion, digestion (both chemical and mechanical), swallowing, speech, and respiration.

The mucosa is layered with stratified squamous epithelium.

The mouth is enclosed by the cheeks, lips, and palate. Additional structures within the mouth that will be discussed in more detail include the tongue, salivary glands, and teeth.

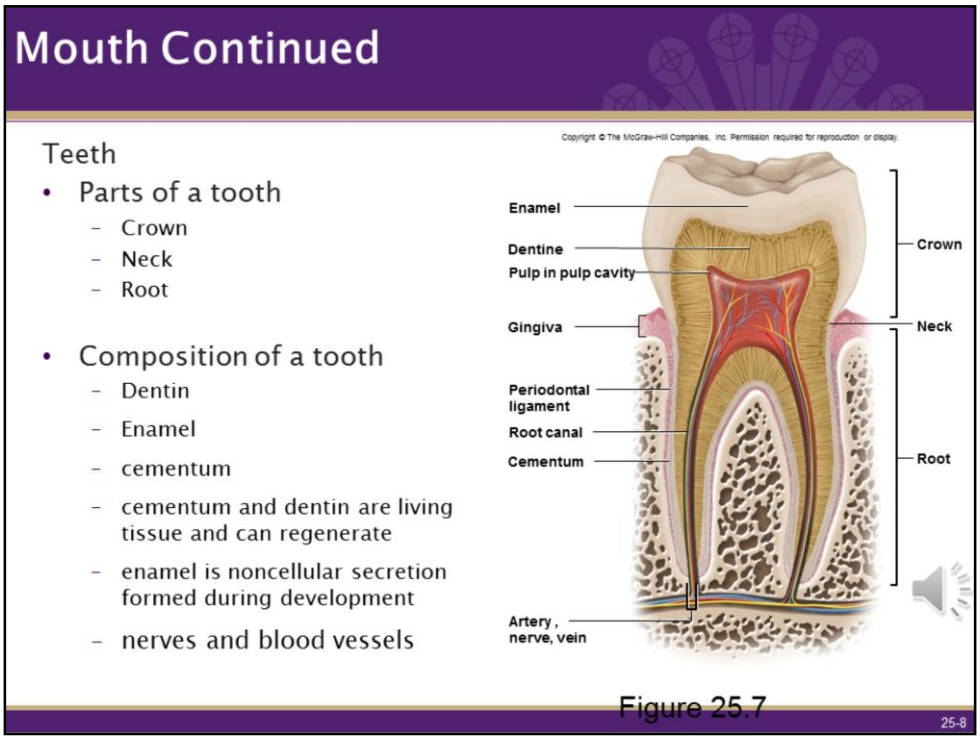
Once food has been mechanically broken up and mixed with saliva, it is referred to as a bolus.



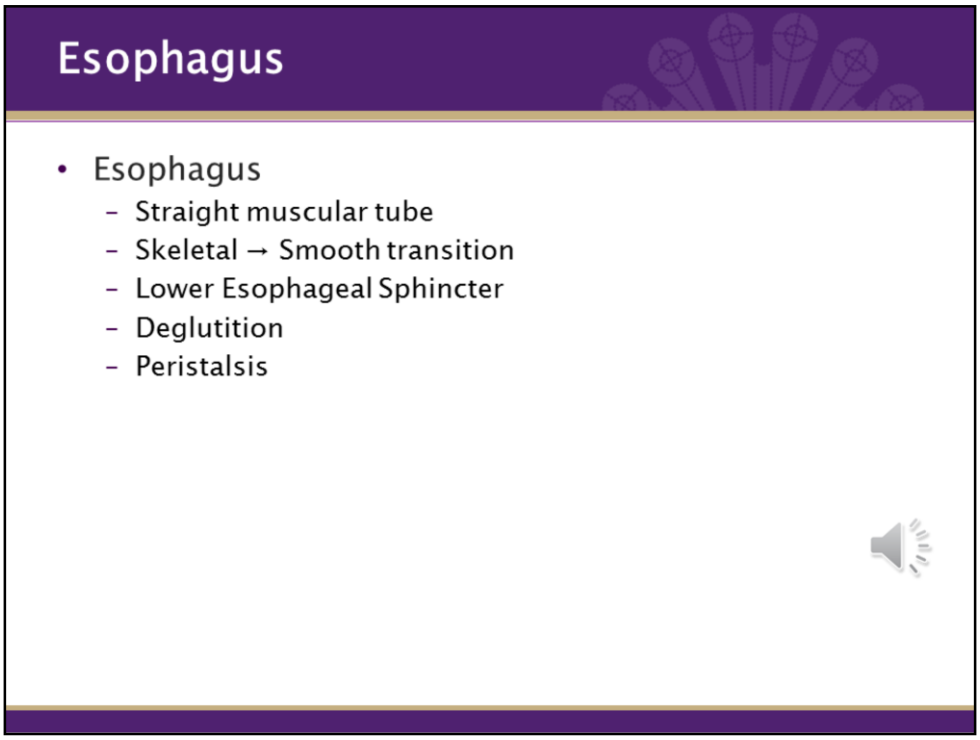
The tongue is an accessory organ in the mouth made of skeletal muscle. It manipulates food, is vital in speech production, and initiates the swallowing reflex. On it you will find the lingual papillae, various bumps and projections, these are also known as taste buds. The lingual frenulum is a bit of connective tissue that attaches the tongue to the floor of the mouth.

Salivary glands are found throughout and around the mouth. There are three: parotid glands (cheeks), sublingual glands (floor of mouth), and submandibular glands (along the body of the mandible). These salivary glands produce saliva - a fluid substance that contains:

- Water (99.5%)
- Mucous which binds and lubricates the food (bolus)
- Electrolytes such as salts (Na, K, Cl, and P) and bicarbonate
- Lysozyme, an enzyme that kills bacteria
- IgA, an antibody found in secretions, antibacterial
- Salivary amylase, enzyme that begins starch digestion in the mouth
- Lingual lipase, an enzyme that digests fats but requires acidic environments to work - and mostly active in the stomach since saliva is neutral (pH 6.8-7)

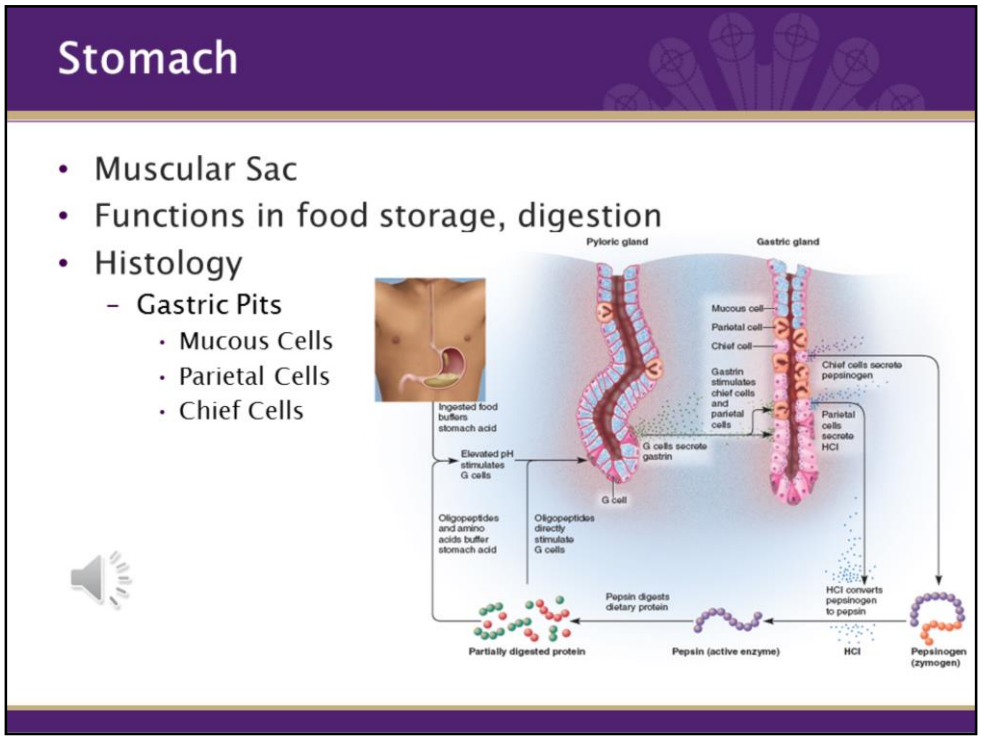


Teeth are responsible for the mechanical breakdown of food in the mouth known as mastication. We have 2 sets, deciduous (baby) and permanent (adult). There are three parts to the tooth. The crown is the exposed part of the tooth. The root is the portion below the gum line and the neck is the portion where the crown and root meet. The tooth is composed of three main substances: dentin, enamel, and cementum. Dentin is a hard yellowish tissue that makes up most of the internal tooth and lines the pulp cavity and root canal. Enamel covers the exposed portion of the tooth such as the crown and neck. Cementum covers the root. Cementum and dentin are living tissue and can regenerate through one's life. Enamel is a noncellular secretion formed during development. Once a tooth erupts, enamel cannot be replaced. This is why if you chip or break a tooth it cannot grow back. The root canal conntects to the pulp cavity in the tooth and both are filled with nerves and blood vessels



The pharynx is the next organ along the digestive tract. Specifically the oropharynx and larngopharynx. Since this has been discussed in the respiratory system, we will move on to the esophagus.

The esophagus is a straight muscular tube that connects the pharynx and the stomach and allows for the passage of food. There is a gradual change from skeletal to smooth muscle. At the end of the esophagus we have the lower esophageal sphincter. It is technically not a true sphincter (a ring of muscle that constricts and dilates to control passage ways), but it is formed by the diaphragm. It prevents food from coming back up and destroying the delicate mucosa of the esophagus. Deglutition (dee glu tish un), or swallowing, is a reflex coordinated by the swallowing center in the medulla oblongata and pons. It is initiated by the tongue. The upper esophageal sphincter then closes and the esophagus pushes the bolus (mucus bonded food particles) down using peristalsis (wave like contracting motions). When near the stomach the lower esophageal sphincter relaxes to allow food pass through.



The stomach is a muscular sac in the upper left of the abdominal cavity. It functions in food storage and digestion. The histology of the mucosa has a number of structures and cells specific to the stomach. The mucosa of the stomach contains gastric pits, which are depressions in the mucosa lined with columnar epithelium. The gastric pits are lined with the following cells:

1. Mucous cells are the most abundant and they secrete mucous.

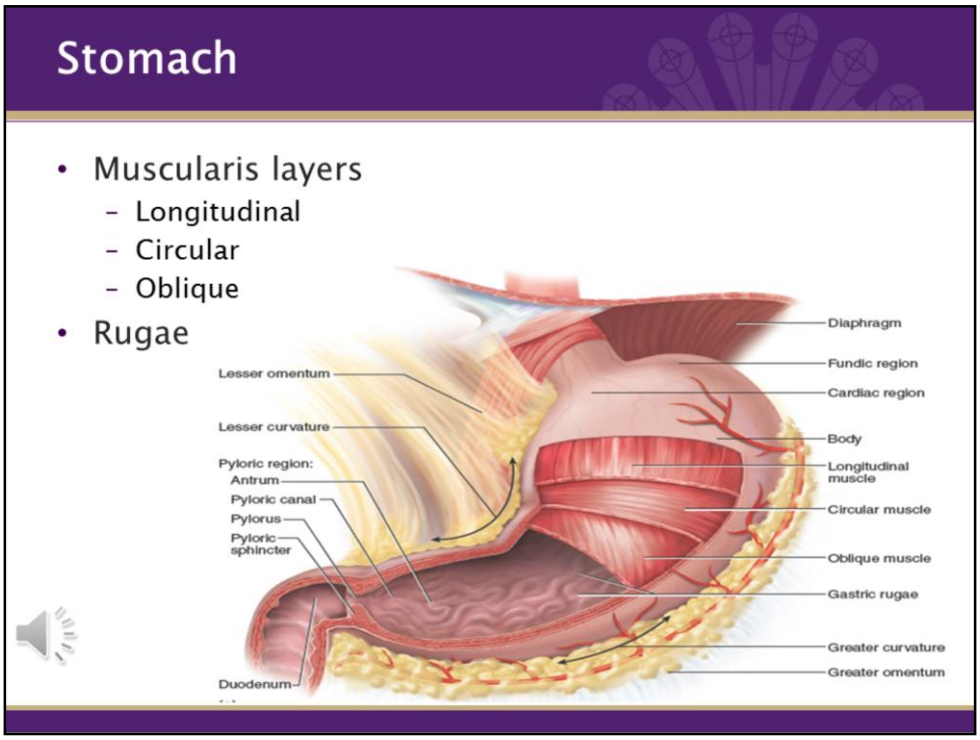
2. Parietal cells secrete HCl (hydrochloric acid) and intrinsic factor.

Intrinsic factor is essential in the absorption of vitamin B12. Without vitamin B12 you can't make hemoglobin. If you can't make hemoglobin, you cannot transport oxygen. This is the primary reason you need a stomach and can't live without it.

HCl activates enzymes (lingual lipase), kills some bacteria, breaks up fibrous plant material, and converts iron to a usable form for hemoglobin

3. Chief cells secrete pepsinogen (an inactive form) and gastric lipase. Pepsinogen is activated by HCl acid and converted to pepsin.

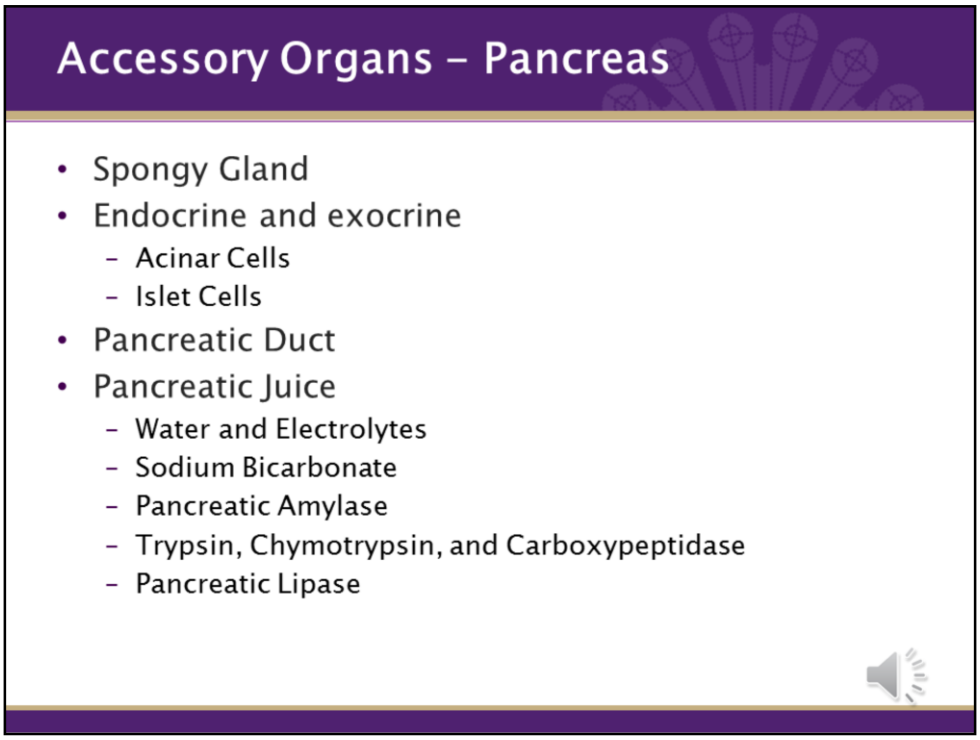
In terms of chemical digestion: Pepsin breaks down proteins. Gastric lipase and lingual lipase breaks down fats.



In addition to the differences in the mucosa layer, the stomach also has differences in the muscularis layer.

There are three different layers that form the muscularis of the stomach: Longitudinal (outer), Circular (middle), and Oblique (inner). These three all contract in different directions ensuring that the food is thoroughly churned and mixed. At this stage we refer to the processing food as chyme.

Additionally in the stomach also has rugae. Rugae are wrinkles in the mucosa and submucosa when the stomach is empty. As we eat and the stomach fills, this allows for expansion of the stomach.



In addition to the alimentary canal, the digestive system has accessory organs. These structures aid in the digestion of food. The first one we are going to talk about is the pancreas.

The pancreas is a spongy gland. It has both exocrine and endocrine functions. As an endocrine gland, its islet cells will secrete insulin and glucagon to regulate blood glucose levels. We will discuss this in more detail later in the endocrine system.

The acinar cells are key in the exocrine functions of the digestive system. These cells secrete pancreatic juices into the small intestines via the pancreatic duct. The pancreatic duct runs down the middle of the pancreas and merges with the common bile duct coming from the gall bladder and liver.

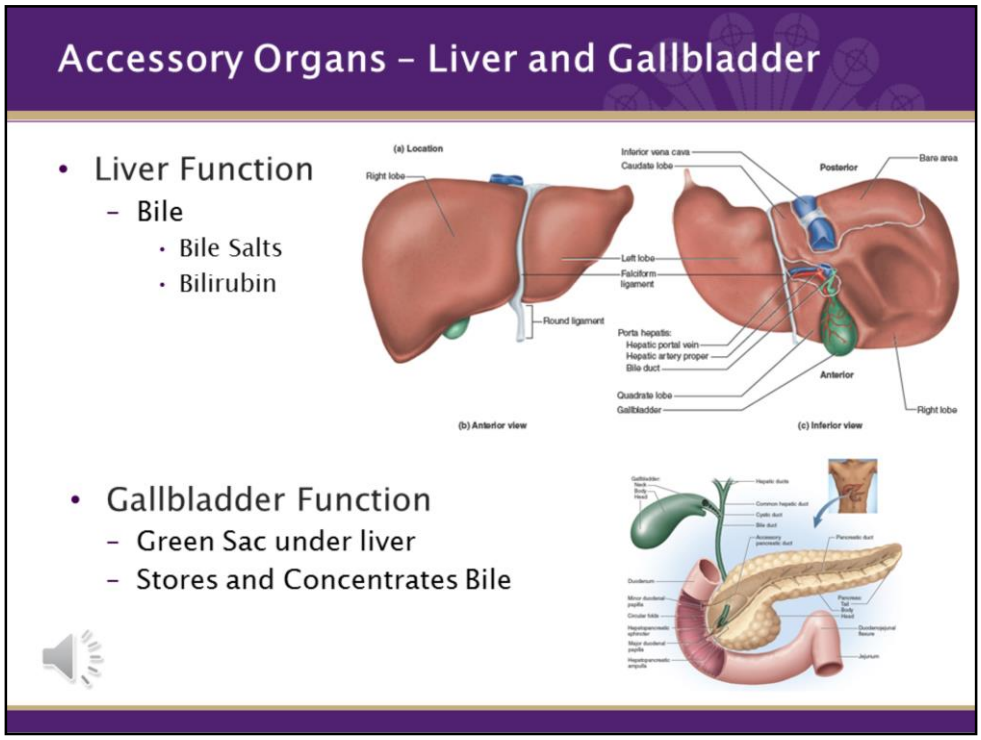
Pancreatic Juice is an alkaline mixture of H_2O, enzymes, electrolytes, and sodium bicarbonate. The pancreas produces a number of essential enzymes:

1. Pancreatic Amylase helps in the digestion of carbohydrates.

2. Trypsinogen (activates into trypsin), Chymotrypsinogen (activates into chymotrypsin), and Procarboxypeptidase (activates into carbodypeptidase) are responsible for the break down of proteins.

3. Pancreatic Lipase breaks down lipids.

Additionally, pancreatic juice contains Sodum Bicarbonate which neutralizes the HCl coming from the stomach. This makes the chyme neutral and no longer acidic and keeps the mucosa of the intestines from being destroyed by HCl



The next accessory organ is the liver. The liver has many functions, however we will focus on its digestive functions. The liver is made of hepatocytes and functions in the digestive system to produce bile. Bile is a yellow-green liquid composed of minerals, cholesterol, phospholipids, bile salts and bilirubin (pigment).

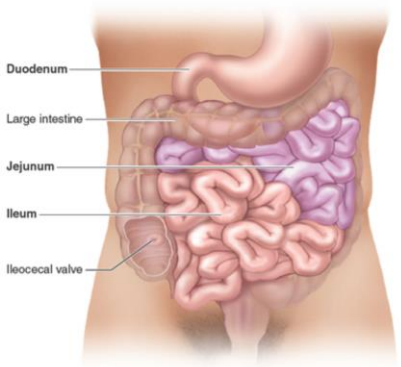
Bile salts are steroids synthesized from cholesterol. They aid in the digestion and absorption of fats. 80% of the bile salts are reabsorbed by the small intestines and returned to liver. The remaining 20% are defecated, this is the only way to get rid of cholesterol. Bilirubin is a pigment derived from the decomposition of hemoglobin.

As you will learn in lab, the liver has four different lobes (right, left, quadrate, and caudate). The gallbladder is also found underneath the right lobe. We'll be talking about the gallbladder next.

The gallbladder is a greenish sac on the underside of liver. It functions to store and concentrate bile. Bile leaves the liver via the hepatic duct. It then fills the bile duct and overflows into the gallbladder through cystic duct. The gallbladder absorbs the water and electrolytes from the bile – concentrating the bile before it is secreted into the duodenum to digest fats.

Small Intestines

- Structure
  - Duodenum
    - Begins at Pyloric Valve, First 25cm
    - Receives Stomach Contents, Pancreatic Juices, and Bile
  - Jejunum
    - Middle section, 8ft in length
    - Thick muscular wall
    - Most of digestion occurs here
  - Ileum
    - Last 12 feet
    - Thinner muscular walls



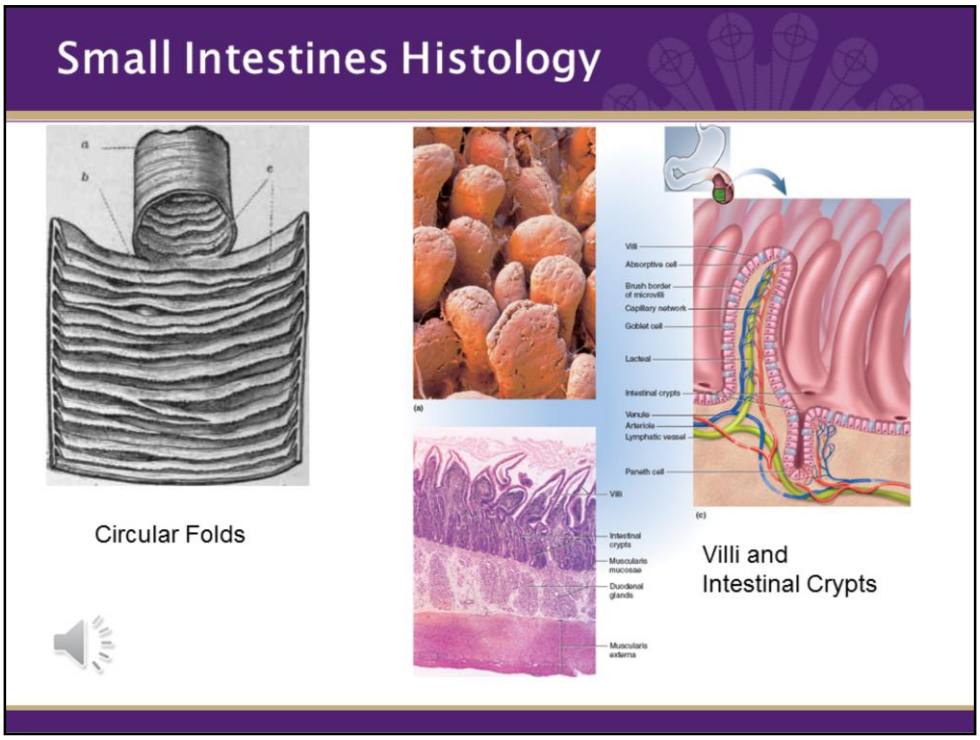
We'll now return to the organs of the alimentary canal.

The small intestines is made of 3 segments:

1. The Duodenum begins after the pyloric sphincter of the stomach and constitutes the first 25 cm or 10 in of the small intestines. The pancreatic secretions and bile are transported into the duodenum for chemical digestion

2. The Jejunum is the middle segment at 8ft long and constitutes about 40% of the small intestines. Most of the digestion and absorption occurs here. Because of this, the jejunum has a thicker muscular wall.

3. The Ileum is the last 12 ft and about 60% of the small intestines. It is thinner and less muscular than the jejunum. Absorption occurs here.



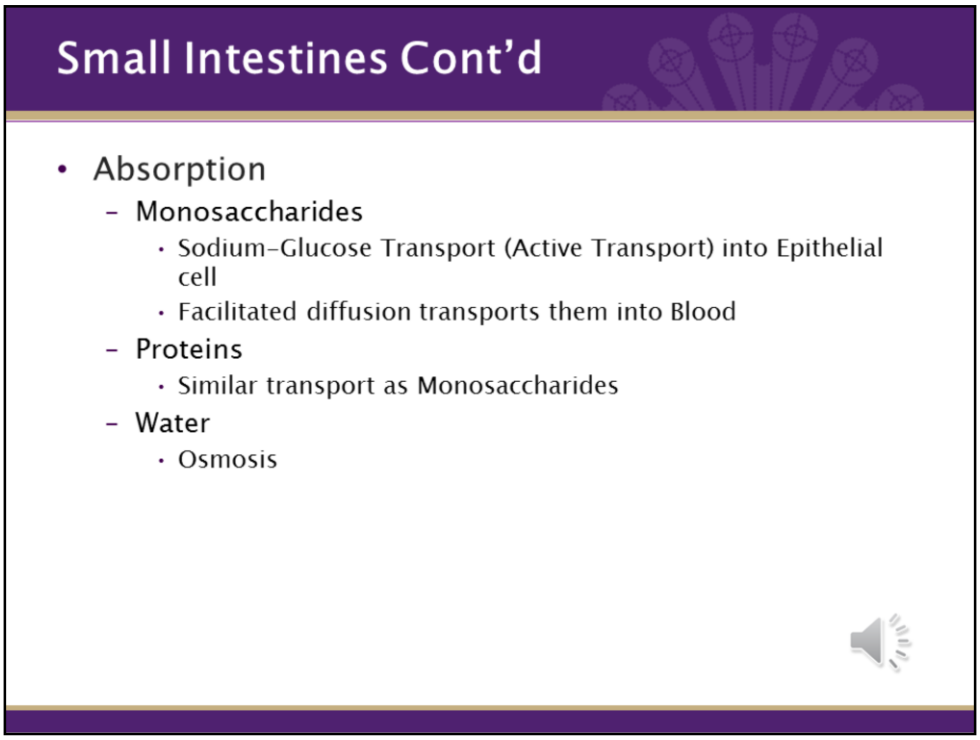
The histological differences in the small intestines include: circular folds, villi, and intestinal crypts.

Circular Folds are the largest folds in the intestinal wall, the are found in the mucosa and submucosa. They run the entire length of the small intestines from the duodenum to the ileum. They act like speed bumps and causes the chyme to move more slowly and spiral down the small intestines. This action slows progression so the chyme can mix with the pancreatic enzymes and bile.

The villi are projections of the mucosa, they make the small intestines. They are largest in the duodenum and become smaller as you move through the small intestines. The villi are made of simple columnar epithelium (enterocytes or absorptive cells) and goblet cells. The enterocytes are where absorption occurs and the goblet cells secret mucous. The enterocytes contain microvilli – which are tiny hair like structures on the surface of these cells that form the brush border. The brush border aids with contact digestion and is usually the final digestion before absorption occurs.

Inside the villi you will find blood vessels and lacteals. A lacteal is a lymphatic vessel that absorbs the majority of fat, where the remaining nutrients are absorbed into the blood vessels.

The intestinal crypts are pores between the villi on the floor of small intestine. Within the crypts are paneth cells which release enzymes that have an antibacterial function to keep invading bacteria out of the small intestine.



Absorption of nutrients occurs in the small intestine. Depending on the type of nutrient, the mechanism for moving into the blood vessel is different.

Monosaccharides move from the lumen into the columnar cells via sodium-glucose transport. This is an active transport process (requires ATP) and essentially glucose is piggy-backing on sodium. They are transported together. Once in the cell, facilitated diffusion transports them into the blood vessels.

Proteins follow a similar pattern as carbohydrates. They are co-transported into the cell and then diffuse into the blood supply. Water follows it usual path of osmosis.

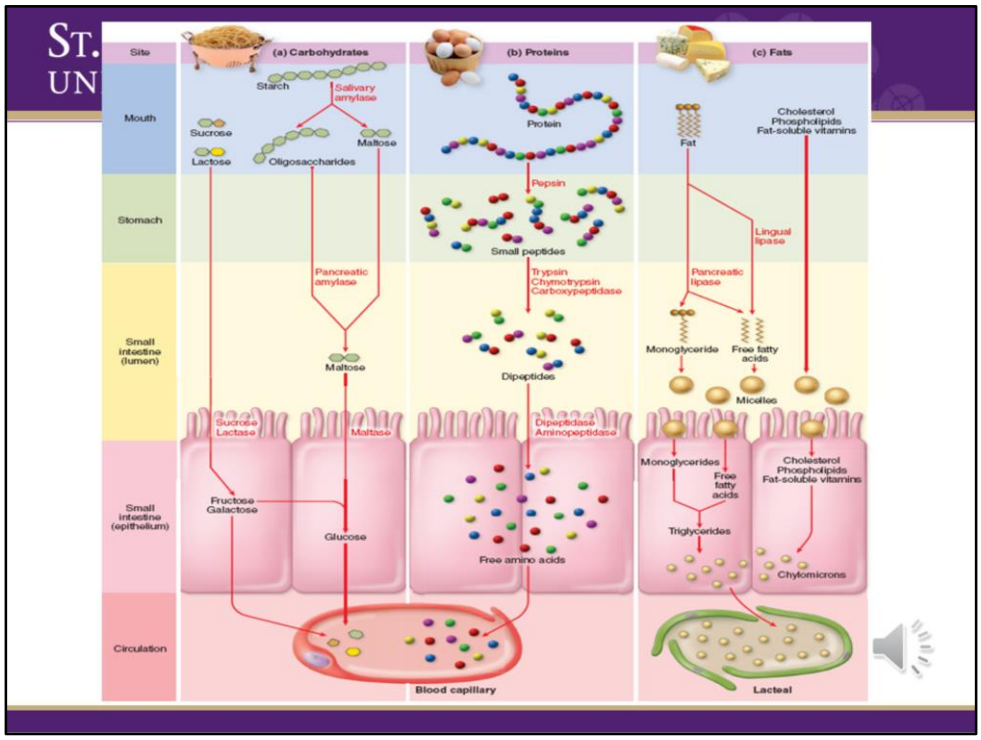
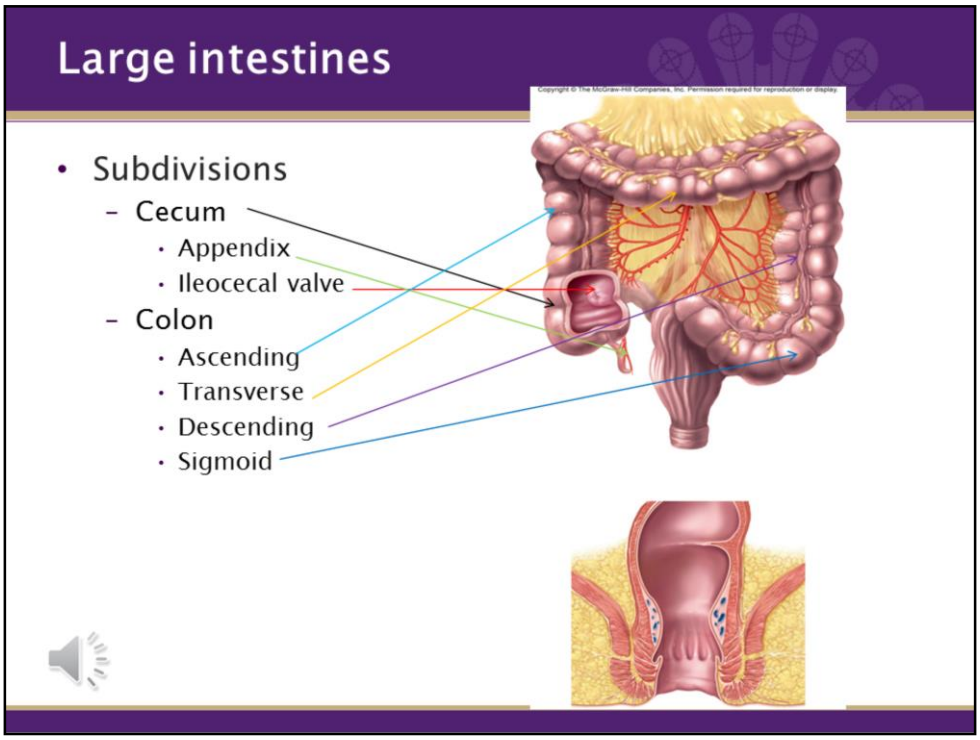


Figure 25.31 in your textbook does a wonderful job of following the main types of organic compounds through the digestive tract.

You can see that starches begin digestion in the mouth due to salivary amylase. The starches are broken down into oligosaacharides and disaccharides (such as maltose, sucrose, and lactose). Then these carbohydrates move through the esophagus and stomach as no chemical digestion happens in those organs. In the small intestine the pancreatic amylase breaks down the oligosaccharides into disaccharides as well. The disaccharides go through contact digestion with the brush borders of the microvilli and are broken down into monosaccharides which are absorbed into the blood vessels.

Protein begins digestion in the stomach due to the pepsin. The protein are broken down into small chains of peptides that move to the small intestine. In the small intestine, the trypsin, chymptrypsin, and carboxypeptidase breaks down the chains of peptides into dipeptides. The dipeptides go through contact digestion with the brush borders of the microvilli and are broken down into amino acids which are absorbed into the blood vessels

Fats begin digestion in the stomach due to the lingual and gastric lipase. The fats are broken down further in the small intestine by the pancreatic lipase and bile into micelles. The micelles go through contact digestion with the brush borders of the microvilli and are broken down into tryiglycerides and chylomicrons which are absorbed into the lacteal

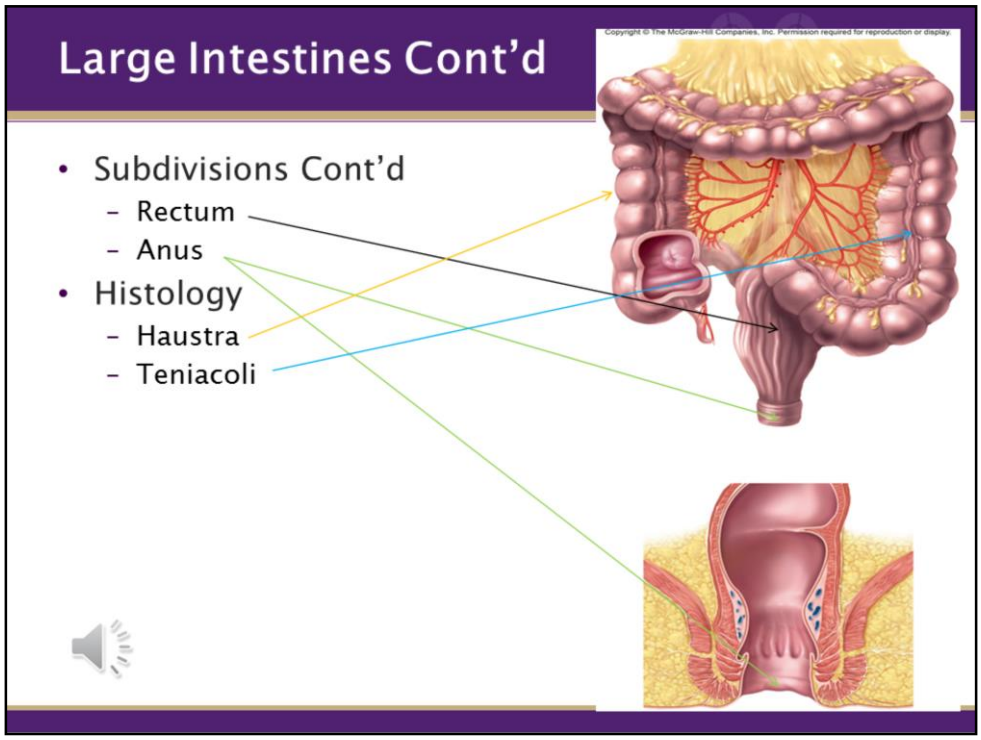


The large intestine is structurally broken into different segments: cecum, colon, rectum, and anus.

The cecum is a small pouch at the beginning of the large intestines. It attaches to the appendix and iliocecal valve/junction (which regulates the passage of chyme from the small to large intestines). The appendix contains lymphocytes, immune cells, and some bacteria. No one really is sure what the function of the appendix is. Some speculate that it is a reservoir of our good gut bacteria. When our bacteria is wiped out due to illness, the appendix can help repopulate it and get it working properly again.

The next section is the colon. The colon has 4 parts: the Ascending, Transverse, Descending, and Sigmoid colon.

Note: once chyme enters the large intestine, it is no longer referred to as such. We call the indigestible food feces.

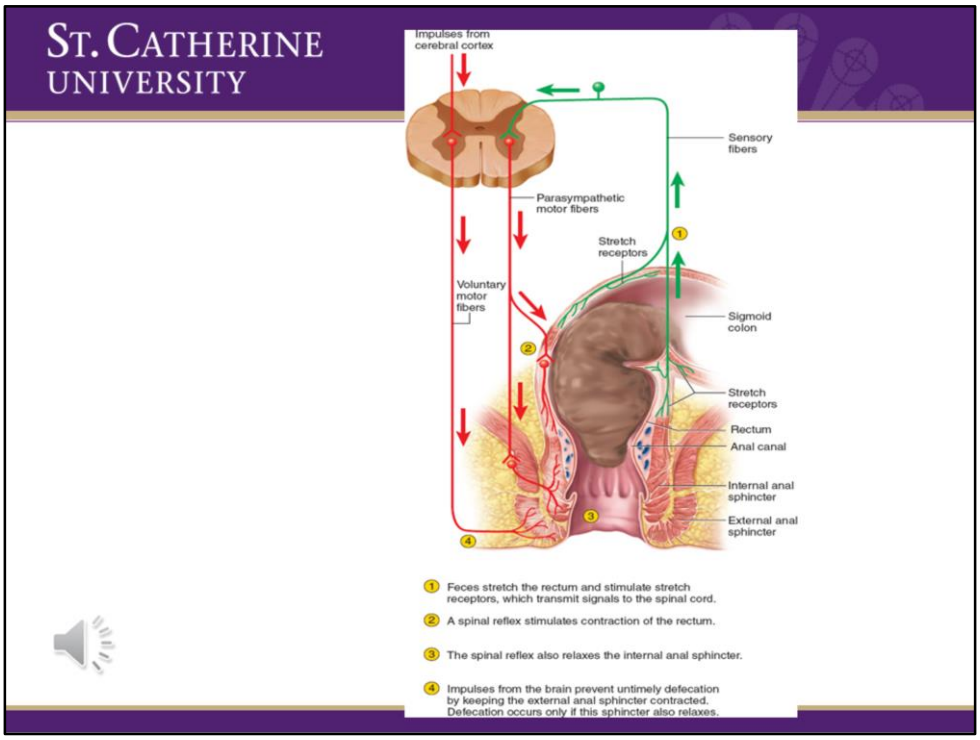


After the sigmoid colon the rectum starts where the colon straightens back out again. The anus is the final 3 cm of large intestine and is the external opening. It is also referred to as the Anal canal. The anus has both external and internal sphincters.

Haustra can be found throughout the cecum and colon. They are small pouches throughout the wall of colon. The tenia coli are longitudinal fibers, a ribbon-like structure that runs the entire length of the colon. They contract the colon lengthwise and help form the haustra.

The large intestines are lined with simple columnar epithelium, except in the last ½ of the anal canal where it becomes stratified squamous.

No chemical or mechanical digestion occurs here, but some absorption of water and electrolytes does occur here. Additionally, there is fermentation by bacteria. As a by-product, flatus, or gas, is produced by bacteria. About 800 different species of bacteria inhabit the colon. They help digest food that we are unable to breakdown and provide us with some additional nutrients, like vitamin K.



The large intestines have a mass peristalsis a few times a day. Defecation is the release of indigestible food from the body. A spinal reflex controls the process of defecation. Stretch receptors sense the presence of the feces in the colon and send a message to the spinal cord. The spinal cord responds by contracting the rectum and relaxing the internal anal sphincter. An impulse from the brain allow us to have some voluntary control over this reflex by keeping the external anal sphincter contracted. This allows us to defecate at the appropriate times when the brain allows the external anal sphincter to relax. Although, certain illness and flight-or-fight responses can override our voluntary control.