Anatomy Lecture Notes Section 6: The Digestive System

The **Digestive System** has two main components: The **Gastrointestinal (G.I.) Tract** and various **Accessory Structures** and **Organs**.

The **G.I. Tract** is also called the alimentary ('nourishment') canal and consists of long muscular tube starting from the oral cavity, where food enters the mouth, continuing through the pharynx, esophagus, stomach, small and large intestines, to the rectum and anus, where waste is expelled as fecal matter.

The **Accessory Structures** and organs include: The salivary glands; mucous glands; tongue; teeth; the liver; gallbladder and pancreas. All of these have important functions in the digestive system. Food is propelled along the length of the G.I. tract by peristaltic movements provided by the muscular layers in the walls of the G.I. tract. Many accessory structures assist the tract by secreting enzymes or substances to help transform, digest, absorb or transport food as it travels along the tract.

The primary purpose of the gastrointestinal tract is to break down the large nutrients (polymers) from the food ingested into smaller units (monomers). Once the nutrients have been broken down into their smallest unit, they can then be absorbed across the epithelial lining into the body and these nutrients and materials can be used in a number of ways, including providing energy for the body.

The 6 Basic Digestive Processes

1. Ingestion – taking food or drink into the mouth or oral cavity.

2. Propulsion – movement through alimentary canal. This includes movement of tongue and cheeks and involves contraction of the muscles of swallowing, in addition to the peristaltic movement generated by the muscular layers of the tract and the cavities created by the canal.

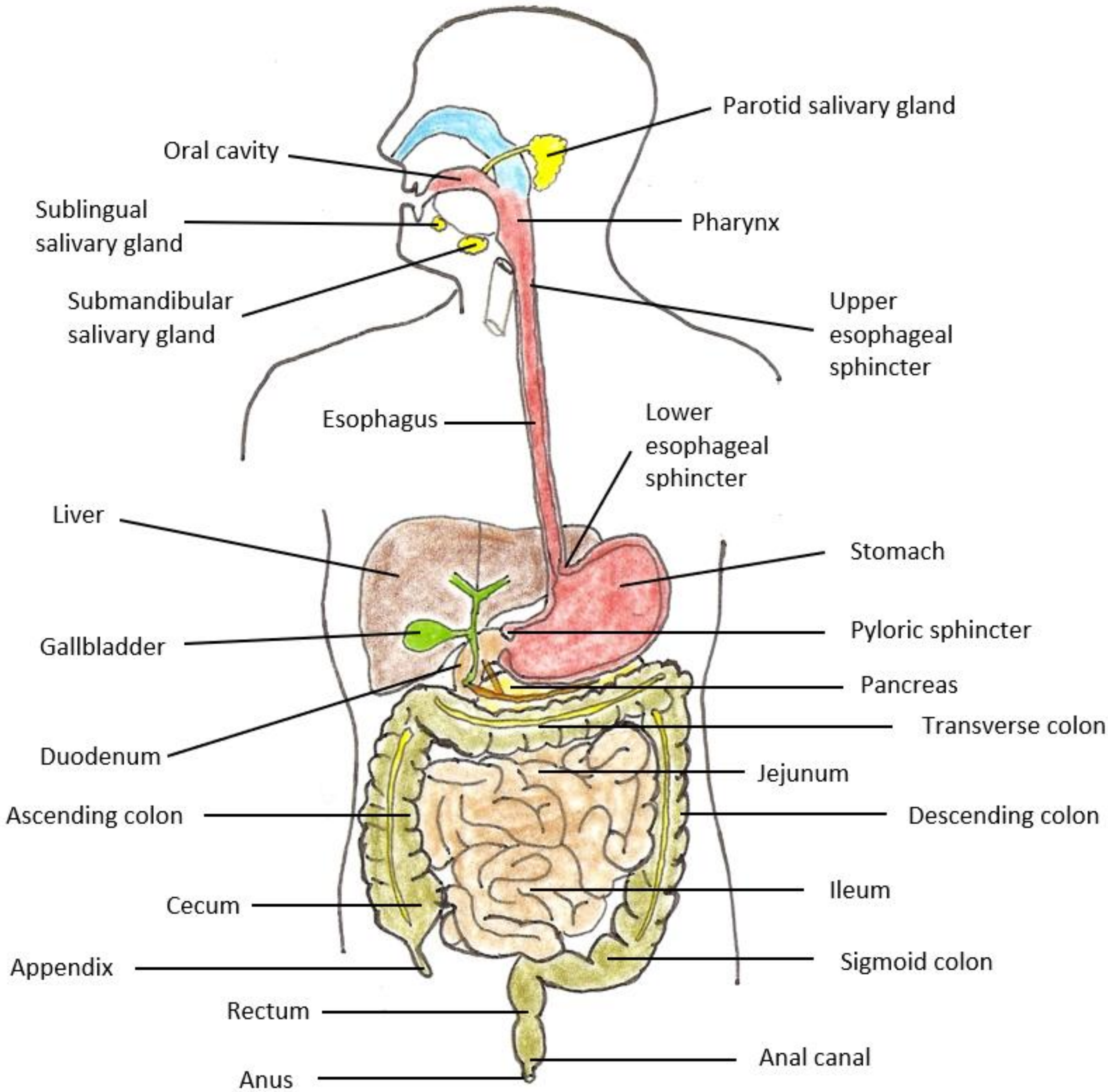
3. Mechanical Digestion – the *Physical* breakdown of food (chewing, churning), mechanical processing and moistening of foods. This is most often required prior to chemical digestion.

4. Chemical Digestion – the *Enzymatic* breakdown of food (from complex to simple building blocks) by the use of enzymes made by the body. This involves the breaking of chemical bonds.

5. Absorption – the transportation of digested products from lumen of G.I. tract across an epithelial lining and into the blood and lymph vessels, which are considered to be *inside* the body.

6. Defecation – the *Elimination* of indigestible material and waste products from the body (feces).

In summary, mechanical digestion occurs mainly in the mouth and stomach, and chemical (enzymatic) digestion begins in the stomach (protein digestion only) and becomes significant for all nutrients in the small intestine, where proteins, fats and carbohydrates are all chemically broken down into their basic building blocks by a series of enzymes. Once they are broken down (catabolized) into smaller molecules, they can then be absorbed across the epithelium of the small intestine and subsequently enter the circulation of the body. The large intestine plays a key role in the reabsorption of excess water and electrolytes. Finally, undigested material and the secreted waste products continue along the tract and are excreted from the body via defecation - the mass movement and elimination of feces.



The **Alimentary Canal** is a hollow, compartmentalized and specialized tube starting at the oral cavity and ending at the anus.

The Oral Cavity

The mouth or the oral cavity is the hollow space formed by the area between the lips, cheeks, tongue, hard, soft palates and the throat. It allows food, liquid and air to enter the body. The mouth contains many other organs, such as the teeth, tongue and the ducts of the extrinsic salivary glands. These structures work together to aid in the **ingestion** and **digestion** of food. The mouth also plays a major role in the production of speech through the movements of the tongue, lips and cheeks.

The lips form the anterior border of the external opening of the mouth and are very flexible and elastic structures. They contain collagen, elastin fibers and adipose tissue covered by a thin layer of **keratinized stratified squamous epithelium**. The epidermis of the lips is so thin that the color of the blood supply immediately deep to the surface can be seen, hence the lips are usually red in color. The exterior of the lips is continuous with the skin (covered by keratinized epithelium) while the inner surface is continuous with the mucous membrane of the mouth and is covered by **non-keratinized stratified squamous epithelium**.

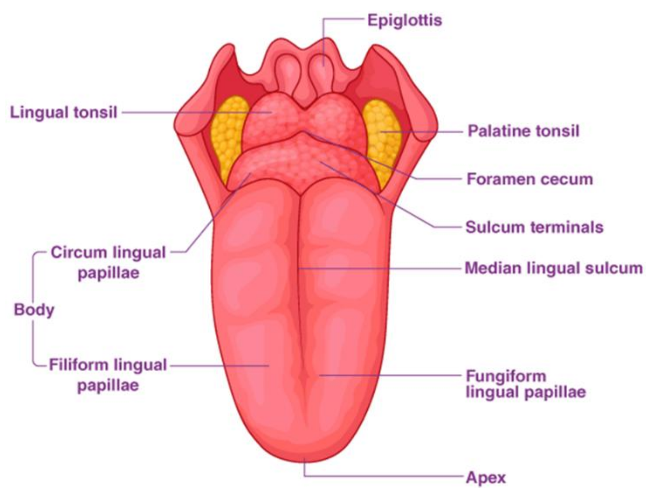
The same arrangement found in the lips applies for the exterior and interior cheeks. Between the epithelial layers of the cheeks are layers of connective tissues, nerves and muscles. As a review, muscles of the cheeks include the **buccinator**, **orbicularis oris**, the **depressor anguli oris**, and the **zygomaticus major**, to name a few, which assist in the movement of the lips and cheeks.

Tongue

While many people think of the **tongue** as a muscle, it is actually an organ made of **epithelium**, several **skeletal muscles**, **nerves**, and **connective tissues**. The tongue forms the inferior portion of the mouth, but often moves throughout the mouth to occupy almost any region of the hollow cavity.

The apex is the tip of the tongue, the most distal part of the tongue. The body of the tongue (the corpus linguae) is the portion of the tongue between the tip and base and is about four inches long. The body is separated into two halves by the median sulcus. The body is separated from the base of the tongue by a V-shaped furrow, or groove, called the terminal sulcus.

The tongue contains many small ridges known as **papillae** that help it to grip and move food around the mouth. Taste buds are hidden in valleys around some of the papillae which contain a type of chemoreceptor called taste buds and contribute to gustation (the sense of taste) by detecting chemicals found in food. The tongue also helps to produce speech by altering or stopping the flow of air through the mouth and teeth to produce the sounds of many consonants.



The hard and soft palates form the roof of the mouth. On the anterior end of the mouth, the hard palate is formed by the inferior surface of the **maxillae** and **palatine bones**. These bones are covered with a thin layer of connective tissues and mucous membranes, which form small ridges you can feel with your tongue. The roof of the mouth continues posteriorly as the soft palate, a flexible fleshy mass of tissues that ends in the **uvula**. The hard and soft palates work together to separate the mouth from the nasal cavity. This allows humans to breathe and chew food at the same time. The big and relatively flat molars are specialized for extensive chewing time! The soft palate moves superiorly during swallowing to cover the nasopharynx of the throat, preventing food from entering the nasal cavity.

Teeth

Teeth are a group of hard organs found in the oral cavity specialized for the biting and grinding of food, known as **mastication**, or chewing, convert food into tiny pieces, which is the main function of the teeth. Every bite forces food into the interface of the teeth to be chopped, while lateral motion of the jaw is used to grind food in the premolars and molars.

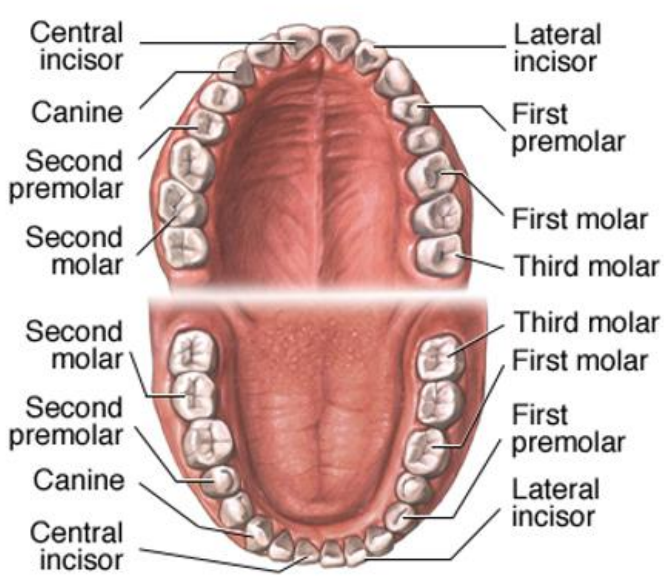
Teeth also provide shape to the mouth and face and are important components in producing speech. Teeth form deep roots into the bones of the maxillae and the mandible but grow out through the gums of the mouth to form biting surfaces. The gums, or **gingiva**, are soft mucous membranes surrounding the teeth, protecting the roots from decay and helping to hold the teeth in place.

A tooth can be divided into two main parts: the **crown** and **root**. The **crown** is the enlarged region of the tooth above the gum line, involved in chewing. Like an actual crown, the crown of a tooth has many ridges on its top surface to aid in the chewing of food. The **root** is the tapered region below the gum line of the tooth, which anchors the tooth into a bony socket known as an **alveolus**. Each tooth may have between one to three roots. The exterior surface of the root is covered in a bone-like mixture of calcium and collagen fibers known as **cementum**. Cementum provides grip for the periodontal ligaments that anchor the root to the surrounding alveolus.

Each tooth is an organ consisting of three layers: the **pulp**, **dentin**, and **enamel**. Typically, a total of **32** permanent adult teeth form and erupt. The adult teeth are arranged with 8 teeth in 4 quadrants (upper and lower, right and left).

Teeth are classified into **4** major groups and there are 8 teeth in one of four quadrants as follows:
2 incisors (1 central and 1 lateral) - chisel-shaped teeth found in the front of the mouth.
1 canine (cuspid) - sharply pointed, cone-shaped teeth on both sides of incisors.
2 premolars (bicuspid) - large, flat-surfaced teeth found in the back of the mouth.
3 molars (tricuspids) – the 3rd molars are the 'wisdom' teeth.

The Teeth



Babies are born without teeth and between the ages of six months and three years grow a temporary set of twenty **deciduous** teeth that fall out when the permanent teeth arrive. There are eight incisors, four canines, and eight molars. Adult teeth develop while hidden within the maxilla and mandible after the deciduous teeth have erupted. When an adult tooth erupts, it triggers the roots of the tooth deciduous above it to atrophy. This causes the baby tooth to become loose and fall out. Then this can lead to the commencement of a period of collecting some cash from the tooth fairy on a regular basis.

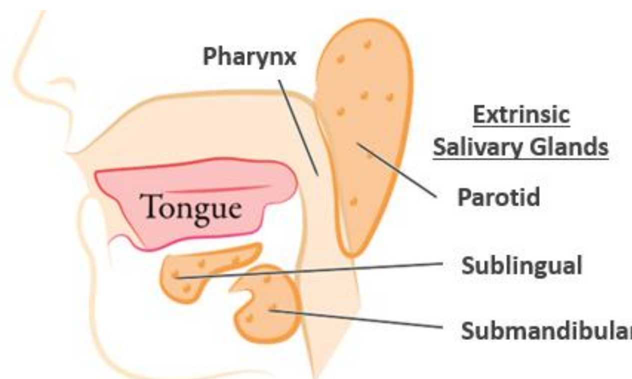
Salivary Glands

Saliva is composed mostly of water and mucous, but it also contains lingual amylase, an enzyme that breaks down starch, and lysozyme, an antibacterial agent in saliva that protects the body.

Intrinsic salivary glands – there are many small salivary glands that are located inside the oral cavity embedded in the lips and cheeks.

Extrinsic salivary glands – there are **3** sets of larger salivary glands that are located outside of the oral cavity but have ducts delivering secretion to the oral cavity. Each salivary gland is a complex, the secretory portions of these glands are rounded and called acini (for acinar or rounded). The acini secrete their contents into specialized ducts. Each gland is divided into smaller segments called lobes. Salivation occurs in response to the taste, smell or even appearance of food.

Parotid gland is the largest of the three major pairs of salivary glands. It is a serous gland and located anteriorly and inferiorly to the ear between the skin and the masseter muscle of chewing. The parotids produce about 25% of saliva and it is a serous (watery) secretion which is also rich in proteins. Immunoglobins are secreted help to fight microorganisms and a-amylase proteins start to break down complex carbohydrates. The parotid duct delivers saliva into the oral cavity at the second molar of the upper jaw. It is the parotid gland that becomes swollen and infected with the mumps.



Submandibular gland is a serous gland, located inferiorly to the mandible and it has a muscular covering and empties its contents by way of the submandibular duct into the floor of the mouth on both sides. This gland secretes 70% of the saliva in the mouth. These glands produce a more viscid (thick) secretion, rich in mucin and with a smaller amount of protein. Mucin is a glycoprotein that acts as a lubricant.

Sublingual gland is the smallest of the three, is a mucus gland and as its name implies, lies under the floor of the mouth and on either side of the tongue. Covered by a thin layer of tissue at the floor of the mouth, they produce approximately 5% of the saliva and their secretions are very sticky due to the large concentration of mucin. The main functions are to provide buffers and lubrication. Each sublingual gland possesses several small sublingual ducts that empty into the floor of the mouth in an area posterior to the submandibular duct.

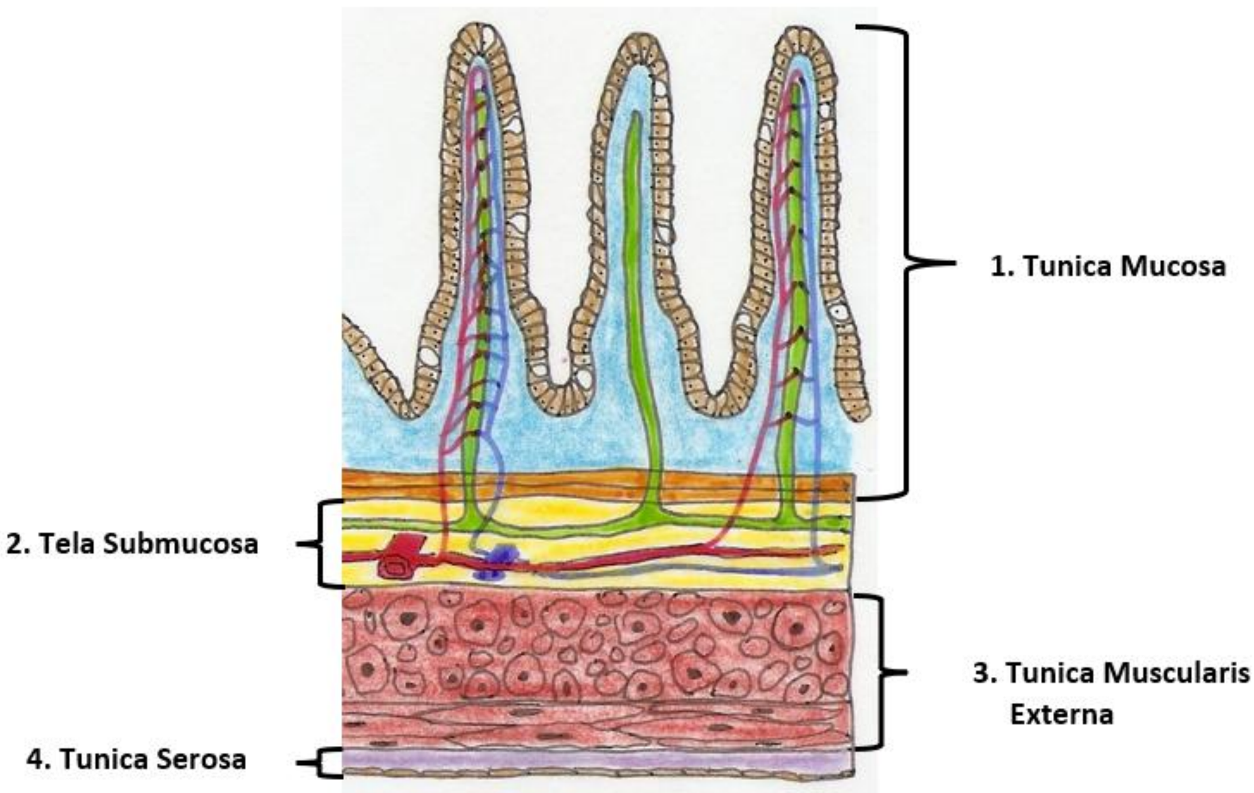
Pharynx

The throat is the **pharynx**, a funnel-shaped tube posterior to the mouth. The pharynx connects the nasal cavity and mouth to the **esophagus** and **larynx** (voice box) in the neck. The region of the throat forming the posterior wall of the mouth is the **oropharynx**. Food in the mouth is swallowed into the oropharynx and passed on to the **laryngopharynx** and then to the **esophagus** and the rest of the G.I. tract. Air inhaled through the mouth or nose also passes through the pharynx on its way to the larynx, and then passes through the pharynx on its way out of the body during exhalation.

As food is swallowed and it exits the oral cavity, the processes of propulsion, digestion and absorption become highly automated throughout the rest of the tract. The food continues on to the following general regions: Esophagus - > Stomach - > Small Intestine - > Large Intestine - > Eliminated from body.

Before we continue with detailed descriptions of each of these regions, it is useful to know the wall of the hollow G.I. tract has 4 distinct layers. Below is an overview of the four layers and their basic function.

The 4 Layers of the G.I. Tract Wall



1. Tunica Mucosa

The tunica mucosa is the innermost layer of the digestive tract, this is the surface that is in direct contact with ingested nutrients. It is a mucous membrane and is composed of 3 parts: **a)** specialized epithelial cells; **b)** underlying areolar connective tissue called the 'lamina propria'; and **c)** a layer of smooth muscle called the muscularis mucosae.

Depending on its function, the epithelium may be stratified (for protection) or simple (for absorption). The mouth, esophagus and anal canal are covered with a stratified squamous epithelium so they are protected from the wear and tear of passing material. Simple columnar (and glandular epithelium) lines most of the G.I. tract, such as the stomach, small and large intestines to aid secretion and absorption. The inner lining is constantly shed and replaced, making it one of the most rapidly dividing areas of the body! The lamina propria contains blood vessels, nerves, lymphoid tissue and glands that support the mucosa. The thin strip of smooth muscle that makes up the muscularis mucosae represents the lower boundary of the tunica mucosa and contracts to change the shape of the lumen.

2. Tela Submucosa

This is deep to the muscularis mucosa and is mostly areolar connective tissue with large blood vessels and nerves, as well as adipose (fat) and fibrous connective tissue. At its outer margin there is a specialized nerve plexus called the submucosal (Meissner) plexus. This radiates upwards and supplies the tunica mucosa and the tela submucosa.

3. Tunica Muscularis Externa.

This layer is usually composed inner circular and outer longitudinal smooth muscle layer, with the two muscle fibers separated by the **Myenteric Plexus**, giving neural innervation and controls the contraction of these muscles and hence the mechanical breakdown and peristalsis of the food within the lumen.

4. Tunica Serosa or Tunica Adventitia.

This outermost layer of the G.I. tract is either a serous membrane (tunica serosa) if the region of the tract is inside the peritoneal cavity, or it is a fluffy fibrous connective tissue (tunica adventitia) if it is located outside of the peritoneal cavity.

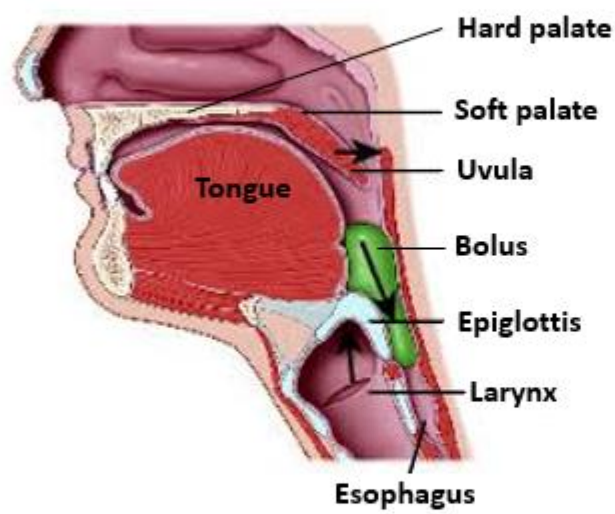
Quickie Review of Regional Histological Anatomy Descriptions:

The oral cavity or mouth is responsible for the intake of food. It is lined by a **stratified squamous epithelium** and it can be either keratinized (more protective) and non-keratinized (more absorptive).

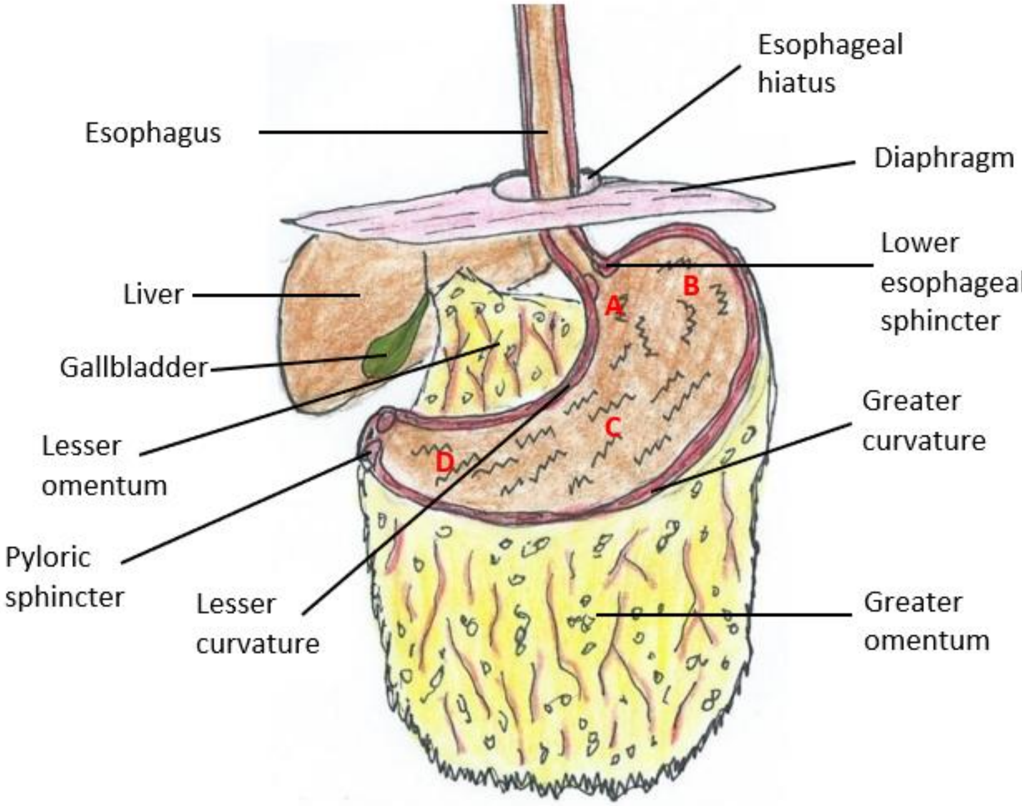
In areas of the mouth that are subject to significant abrasion, such as the tongue, the gums, the hard palate and the roof of the mouth, it is keratinized. For other areas, like the cheeks and lips, there is the protective but non-keratinized epithelial lining.

'Insalivation' refers to the mixing of the oral cavity contents with salivary gland secretions. The **mucin** (a glycoprotein) in saliva acts as a lubricant. The oral cavity also plays a limited role in the digestion of carbohydrates. The enzyme **lingual amylase** is a normal component of saliva and it starts the process of digestion of complex carbohydrates in the mouth.

Although it is not a significant function of the ora cavity, it actually can have a role in absorption of small molecules from the mouth, such as glucose and water, across the mucosa. From the mouth, food is pushed toward the back and the swallowing reflex is engaged in as the food or fluid (called a **bolus** once it is swallowed) passes through the pharynx and into the **esophagus** via the action of swallowing.



The action of swallowing is very complex, involving voluntary and involuntary actions and the coordination of 30 muscles in and around the mouth. The tongue prepares and moves the **bolus** of food or liquid toward the **soft palate**, and the tail of it is the **uvula** which blocks any entry of the bolus into the nasal cavity. The **epiglottis** covers the entry into the **larynx** (protecting the airways) encouraging the bolus to move into the **laryngopharynx** through to the **upper esophageal sphincter**, allowing it into the **esophagus**. The bolus travels down the esophagus which is a long muscular tube that delivers the bolus to the stomach.



Esophagus
The esophagus is a muscular tube of approximately **10** inches long and a little less than 1 inch in diameter. It extends from the pharynx to the stomach, going through an opening in the diaphragm called the **esophageal hiatus**. The esophagus functions primarily to transport the bolus from the mouth to the stomach. It only extends about 2 inches into the abdominal cavity before becoming the stomach. Just proximal to the gastro-esophageal junction is the **lower esophageal** (cardiac) **sphincter**, which prevents regurgitation of stomach contents into esophagus.

The muscular wall of the esophagus changes or transitions as it travels down to the stomach. The proximal 1/3 is skeletal muscle; the middle 1/3 is both skeletal and smooth and the distal 1/3 is entirely smooth muscle, made up of an inner circular and outer longitudinal layer of muscle supplied by the esophageal nerve plexus. This nerve plexus surrounds the lower portion of the esophagus.

Stomach
The stomach is a J shaped expanded bag, located just left of the midline between the esophagus and small intestine. It is divided into four main regions and has two borders called the greater and lesser curvatures. The first section is the **cardia** which surrounds the cardial orifice where the esophagus enters the stomach. The **fundus** is the superior, dilated portion of the stomach that has contact with the left dome of the diaphragm. The **body** is the largest section between the fundus and the curved portion of the J. The last section of the stomach is the **pylorus**, which contains the pyloric sphincter.

This body is where most gastric glands are located and where most mixing of the food occurs. Gastric contents are expelled into the proximal duodenum via the pyloric sphincter. The inner surface of the stomach is contracted into numerous longitudinal folds called rugae. These allow the stomach to stretch and expand when food enters. The stomach can hold up to 1.5 Liters of materials. The functions of the stomach include: The short-term storage of ingested food. Mechanical breakdown of food by churning and mixing motions. Chemical digestion of proteins by acids and enzymes. Stomach acid kills bugs and germs. Some absorption of substances such as alcohol. Most of these functions are achieved by the secretion of stomach juices by gastric glands in the body and fundus. Some cells are responsible for secreting acid and others secrete enzymes to break down proteins.

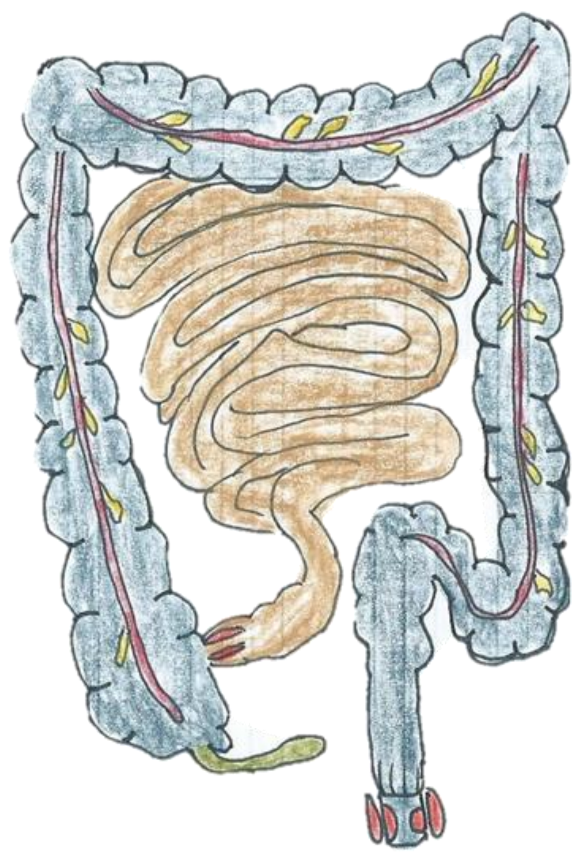
Stomach – acidic (pH 2) storage of chyme – a semi-liquid material. This region is important in the continuation of mechanical **digestion**, for example the significant churning of the stomach to create **chyme** ('juice'). This is the only region of the entire tract that has 3 muscle layers for the significant churning and mixing activity. In addition to the usual circular and longitudinal muscle layers in the tunic muscularis externa, there is the **oblique** layer that is innermost; followed by **circular** and **longitudinal** muscle layers.

The start of **enzymatic digestion** of proteins occurs here (Pepsin breaks down proteins). The process of **nutrient absorption** does not occur in the stomach. The only things that are absorbed are alcohol and aspirin – either one of which, less is more, especially aspirin. Both of these substances erode away the protective mucous coat that covers and the simple columnar epithelium of the stomach.

The **rugae** of the stomach are internal 'wrinkles' which allow for expansion of the structure when volume of contents increases. Production and secretion of gastric juices controlled by CNS in a reflex network! This is mostly triggered by the ingestion of proteins and fats. Important cells of the gastric glands are **Parietal cells:** make Hydrochloric acid (HCl) in gastric glands; and **Chief cells:** make Pepsinogen, which is cleaved to pepsin (↑HCl), to digest proteins.

Small Intestine

The 20 or so feet of small intestine extend from the pyloric sphincter of the stomach to the ileocecal valve separating the ileum from the cecum. It is compressed and folded over but still occupies a large proportion of the abdominal cavity.



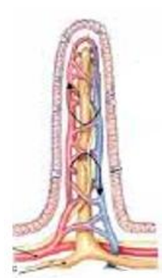
The Small Intestine has 3 Regions

Duodenum – about 10 inches long. It is the proximal C-shaped region that curves around the head of the pancreas. The duodenum serves a crucial function as it receives digestive secretions from the pancreas (pancreatic juices) and bile from the liver at the greater duodenal papilla that immediately mix with the contents passing through the pyloric sphincter from the stomach.

Jejunum – about 8 feet long. The start of the jejunum is marked by a sharp bend, the duodenojejunal flexure. It is in the jejunum where the majority of digestion and absorption occurs.

Ileum – about 12 feet long. This is the final and longest segment and continues the absorption of nutrients. The ileum empties into the cecum at the ileocecal junction.

The small intestine performs most of the digestion and absorption of nutrients. Partly digested food from the stomach is further broken down by enzymes from the pancreas and bile salts from the liver and gallbladder. These secretions enter the duodenum at the **greater duodenal papilla**. After further digestion, food constituents such as proteins, fats, and carbohydrates are broken down to small building blocks and absorbed into the body's blood stream. The lining of the small intestine is made up of numerous folds called **plicae circulares**. Each plica has numerous **villi** (folds of mucosa) and each villus is covered by columnar epithelium with projecting **microvilli** (brush border). All of these anatomical arrangements increase the surface area for absorption by a factor of several hundred. The mucosa of the small intestine contains several specialized cells. Some are responsible for absorption, whilst others secrete digestive enzymes and mucous to protect the intestinal lining from digestive actions.



Villi of Small Intestine – these are the finger-like projections that help to increase the surface are for absorption (see image at right). Contained within the villi are a collection of blood and lymphatic vessels, called the **vascular arcade**, which arise from the superior mesenteric a. In medical anatomical terminology, an arcade is any structure composed of a series of arches. There is also nerve fibers that travel up into the arcade.

Mesentery Proper - is a double layered serous membrane attached to the small intestine. **Roles:**

- Supports branches of blood vessels.
- Supports lymphatics of the jejunum and ileum.
- Supports nerves of the jejunum and ileum.

The Large Intestine

The large intestine extends around the periphery of the small intestine like a frame. It consists of the appendix, cecum, ascending, transverse, descending and sigmoid colon, and the rectum. It has a length of approximately 4.5 feet and a width of about 3 inches.

Functions of Large Intestine

1) Reabsorbs water and compact feces.
2) Absorbs vitamins and electrolytes and helps make Vitamin K.
3) Stores fecal matter.

The **cecum** is the first part of the large intestine and so receives the contents from the ileum and so contains the **Ileocecal valve**. It is like a blind-ended pouch and the vermiform appendix attaches to its terminal end. From the cecum, the Colon begins, it is composed of 4 regions: **Ascending Colon**, **Transverse Colon**, **Descending Colon** and **Sigmoid Colon**. There are two points where the colon 'turns' and these are called flexures. The **right colic** (or hepatic) **flexure** occurs where the ascending turns into the transverse colon; and the **left colic** (or splenic) **flexure** occurs where the transverse turns into the descending colon.

Anatomically, the cecum is an expanded pouch that receives material from the ileum and starts to compress food products into fecal material. It also has the **vermiform appendix** attached to it at its base. Food then travels along the **colon** (regions outlined above). The wall of the colon is made up of several pouches (**haustra**) that are held under tension by three thick bands of muscle (**taenia coli**). The rectum is the final 15cm of the large intestine after the distal portion of the colon (sigmoid colon). It expands to hold fecal matter before it passes through the anorectal canal to the **anus**. Thick bands of muscle, known as sphincters, control the passage of feces.

The mucosal lining of the large intestine lacks the villi that are seen in the small intestine. The mucosal surface instead is very flat with several deep intestinal glands. Numerous goblet cells line the glands that secrete mucous to lubricate fecal matter as it solidifies. The functions of the large intestine can be summarized as: The accumulation of unabsorbed material to form feces. Some digestion by bacteria. The bacteria are responsible for the formation of intestinal gas. Reabsorption of water, salts, sugar and vitamins. The Large Intestine begins as pouch inferior to end of ileum and ends at anus.

The Peritoneum: Two layers

Visceral peritoneum (a.k.a. serosa) – is the outermost surface of the organs in the peritoneum.
Parietal peritoneum – Lines inner surfaces of abdominal wall creating a cavity within the abdomen.

These two layers of the peritoneum, the visceral (of the organ) and the parietal (wall), are just the two serous membrane s that are within the abdominal cavity. These layers technically can only be found in the **peritoneal cavity**, which exists within the abdominal cavity.

Mesenteries: Fused double sheets of peritoneal membrane to suspend portions of digestive tract. In general, there are 4 main types:

Greater omentum – from the greater curvature of the stomach, it drapes over all of the intestines and other abdominal structures like an "apron of fat" providing insulation and protection.

Lesser omentum – from the lesser curvature of the stomach connecting to the liver, it tethers these two organs loosely to one another.

Mesentery proper – this is specific to the small intestine. It is really like a double-layer of serous membrane, since it is a continuation and fusion of the outer layer of the GI tract (the tunica serosa) that allows for the passageway of blood vessels nerves and lymphatics to and from the intestines. It also allows the entire 20 or so feet of small intestines to be held together but also permits movement too.

Mesocolon – this is specific to the colon, and also a double-layered serous membrane that gives stability to the various regions of the colon and allows for the passageway of blood vessels nerves and lymphatics to and from the colon.

The Liver

The liver is a large, reddish-brown organ situated in the right upper quadrant of the abdomen. It is surrounded by a strong capsule and divided into four lobes namely the **right, left, caudate** and **quadrate lobes.** The liver has several important functions. It acts as a mechanical filter by filtering blood that travels from the intestinal system. It **detoxifies** several metabolites including the breakdown of bilirubin and estrogen. In addition, the liver has synthetic functions, producing the plasma protein **albumin** and blood clotting factors. However, its main roles in digestion is in the production of **bile** and the subsequent metabolism of nutrients.

All nutrients absorbed by the intestines must pass through the liver and are processed here before traveling to the rest of the body. The bile produced by the **hepatocytes** of the liver are delivered through a series of ducts to the gallbladder and then enter the intestines at the duodenum. Here, bile salts break down lipids into smaller particles so there is a greater surface area for digestive enzymes to act. The liver also has resident macrophages called **Kupffer cells** that hang around in the sinusoids!

The Gallbladder

The gallbladder is a muscular pear-shaped pouch-like organ nestled in a fossa on the posterior surface of the liver's right lobe. It consists of a fundus, body and neck. It empties via the cystic duct into the biliary duct system. The gallbladder does not make bile, but it stores in and concentrates it and releases large amounts of it when triggered by the ingestions of lipids.

Bile is made by hepatocytes of the liver and is composed mostly of cholesterol salts for the **emulsification** of ingested fats in the intestines, and not for the digestion of fats, but emulsification does aid in enzymatic digestion. Lipid emulsification is when one large lipid droplet is made into many smaller lipid droplets. This creates a larger surface area for the lipase enzymes to act on, and therefore makes lipid digestion more effective.

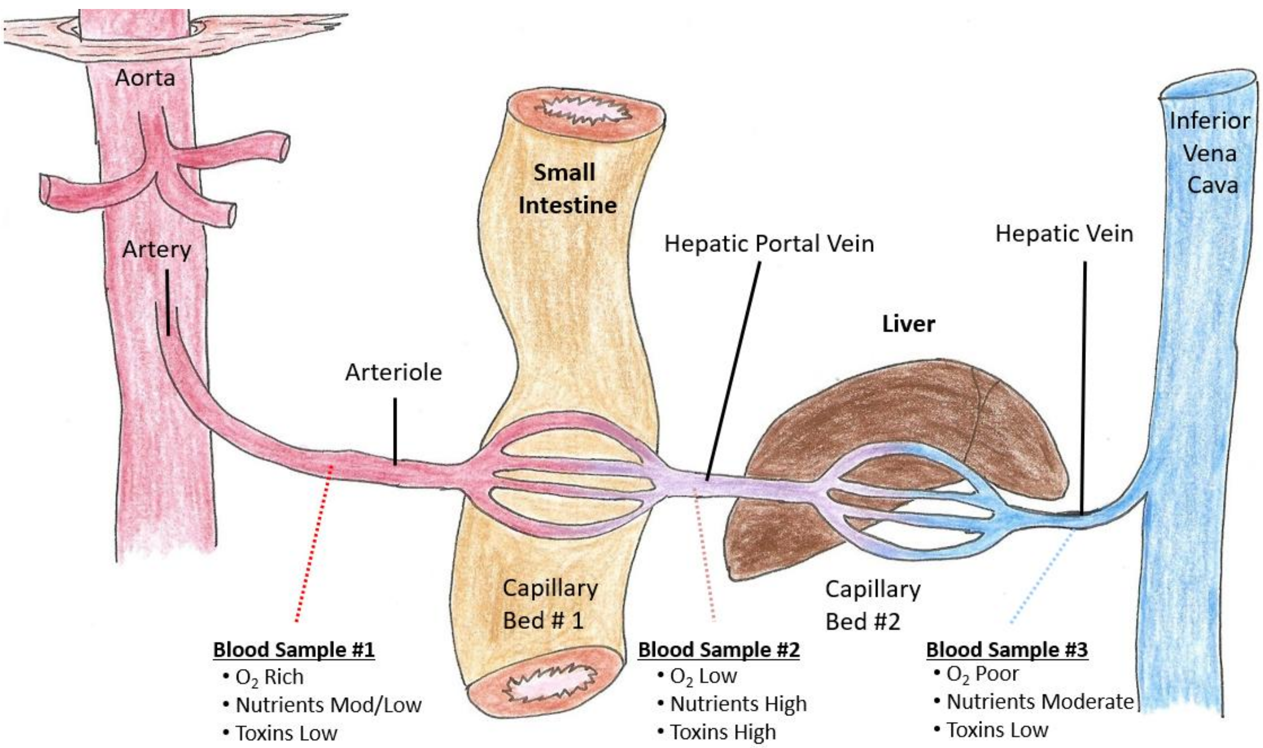
Bile is stored and concentrated in the gallbladder until it is needed. The release of bile from the gallbladder is triggered in response to hormone signals from the duodenum to the presence of foods rich in lipids. This causes contractions of its muscular walls and pushes bile down the cystic duct to the common bile duct and into the duodenum at the greater duodenal papilla.

The Hepatic Portal System

In the cardiovascular system a **portal system** is a vascular arrangement linking 2 different capillary beds in series (one coming before the other) from one organ to another organ by connecting vessels. It involves two distinct sets of capillaries before returning to the heart.

There are three (3) examples of Portal Systems in the Body:
1) Hepatic Portal System
2) Renal (Nephron)
3) Hypothalamic - Hypophyseal

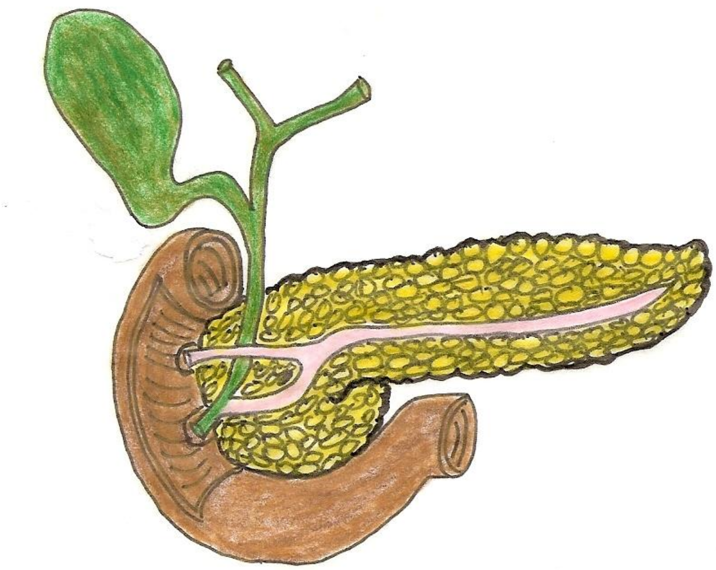
In digestive system, this is called the hepatic portal system, and it connects the capillaries of the **small intestine** with the capillaries of the **liver**. The main purpose of the hepatic portal system is to stabilize the systemic blood after a meal. The first set of capillaries function to transport nutrient-rich oxygen-poor blood mostly from the small intestines, but also from the large intestines, spleen, and pancreas to the liver by way of the **portal hepatic vein** – this is the vessel that connects to 2 capillary beds: Capillary bed #1 is from the gastrointestinal (GI) tract), and capillary bed #2 are the sinusoids of the liver (see drawing below).



It is in the liver that this blood is **processed**, **detoxified**, and sorted for storage as a way of stabilizing the potentially highly variable blood as it exits the intestines. In this way it stabilizes the contents of blood coming from the GI tract prior to it returning to the inferior vena cava, and therefore into the general circulation. This portal arrangement allows for the delivery of nutrient rich blood to the liver that contains various levels of glucose, lipids, amino acids, vitamin, etc., and balance these levels in the blood. The liver also acts to filter out harmful toxins and to reduce their toxicity prior to elimination of them from the body as fecal matter or urine.

The Pancreas

The pancreas is a lobular, pinkish-grey organ that lies behind the stomach. Its head communicates with the duodenum and its tai The hepatic portal system's main function is to transport nutrient-rich, oxygen-poor blood from the gastrointestinal (GI) tract, spleen, and pancreas directly to the liver for processing, detoxification, and storage before it enters general circulation. This "first-pass" system allows the liver to regulate blood sugar, convert nutrients (like glucose and amino acids) for the body's use, and filter out toxins, acting as a critical defense mechanism for the body. l extends to the spleen. The organ is approximately 6 inches in length with a long, slender body connecting the head and tail segments. The pancreas has both **exocrine** and **endocrine** functions.



The exocrine (secretory) portion makes up the bulk of the pancreas (80-85%) and is the area relevant to the GI tract. It is made up of numerous rounded acinar glands called acini that secrete contents into ducts which deliver the digestive enzymes, called **pancreatic juices**, to the duodenum at the greater duodenal papilla. The acini of the pancreas secretes fluid rich in carbohydrates and inactive enzymes. Secretion is triggered by the hormones released by the duodenum in the presence of food. Pancreatic enzymes include **amylases** (for the digestion of carbohydrates), **lipases**, (digests lipids), **proteases** (digests proteins), and **nucleases** (digests nucleic acids like GTP and DNA) – all enzymes that can break down different components of food, indicated by the names of the enzymes. These are secreted in an inactive form to prevent digestion of the pancreas itself. The enzymes become active once they reach the **duodenum**, due to the change in the pH of the environment there.

The endocrine function involves the production of hormones which are made in the **Islets of Langerhans** (an eponym), also known as the **pancreatic islets**. The islets produce **insulin**, **glucagon** and other substances and these are the areas damaged in diabetes mellitus.