BP 201T. HUMAN ANATOMY AND PHYSIOLOGY-II (Theory)

PREPARED BY,
Dr.REMYA RADHAKRISHNAN
ASSISTANT PROFESSOR
RAMA UNIVERSITY
KANPUR

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DIGESTIVE SYSTEM

Anatomy of GI Tract with special reference to anatomy and functions of stomach, (Acid production in the stomach, regulation of acid production through parasympathetic nervous system, pepsin role in protein digestion) small intestine 54 and large intestine, anatomy and functions of salivary glands, pancreas and liver, movements of GIT, digestion and absorption of nutrients and disorders of GIT.

DIGESTIVE SYSTEM

DEFINITION

Digestion involves the breaking of complex organic food molecules into simpler one by hydrolysis. Carbohydrates, proteins, fats and nucleic acids are large complex organic food molecules. They are insoluble and polymeric in nature. During digestion different enzymes helps in breakdown of these complex polymers into soluble monomers which are required for energy generation.
The different steps of digestion involve:

Movement of food through the alimentary tract
Secretion of digestive juices and digestion of food
Absorption of water, various electrolytes, vitamins and digestive end products.

Human digestive system mainly consists of two parts:

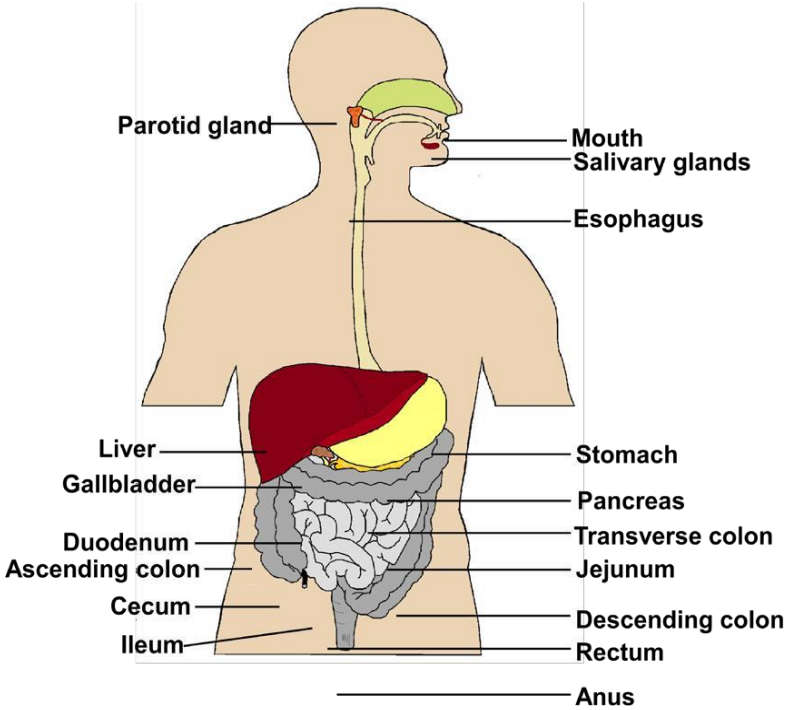
1) Alimentary tract
2) secretory glands

Alimentary tract: It provides continual supply of nutrients, vitamins, electrolytes and ater.
The following steps involved to achieve this.

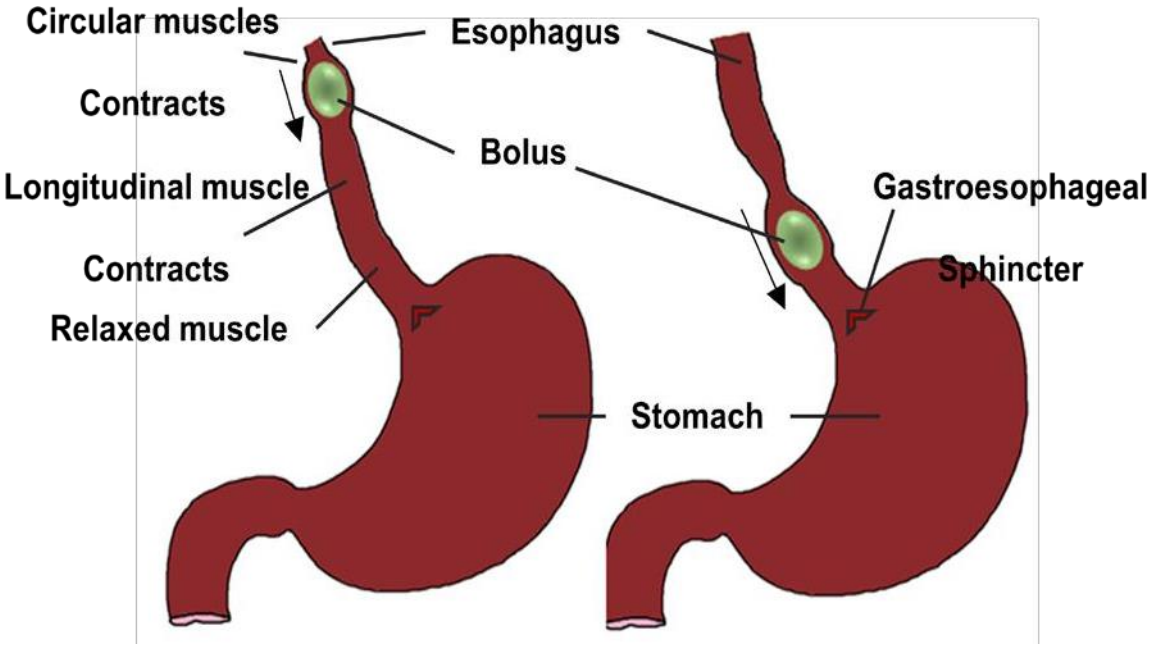
- Movement of food through tract
- Secretion of digestive juices
- Digestion of food components
- Absorption of digestive product and water
- Excretion of unabsorbed food.

PARTS OF THE DIGESTIVE SYSTEM

Mouth: Human mouth consists of vestibule and oral cavity. The slit like space between cheeks and gums is known as **vestibule**. The cavity surrounded by palate, tongue and teeth is known as **oral cavity** or **buccal cavity**. Mouth is the first passage of food where large piece of food is fragmented to small pieces with the help of teeth and mixed with saliva. Tongue manipulates food during chewing and mixing with saliva. This mixture of food with saliva, **bolus**, is then moved inward through pharynx into Esophagus. This process is known as **deglutition** or **swallowing**.



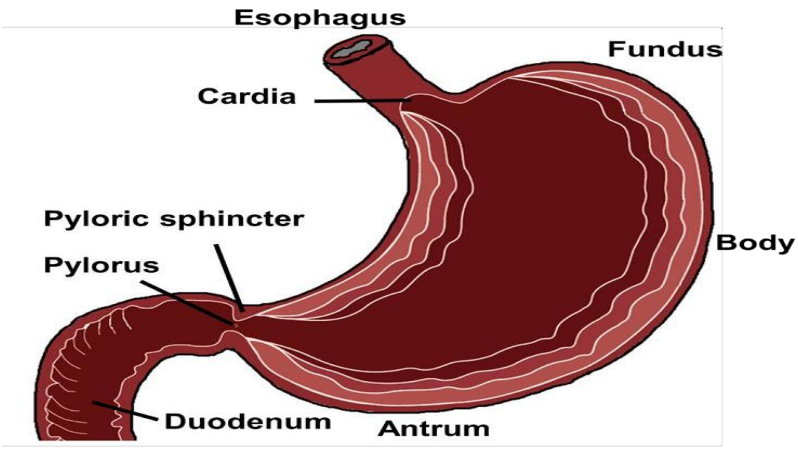
Esophagus: It is also known as **food pipe** or **gullet**, is about 25 cm long. It is found behind the trachea and heart. Its primary function is to conduct food from pharynx to the stomach. Food in esophagus is pushed downward by involuntary muscle contraction of circular muscle, this movement is called as **peristalsis**. Due to contraction of the longitudinal muscles lower part of esophagus become short which pushes its wall outward so that it can receive the bolus. The circular muscles of esophagus then relax. The contractions are repeated in a wave that moves downward to the stomach .The cardiac sphincter lies between esophagus and stomach allows the conduction of bolus into stomach. The sphincter closes again. Medulla oblongata controls the peristalsis.



Peristalsis.

Stomach: It is the widest organ of the alimentary canal. It is divided into two major parts 1) the **body** and 2) the **antrum**. Physiologically we can divide it into 1) the *orad portion* (first two third of the body) 2) the *caudad portion* (remainder portion of body and antrum).

As food enters in the orad portion of stomach, it forms concentric circles. When food stretches the wall of stomach, vagovagal reflex travels from stomach to brain and back to stomach. Due to which the tone of muscular wall of stomach body reduces and the wall starts bulging out so that it accommodate greater quantity of food. In the completely relaxed stomach 0.8 to 1.5 litres food can occupy. After mixing of food with the stomach secretions, the resulting mixture is called **chyme**, further passes down the gut. Partial digestion of food (protein and fats) takes place here. It produce castle's intrinsic factor which is required for the absorption of vitamin B_{12} to be absorbed through intestinal wall.



Parts of stomach

Small intestine: It comprises three parts viz. **duodenum, jejunum** and **ileum**. Due to its small diameter, it is named so. The length of small intestine is correlated with the height of person but not with the weight. It is about 6.25 meters long. Thus, it is the longest part of alimentary tract. Chyme is conducted through small intestine by peristaltic movement. When chime stretches the intestinal wall, it elicits localized concentric contractions spaced at intervals cause segmentation of small intestine. In such a way chyme moves toward the anus at a speed of 0.5 to 2.0 cm/s. Movement in proximal parts is faster than terminal portion. During movement of chyme through small intestine complete digestion of proteins, carbohydrates, fats and nucleic acids occurs.

Large intestine: Its diameter is always larger than small intestine but it varies from one region to another. It is about 1.5 m long. It is divided into three parts: **caecum, colon** and **rectum**. Cecum is a pouch type structure. The outgrowth of cecum is a vestigial body known as *vermiform appendix*. The cecum is more developed in herbivorous mammals than carnivorous. The junction of ileum with cecum is guarded by the **ileocecal valve**. The function of this valve is to prevent backflow of fecal contents from colon to ileum. The valve can resist back pressure of at least 50 to 60 cm of water.

The main functions of colon are Absorption of electrolytes and water from chyme.
Temporary storage of fecal matter.

The proximal region of colon concerned mainly with absorption and distal region with storage. The colon has three longitudinal bands called *teniae coli* and small pouches called *haustra*. Thus the mixing movement in colon is called as **haustration**. The movement in colon are sluggish.

The lower portion of descending colon is sigmoidal in shape and opens into rectum. It is 20 cm long and terminates in the 2 cm long anal tract. When a mass movement propels

feces into rectum, the desire for defecation occurs.The opening of anal tract is called anus. The anus has two sphincter. Internal anal sphincter composed of smooth muscle fibre and external anal sphincter composed of striped muscle fibre (voluntary in nature). The moderate quantities of vitamin B complex and vitamin K also found by bacteria in large intestine.

SITE OF DIGESTION AND FINAL PRODUCTS.

Macromolecule	Digestion starts	Digestion complete	Final products
Carbohydrate	Mouth	Duodenum	Glucose
Protein	Stomach	Duodenum	Amino acids
Fat	Duodenum	Duodenum	Fatty acids & glycerol
Nucleic acid	Duodenum	Jejunum	Nitrogenous bases + pentose sugar + inorganic phosphate

Secretary Glands: The primary function of secretary glands is the secretion of digestive enzymes for digestion of food and mucus for lubrication and protection of tract. Most digestive secretion occurs in precise amount only in response to the presence of food in alimentary tract. We have discussed major digestive glands.

Salivary glands: The major gland of salivation are **parotid, submandibular** and **sublingual** glands. Along with this there are many small *buccal glands*. A Healthy individual secretes about 0.8 to 1.5 litres of saliva daily. Saliva mainly composed two major type of proteins. A) **Ptyalin** (an α-amylase) - for digestion of starch, B) **Mucin** – for protection of surface. Parotid glands are larges salivary glands situated near ears. The parotid glands secrete mainly ptyalin, whereas submandibular and sublingual glands secrete both ptyalin and mucin. The small buccal glands secrete only mucus. The pH of saliva is between 6 to 7 which favours the digestive action of ptyalin.

The esophageal glands secretes only mucous which provide lubrication for swallowing.

Gastric glands: The entire surface of stomach lining contains mucus- secreting cells. The stomach mucosa has two types of tubular glands: *Oxyntic glands* (gastric glands) and *pyloric glands*. The oxyntic glands secrete hydrochloric acid pepsinogen, intrinsic factor and mucus. The pyloric gland secretes mainly mucus for protection from stomach acid. They also secrete gastrin hormone.

Liver: It is larges gland of the body, mainly secrete bile normally between 0.6 to 1 litre/day. Bile serves two major function.

FAT DIGESTION AND ABSORPTION: Along with the enzymes for fat digestion bile acids in bile helps to emulsify the large fat particles of food into many small particles, the surface of which attacked by lipase enzymes secreted in pancreatic juice. Bile acids aid in absorption of end product digested fat through the intestinal mucosal membrane.

EXCRETION OF WASTE PRODUCTS FROM BLOOD: An important waste product bilirubin, an end product of haemoglobin digestion and excesses of cholesterol are excreted out with the help of bile.

A pear shaped structure attached to the posterior surface of the liver stores 30 to 60 ml bile secreted by the liver.

Pancreas: The pancreas is soft lobulated large compound gland whose internal structure is similar to salivary gland. It lies parallel to and posterior to stomach. *Pancreatic acini* secrete digestive enzymes whereas large amount of sodium bicarbonate solution are secreted by small ductules and larger ducts. The mixture of enzymes and sodium bicarbonates passes through a long pancreatic duct. Pancreatic duct joins with hepatic duct before it empties into duodenum through the *papilla of vater*.Pancreatic secretion contains enzymes for digesting all three major food component: carbohydrate, protein and fats.

ENZYMES	**SUBSTRATE**
Trypsin Chymotrypsin Carboxy peptidase	Protein
Pancreatic amylase	Carbohydrate
Pancreatic lipase Cholesterol-esterase Phospholipase	Fats

e)Intestinal glands: These are formed by modification of surface epithelium of small intestine. The two main intestinal glands are *Brunner's gland* and *Crypts of Lieberkühn*.

Brunner's glands are found only in first few centimetres of duodenum. They secrete large amount of alkaline mucus to protect the duodenal wall from highly acidic gastric juice and to neutralize hydrochloric acid.

Crypt of Lieberkühns are small pits located all over the entire surface of the small intestine, lies between the intestinal villi. They are covered by epithelium composed of two types of cells. 1) *Goblet cells*: secrete mucus. 2) *Enterocytes*: secrete water and

electrolyte, also reabsorb the water and electrolyte along with the end product of digestion over the surface of adjacent villi. At the base of these crypts, *paneth cells* and *argentaffin cells* are present.

LIST OF DIGESTIVE ENZYMES IN HUMAN

Enzyme	**Substrate**	**Site of action**
Ptyalin (salivary amylase)	Starch	Mouth
Pepsin Gastric Lipase	Proteins Little amount of fats	Stomach
Renin	Casein	Child's stomach
Pancreatic amylase	Starch	Small Intestine
Trypsin	Proteins	
Chymotrypsin	Proteins	
Elastase	Protein (Elastin)	
Carboxypeptidase	Large peptides	
Pancreatic lipase	Fats (Triglycerides)	
Nuclease	Nucleic acids (DNA, RNA)	
Enterokinase	Trypsinogen	
Aminopeptidase	Large peptides	
Dipeptidase	Dipeptides	
Disaccharidase	Disaccharide	
Intestinal lipase	Fats	
Nucleotidase	Nucleotide	
Nucleosidase	Nucleoside	

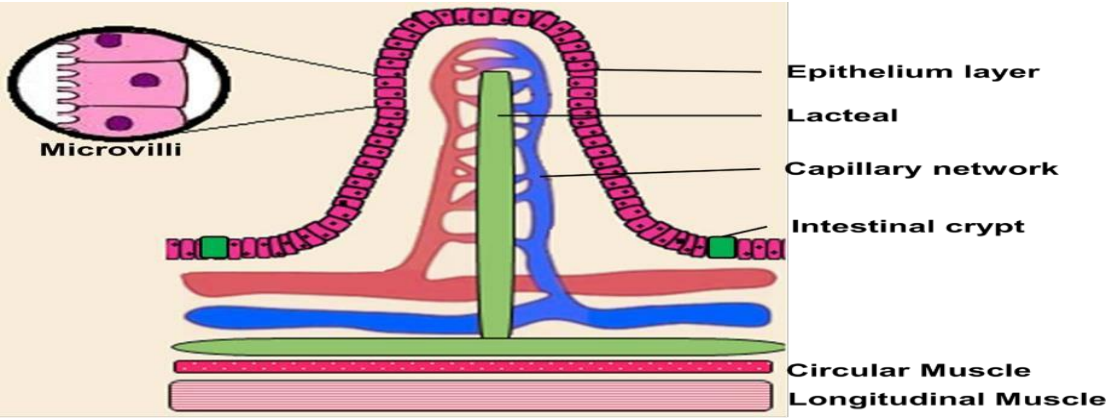
Paneth cells found mainly in duodenum are rich in zinc and contain acidophilic granules. Argentaffin cells synthesize secretin hormone and5-hydroxytryptamine.

ABSORPTION

It is the process by which simpler nutrients (monosaccharide, amino acids, fatty acids etc.) pass from alimentary tract into blood and lymph. It can be occur by simple diffusion, facilitated diffusion, osmosis and active transport.

Absorption starts from stomach but it is poor absorptive area because here junction between epithelial cells are tight junction and villi are absent on its inner wall. Little amount of water, salts, alcohol, few drugs and moderate amounts of sugar are absorbed through stomach. Absorption of nutrients mainly occurs in small intestine. Vitamins produced due to bacterial digestion and water absorbed in large intestine.

Intestines absorbs collective amount of ingested fluid and fluid secreted in gastrointestinal secretions. Throughout the inner wall of small intestine many folds called *valvulae conniventes* (also known as *folds of kerckring*) present, which increase the surface area for absorption. The valvulae conniventes covered by small protrusions known as *villi* (singular '*Villus*').



Longitudinal section of villi

Absorption of Monosaccharides: Absorption of glucose and galactose occur through active transport. Sodium pump on the cell membrane helps in its active transport. Fructose is absorbed by facilitated diffusion. Glucose, galactose and fructose are absorbed into the blood capillaries. Galactose is the most rapidly transported monosaccharide.

Absorption of amino acids: Amino acids are absorbed by active transport coupled with active sodium transport. They also enter the blood stream.

Absorption of fatty acids and glycerol: Fatty acids and glycerol are insoluble in water

thus they can't enter in blood stream directly. In intestinal lumen, bile salts and phospholipids incorporates fatty acids and glycerol into small, spherical water soluble droplets known as micelles. Fat soluble vitamins and sterols along with fatty acids and glycerol are absorbed by diffusion by the help of micelles into intestinal cells, where they are resynthesized in the endoplasmic reticulum and are converted into small droplets known as *chylomicrons*. Latter most of them released into lymph present in *lacteals* (lymphatic capillaries).

Absorption of water: Osmosis helps in the absorption of water in small intestine through epithelial cells surface and villi into the blood capillaries. In order to maintain the osmolality, electrolytes and digested food absorb along with water.

Absorption of electrolytes: Sodium can move in and out of epithelial cells by diffusion process and in mucosal cells it moves by active transport. Many others ions such as potassium, calcium, magnesium, iron and phosphate absorbed by active transport. Whereas chloride ions can be absorbed through diffusion or active transport. Vitamin D and parathyroid hormone enhance the absorption of calcium.

Absorption of vitamins: Most water soluble vitamins (Vitamin B complex, Vitamin C, Vitamin P) absorbed by diffusion. Castle's intrinsic factors play an important role in reabsorption of vitamin B_{12}.

Assimilation and egestion:

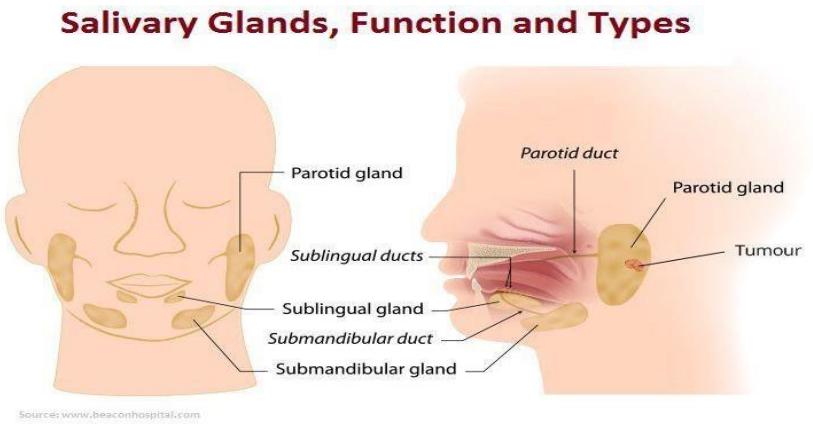
Finally, all absorbed nutrients transported by blood and lymph further transferred to blood circulation. With the help of blood nutrients reach to target body cells, where it become integral component of protoplasm and used for energy, growth and repair. This process is known as **assimilation**.

The excess of monosaccharide stores in liver and muscles in the form of glycogen by the process called *glycogenesis*. Excess of amino acids are converted into glucose and then to fat through an irreversible reaction and then stored. Most of the fats stored in subcutaneous layers and mesenteries.

Involuntary action of internal anal sphincter and voluntary action of external anal sphincter thus helps in defecation.Another important step is **egestion**, the process by which undigested food materials eliminated through anus in the form of faeces. Egestion occurs by peristalsis movement. After absorption of water in colon, chyme converted into semisolid faeces. When faeces enters into rectum, wall of rectum feels distension which induces desire of defecation due to a *defecation reflex*. Due to this reflex peristalsis initiated in the sigmoidal colon and reaches to anus through rectum.

SALIVARY GLANDS AND THEIR FUNCTIONS.

Salivary glands are present in the mouth and secrete saliva that helps in the digestion of food.

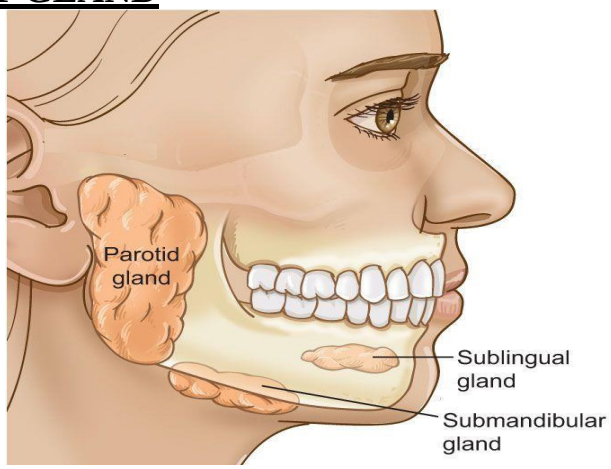


Salivary Glands are a group of organs present in our mouth that secretes saliva. It is found in mammals only. It is an exocrine gland that secretes substances outside the body or within a body cavity. Saliva contains various chemicals with water including mucus, salts, antibacterial substances, enzymes and chemicals that control the pH in the mouth.

FUNCTIONS OF SALIVARY GLAND

Saliva is a mixture of water, mucus, antibacterial substance, and digestive enzymes. Therefore, saliva has many uses. One of the digestive enzyme alpha-amylase helps to break down the starch present in our food into a simpler one like glucose and maltose. While chewing, we activate these glands to secrete an enzyme to breakdown the food. Saliva has lubricating properties. It protects the inside cavity of our mouth, teeth, and throats as we begin to swallow the food bolus. It also cleanses the mouth after the meal and dissolves it into chemicals that we perceive as taste.

TYPES OF SALIVARY GLAND



There are three pairs of glands through which most of the saliva is secreted and symmetrically located on both sides of the jaw. They secrete saliva through ducts. These glands are parotid, submandibular and sublingual.

PAROTID-GLAND

Parotid glands are the largest salivary gland. Each gland is approximately 6 cm long and 3-4 cm wide and can weigh up to 30 grams. They are located within each of our cheeks. In our oral cavity, they are responsible for the secretion of about 20% of saliva. This saliva is known as serous i.e. more liquid and fluid. It helps in the first phase of the digestion of food, facilitate mastication "chewing". These glands secrete a protein-rich fluid which is a suspension of alpha-amylase enzyme. Do you know why alcohol abuse is directly related to the lack of saliva? Because intake of alcohol or some drugs can affect the sympathetic nervous system and produces vasoconstriction of the parotid gland and reduces the secretion of saliva.

SUBMANDIBULAR-GLAND

These glands are located beneath the lower jaw, outside the oral cavity. This is the movable part of our jaw. It is the second-largest salivary gland and produces approx. 65-70% of saliva. It is a mixture of serous and mucous glands and released through submandibular ducts. Its saliva is more viscous as compared to the secretion of the parotid gland.

SUBLINGUAL-GLAND

It is the smallest of the major salivary glands. They are located under the tongue. Approximately 5% of the saliva comes from these glands. The saliva that comes out is mostly mucus, having a viscous texture and flows into the mouth through sublingual ducts. Sometimes, sialoliths also termed as salivary calculi, or salivary stones form in the ducts of salivary glands which block the flow of saliva and cause pain, swelling in the affected gland. Mostly, salivary stones affect submandibular glands and sometimes parotid too.

PANCREAS

Pancreas : most pancreatic enzymes are produced as inactivate molecules , or zymogens , so that the risk of self – digestion within the pancreas is minimized .

More than 98% of the pancreas mass is devoted to its exocrine function: the secretion of pancreatic juice by the pancreatic acini and their ductile cells. Ductile cells produce **Sodium bicarbonate** which helps neutralize the acidic gastric contents .

Acinar cells of the exocrine pancreas produce a variety of **digestive enzymes** to break

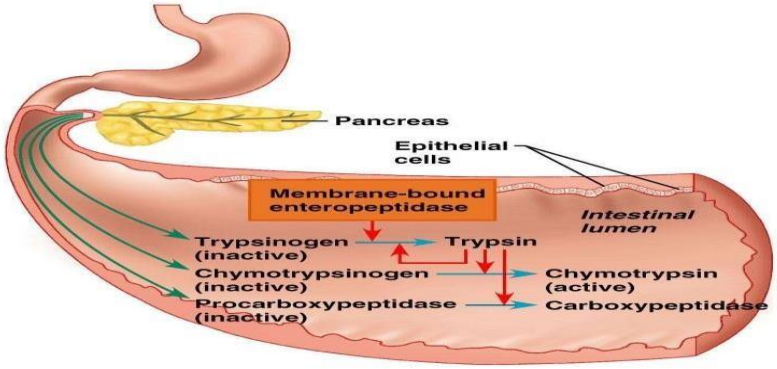
down food substances into smaller absorbable molecules .
Only 2% of pancreas mass is devoted to the islets of langerham , which produce **insulin** and **glucagon** , hormones that regulate blood sugar and carbohydrate metabolism (they have opposite effects) .

Major pancreatic enzymes include:

-**pancreatic amylase:** digest polysaccharides into disaccharides
- **pancreatic lipases** digest triglycerides into fatty acids .
- **pancreatic nucleases** digest nucleic acids into nucleotides .
-**Pancreatic proteinases** (all secreted in their inactive forms) digest peptides into amino acids:
Trypsinogen is activated by enterokinase (secreted by duodenum) into **trypsin** , which in turn activates the other 3 enzymes – **chymo- trypsinogen** becomes **chymotrypisn** , **proaminopeptidase** becomes **aminopeptidase**, **and procarboxypeptidase** becomes **carboxypeptidase**.

ACTIVATION OF PANCREATIC PROTEASES IN THE SMALL INTESTINE

PANCREATIC SECRETION



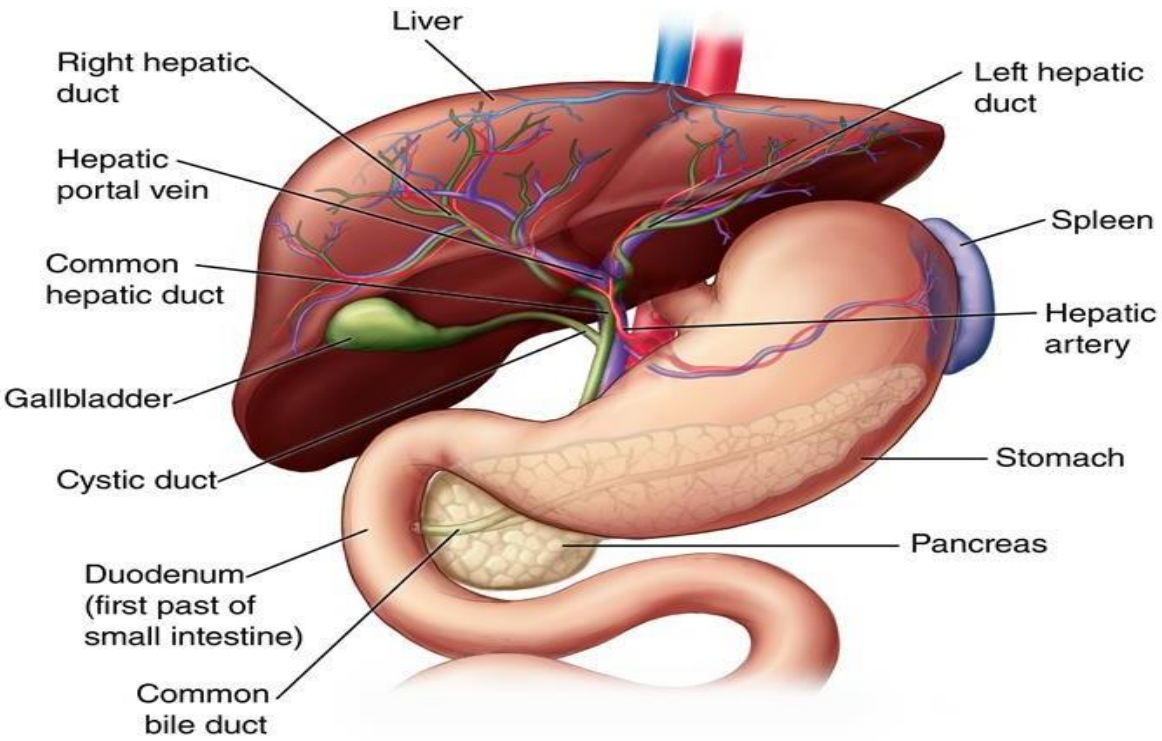
1. The parasympathetic nervous system increases pancreatic secretion
2. Two duodenual hormones also influence pancreatic secretion: Secretin and Cholecystokinin.
3. Food entering the small intestine stimulates the secretion of both hormones.
4. Secretin stimulates the secretion of pancreatic electrolyte – rich fluid , while CCK enhances the enzymatic secretions of the pancreas .

Regulation of pancreatic Juice

1. Acidic chyme enters duodenum.
2. Secretin is released into blood stream from intestinal mucosa.
3. Secretin stimulates pancreas.

4. Pancreas secretes pancreatic juice.
5. Pancreatic juice , high in bicarbonate ions , neutralizes acidic chyme

ANATOMY OF THE LIVER



The liver is located in the upper right-hand portion of the abdominal cavity, beneath the diaphragm, and on top of the stomach, right kidney, and intestines.
Shaped like a cone, the liver is a dark reddish-brown organ that weighs about 3 pounds.
There are 2 distinct sources that supply blood to the liver, including the following:
Oxygenated blood flows in from the hepatic artery
Nutrient-rich blood flows in from the hepatic portal vein
The liver holds about one pint (13%) of the body's blood supply at any given moment. The liver consists of 2 main lobes. Both are made up of 8 segments that consist of 1,000 lobules (small lobes). These lobules are connected to small ducts (tubes) that connect with larger ducts to form the common hepatic duct. The common hepatic duct transports the bile made by the liver cells to the gallbladder and duodenum (the first part of the small intestine) via the common bile duct.

FUNCTIONS OF THE LIVER

The liver regulates most chemical levels in the blood and excretes a product called bile. This helps carry away waste products from the liver. All the blood leaving the stomach and intestines passes through the liver. The liver processes this blood and breaks down,

balances, and creates the nutrients and also metabolizes drugs into forms that are easier to use for the rest of the body or that are nontoxic. More than 500 vital functions have been identified with the liver.

Some of the more well-known functions include the following:

- Production of bile, which helps carry away waste and break down fats in the small intestine during digestion
- Production of certain proteins for blood plasma
- Production of cholesterol and special proteins to help carry fats through the body
- Conversion of excess glucose into glycogen for storage (glycogen can later be converted back to glucose for energy) and to balance and make glucose as needed
- Regulation of blood levels of amino acids, which form the building blocks of proteins
- Processing of hemoglobin for use of its iron content (the liver stores iron)
- Conversion of poisonous ammonia to urea (urea is an end product of protein metabolism and is excreted in the urine)
- Clearing the blood of drugs and other poisonous substances
- Regulating blood clotting
- Resisting infections by making immune factors and removing bacteria from the bloodstream
- Clearance of bilirubin, also from red blood cells. If there is an accumulation of bilirubin, the skin and eyes turn yellow.

When the liver has broken down harmful substances, its by-products are excreted into the bile or blood. Bile by-products enter the intestine and leave the body in the form of feces. Blood by-products are filtered out by the kidneys, and leave the body in the form of urine.

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