Digestive system

DEGULITION

- The movement of food from the mouth into the stomach is achieved by the act of swallowing, or **deglutition** . Deglutition is facilitated by the secretion of saliva and mucus and involves the mouth, pharynx, and esophagus. Swallowing occurs in three stages:
- (1) the voluntary stage, in which the bolus is passed into the oropharynx;
- (2) the pharyngeal stage, the involuntary passage of the bolus through the pharynx into the esophagus; and
- (3) the esophageal stage, the involuntary passage of the bolus through the esophagus into the stomach

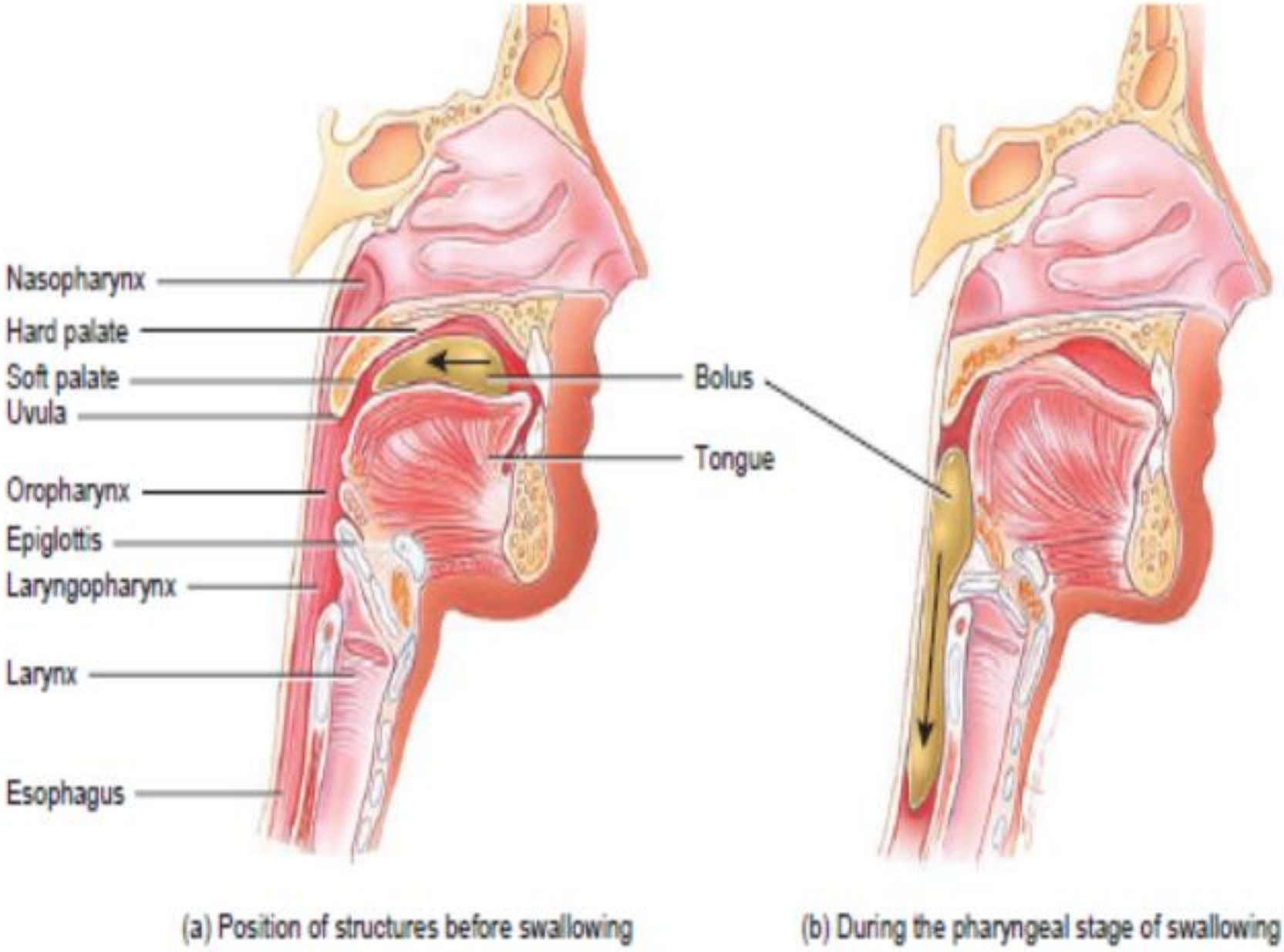
- Swallowing starts when the bolus is forced to the back of the oral cavity and into the oropharynx by the movement of the tongue upward and backward against the palate; these actions. constitute the **voluntary stage of swallowing. With the passage** of the bolus into the oropharynx, the involuntary **pharyngeal stage of swallowing begins**

- The bolus stimulates receptors in the oropharynx, which send impulses to the **deglutition center in the medulla oblongata and lower pons of** the brain stem. The returning impulses cause the soft palate and uvula to move upward to close off the naso pharynx, which prevents swallowed foods and liquids from entering the nasal cavity.

- In addition, the epiglottis closes off the opening to the larynx, which prevents the bolus from entering the rest of the respiratory tract.
- The bolus moves through the oropharynx and the laryngopharynx. Once the upper esophageal sphincter relaxes, the bolus moves into the esophagus

- The **esophageal stage of swallowing begins once the bolus** enters the esophagus. During this phase, **peristalsis** *, a progression of coordinated* contractions and relaxations of the circular and longitudinal layers of the muscularis, pushes the bolus onward
- (Peristalsis occurs in other tubular structures, including other parts of the GI tract and the ureters, bile ducts, and uterine tubes; in the esophagus it is controlled by the medulla oblongata.)
- In the section of the esophagus just superior to the bolus, the circular muscle fibers contract, constricting the esophageal wall and squeezing the bolus toward the stomach

- Meanwhile, longitudinal fibers inferior to the bolus also contract, which shortens this inferior section and pushes its walls outward so it can receive the bolus.
- The contractions are repeated in waves that push the food toward the stomach. As the bolus approaches the end of the esophagus, the lower esophageal sphincter relaxes and the bolus moves into the stomach.
- Mucus secreted by esophageal glands lubricates the bolus and reduces friction. The passage of solid or semisolid food from the mouth to the stomach takes 4 to 8 seconds; very soft foods and liquids pass through in about 1 second.


Nasopharynx
Hard palate
Soft palate
Uvula
Oropharynx
Epiglottis
Laryngopharynx
Larynx
Esophagus
Bolus
Tongue
(a) Position of structures before swallowing
(b) During the pharyngeal stage of swallowing

Summary of Digestive Activities in the Pharynx and Esophagus

STRUCTURE	ACTIVITY	RESULT
Pharynx	Pharyngeal stage of deglutition.	Moves bolus from oropharynx to laryngopharynx and into esophagus; closes air passageways.
Esophagus	Relaxation of upper esophageal sphincter.	Permits entry of bolus from laryngopharynx into esophagus.
	Esophageal stage of deglutition (peristalsis).	Pushes bolus down esophagus.
	Relaxation of lower esophageal sphincter.	Permits entry of bolus into stomach.
	Secretion of mucus.	Lubricates esophagus for smooth passage of bolus.

Stomach

- The **stomach is a J-shaped enlargement of the GI tract directly** inferior to the diaphragm in the Epigastric, umbilical, and left hypochondriac regions of the abdomen . The stomach connects the esophagus to the duodenum, the first part of the small intestine.
- In the stomach, digestion of starch continues, digestion of proteins and triglycerides begins,the semisolid bolus is converted to a liquid, and certain substances are absorbed.

Parts of the stomach

- In humans, stomach has four parts:

1. Cardiac region
2. Fundus
3. Body or corpus
4. Pyloric region.

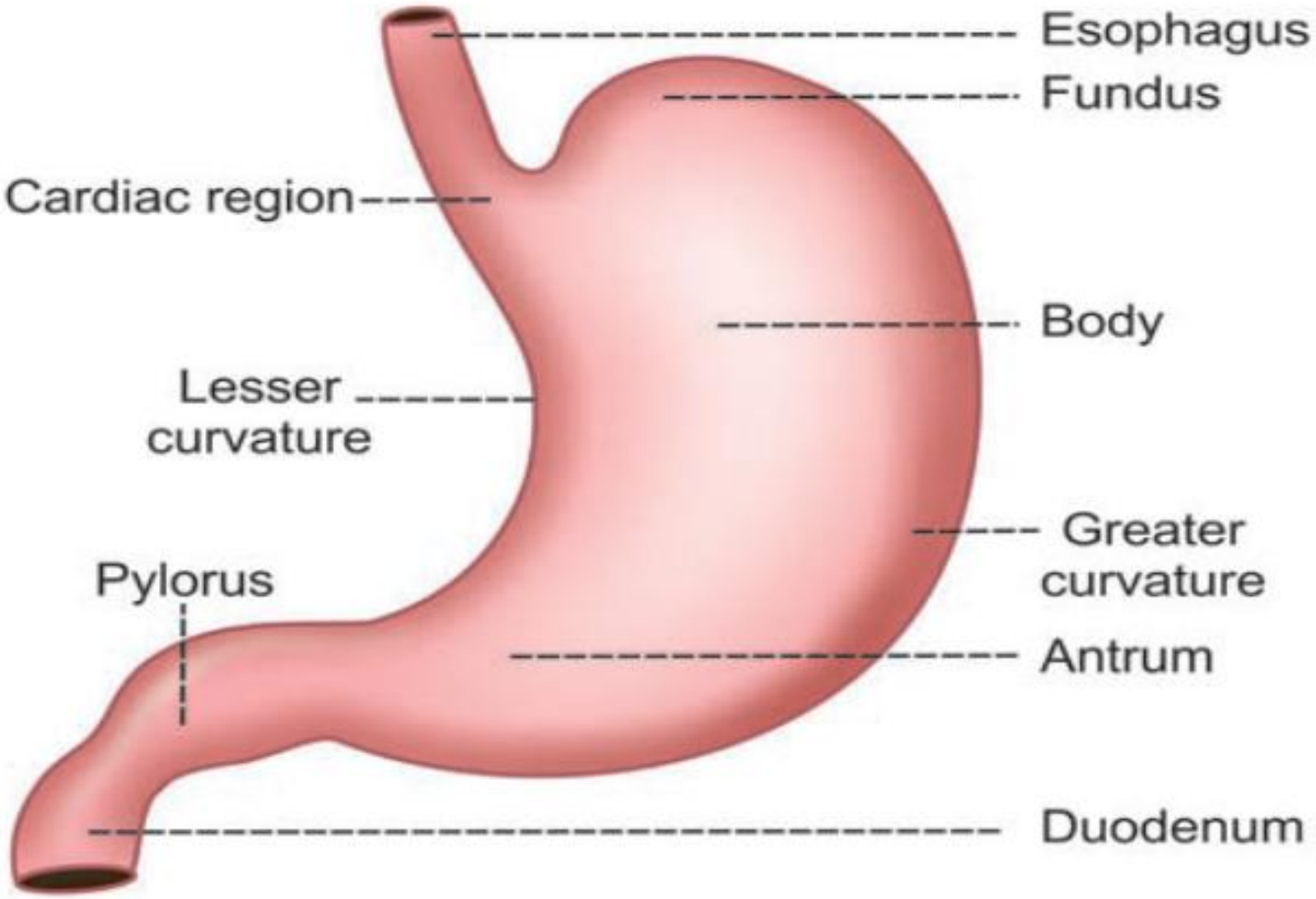
- **1. *Cardiac Region***
- Cardiac region is the upper part of the stomach where esophagus opens. The opening is guarded by a sphincter called **cardiac sphincter, which opens only towards** stomach. This portion is also known as **cardiac end.**
- **2. *Fundus***
- Fundus is a small domeshaped structure. It is elevated above the level of esophageal opening.

- **3. *Body or Corpus***
- Body is the largest part of stomach forming about 75% to 80% of the whole stomach. It extends from just below the fundus up to the pyloric region .

- **4. *Pyloric Region***
- Pyloric region has two parts, antrum and pyloric canal.The body of stomach ends in **antrum. Junction between** body and antrum is marked by an angular notch called **incisura angularis. Antrum is continued as the narrow** canal, which is called **pyloric canal or pyloric end.**
- **Pyloric** canal opens into first part of small intestine called duodenum. The opening of pyloric canal is guarded by a sphincter called pyloric sphincter. It opens towards duodenum. Stomach has two curvatures. One on the right side is **lesser curvature and the other on left side is greater curvature.**

▶

Parts of the stomach



- Stomach wall is formed by four layers of structures:
- 1. *Outer serous layer: Formed by* ***peritoneum***
- 2. *Muscular layer: Made up of three layers of smooth* muscle fibers, namely inner oblique, middle circular and outer longitudinal layers

- 3. *Submucus layer: Formed by areolar tissue, blood* vessels, lymph vessels and **Meissner nerve plexus.**
- 4. *Inner mucus layer: Lined by mucussecreting* columnar epithelial cells. The gastric glands are situated in this layer. Under resting conditions, the mucosa of the stomach is thrown into many folds. These folds are called rugae.
- The rugae disappear when the stomach is distended after meals. Throughout the inner mucus layer, small depressions called **gastric pits are present. Glands** of the stomach open into these pits. Inner surface of mucus layer is covered by 2 mm thick mucus.

GLANDS OF THE STOMACH

- **GASTRIC GLANDS**
- Glands of the stomach or gastric glands are tubular structures made up of different types of cells. These glands open into the stomach cavity via gastric pits.
- ▶ **CLASSIFICATION OF GLANDS OF THE STOMACH**
- Gastric glands are classified into three types, on the basis of their location in the stomach:

1. *Fundic glands or main gastric glands or oxyntic glands: Situated in body and fundus of stomach*
2. *Pyloric glands: Present in the pyloric part of the* stomach
3. *Cardiac glands: Located in the cardiac region of the* stomach.

STRUCTURE OF GASTRIC GLANDS

- **1. *Fundic Glands*** Fundic glands are considered as the typical gastric glands . These glands are long and tubular. Each gland has three parts, . body, neck and isthmus. *Cells of fundic glands*

1. Chief cells or pepsinogen cells
2. Parietal cells or oxyntic cells
3. Mucus neck cells
4. Enterochromaffin (EC) cells or Kulchitsky cells
5. Enterochromaffinlike (ECL) cells.

- Parietal cells are different from other cells of the gland because of the presence of **canaliculi (singular** = canaliculus). Parietal cells empty their secretions into the lumen of the gland through the canaliculi. But, other cells empty their secretions directly into lumen of the gland.

2. *Pyloric Glands*

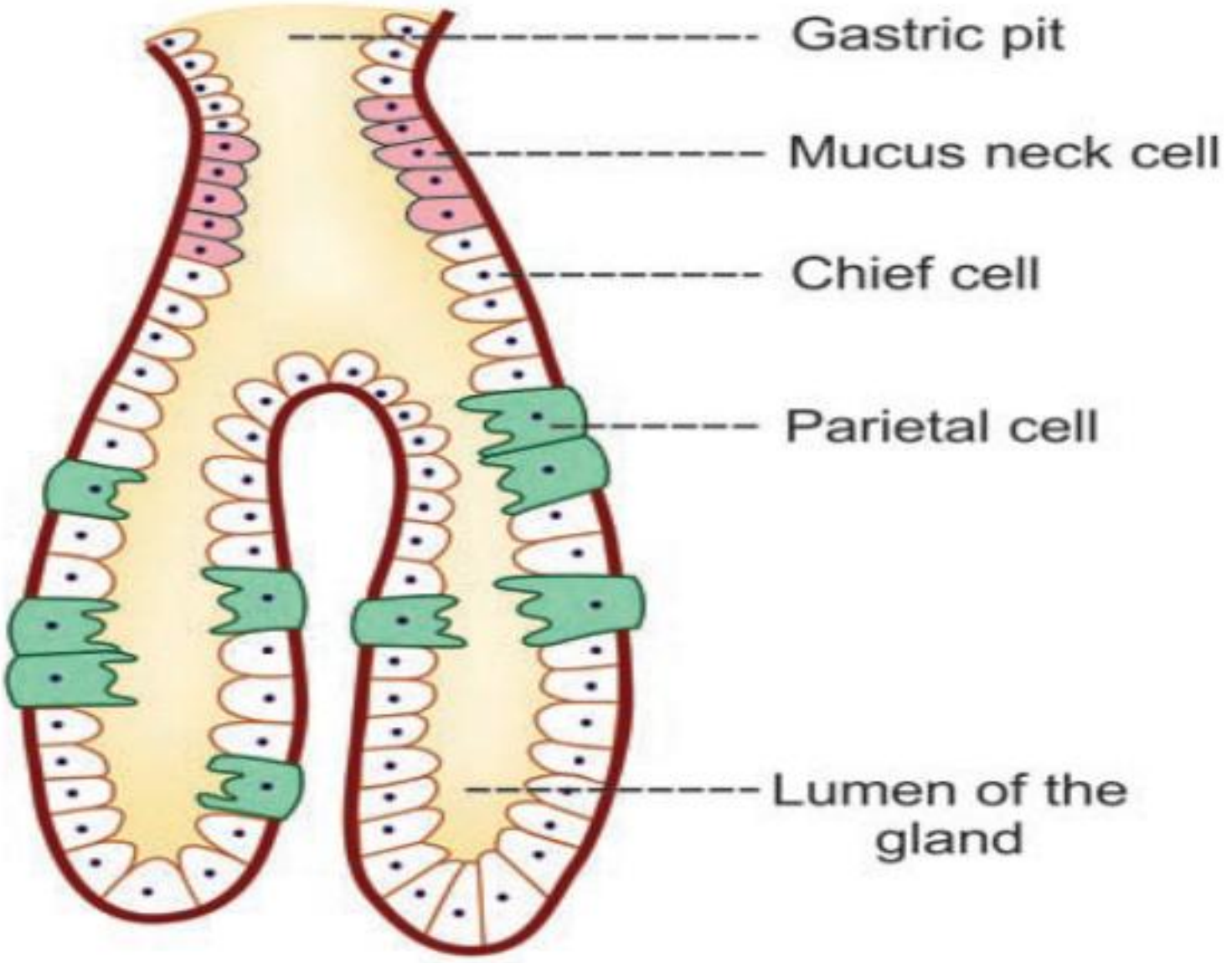
- Pyloric glands are short and tortuous in nature. These glands are formed by G cells, mucus cells, EC cells and ECL cells.

3. *Cardiac Glands*

- Cardiac glands are also short and tortuous in structure, with many mucus cells. EC cells, ECL cells and chief cells are also present in the cardiac glands

- ***Enteroendocrine Cells***
- Enteroendocrine cells are the hormonesecreting cells present in the glands or mucosa of gastrointestinal tract, particularly stomach and intestine. The enteroendocrine cells present in gastric glands are G cells, EC cells and ECL cells .
- ► **FUNCTIONS OF GASTRIC GLANDS**
- Function of the gastric gland is to secrete gastric juice. Secretory activities of different cells of gastric glands and enteroendocrine cells .

Gastric glands



Functions of the stomach.

- **1. MECHANICAL FUNCTION**

i. *Storage Function*

- Food is stored in the stomach for a long period, i.e. for 3 to 4 hours and emptied into the intestine slowly.
- The maximum capacity of stomach is up to 1.5 L. Slow emptying of stomach provides enough time for proper digestion and absorption of food substances in the small intestine.

ii. *Formation of Chyme*

- Peristaltic movements of stomach mix the bolus with gastric juice and convert it into the semisolid material known as chyme.

2.Protective function

3.Digestive function.

- 4.Haemopoetic function.
- 5.Excretory function
- Many substances like toxins, alkaloids and metals are excreted through gastric juice

TABLE 38.1: Secretory function of cells in gastric glands

Cell	Secretory products
Chief cells	Pepsinogen Rennin Lipase Gelatinase Urase
Parietal cells	Hydrochloric acid Intrinsic factor of Castle
Mucus neck cells	Mucin
G cells	Gastrin
Enterochromaffin (EC) cells	Serotonin
Enterochromaffin-like (ECL) cells	Histamine

PROPERTIES AND COMPOSITION OF GASTRIC JUICE

- Gastric juice is a mixture of secretions from different gastric glands.
- ► **PROPERTIES OF GASTRIC JUICE**
- Volume : 1200 mL/day to 1500 mL/day.
- Reaction : Gastric juice is highly acidic with a Ph of 0.9 to 1.2. Acidity of gastric juice is due to the presence of hydrochloric acid.
- Specific gravity : 1.002 to 1.004

- ► **COMPOSITION OF GASTRIC JUICE**
- Gastric juice contains 99.5% of water and 0.5% solids.
- Solids are organic and inorganic substances. 38.3 for composition of gastric juice.

Function of gastric juice

1. DIGESTIVE FUNCTION

- Gastric juice acts mainly on proteins. Proteolytic enzymes of the gastric juice are pepsin and rennin
- Gastric juice also contains some other enzymes like gastric lipase, gelatinase, urase and gastric amylase.

Pepsin

- Pepsin is secreted as inactive pepsinogen. Pepsinogen is converted into pepsin by hydrochloric acid. Optimum pH for activation of pepsinogen is below 6.

- ***Action of pepsin***
- Pepsin converts proteins into proteoses, peptones and polypeptides. Pepsin also causes curdling and digestion of milk (casein).

Gastric Lipase

- Gastric lipase is a weak lipolytic enzyme when compared to pancreatic lipase. It is active only when the pH is between 4 and 5 and becomes inactive at a pH below2.5. Gastric lipase is a tributyrase and it hydrolyzes tributyrin (butter fat) into fatty acids and glycerols.

- ***Actions of Other Enzymes of Gastric Juice***

i. Gelatinase: Degrades type I and type V gela tin and type IV and V collagen (which are proteoglycans in meat) into peptides

ii. Urase: Acts on urea and produces ammonia

iii. Gastric amylase: Degrades starch (but its action is insignificant)

iv. Rennin: Curdles milk (present in animals only).

- **2. HEMOPOIETIC FUNCTION**
- Intrinsic factor of **Castle, secreted by parietal cells of** gastric glands plays an important role in erythropoiesis.
- It is necessary for the absorption of vitamin B12 (which is called extrinsic factor) from GI tract into the bloodVitamin B12 is an important maturation factor during erythropoiesis. Absence of **intrinsic factor in gastric** juice causes deficiency of vitamin B12, leading to **pernicious anemia**

- **PROTECTIVE FUNCTION –**
- **FUNCTION OF MUCUS**
- Mucus is a mucoprotein, secreted by mucus neck cells of the gastric glands and surface mucus cells in fundus, body and other parts of stomach. It protects the gastric wall by the following ways:
- *Mucus:*
- i. Protects the stomach wall from irritation or mechanical injury, by virtue of its high viscosity.
- ii. Prevents the digestive action of pepsin on the wall of the stomach, particularly gastric mucosa.

- iii. Protects the gastric mucosa from hydrochloric acid of gastric juice because of its alkaline nature and its acidcombining power.
- ► **4. FUNCTIONS OF HYDROCHLORIC ACID**
- Hydrochloric acid is present in the gastric juice:

i. Activates pepsinogen into pepsin

ii. Kills some of the bacteria entering the stomach along with food substances. This action is called bacteriolytic action

iii. Provides acid medium, which is necessary forthe action of hormones.

►

Composition of gastric juice

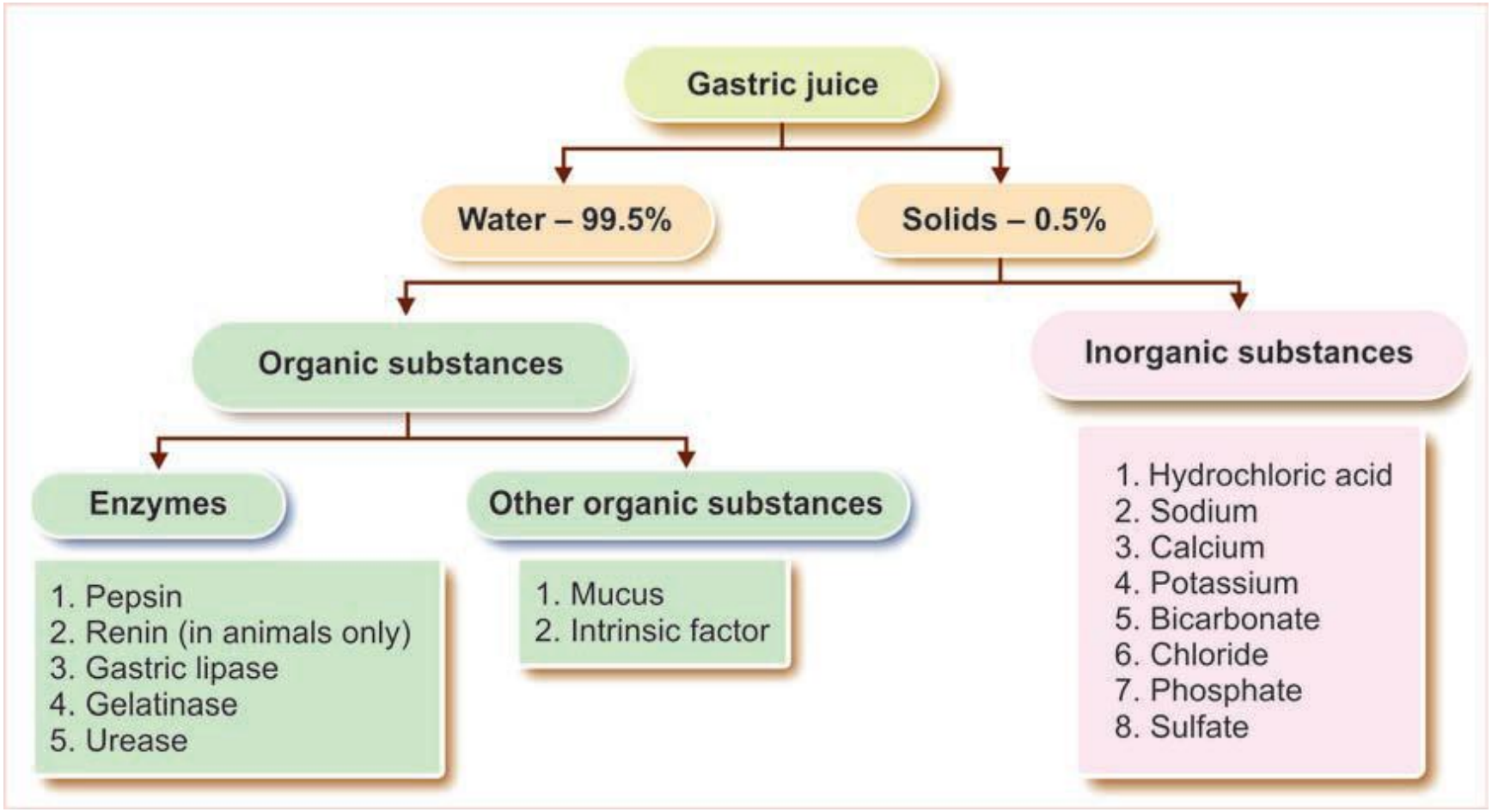


TABLE 38.2: Digestive enzymes of gastric juice

Enzyme	Activator	Substrate	End products
Pepsin	Hydrochloric acid	Proteins	Proteoses, peptones and polypeptides
Gastric lipase	Acid medium	Triglycerides of butter	Fatty acids and glycerols
Gastric amylase	Acid medium	Starch	Dextrin and maltose (negligible action)
Gelatinase	Acid medium	Gelatin and collagen of meat	Peptides
Urase	Acid medium	Urea	Ammonia

Secretion of gastric juice

- **SECRETION OF PEPSINOGEN**
- Pepsinogen is synthesized from amino acids in the ribosomes attached to **endoplasmic reticulum in chief** cells. Pepsinogen molecules are packed into **zymogen**
- **granules by Golgi apparatus.** When zymogen granule is secreted into stomach from chief cells, the granule is dissolved and pepsinogen is released into gastric juice. Pepsinogen is activated into pepsin by hydrochloric acid.

- **SECRETION OF HYDROCHLORIC ACID**
- According to **Davenport theory, hydrochloric acid** secretion is an active process that takes place in the canaliculi of parietal cells in gastric glands.
- The energy for this process is derived from oxidation of glucose. Carbon dioxide is derived from metabolic activities of parietal cell. Some amount of carbon dioxide is obtained from blood also.
- It combines with water to form **carbonic acid in the presence of carbonic anhydrase.** This enzyme is present in high concentration in parietal cells. Carbonic acid is the most unstable compound and immediately splits into hydrogen ion and bicarbonate ions

- The hydrogen ion is actively pumped into the canaliculus of parietal cell. Simultaneously, the chloride ion is also pumped into canaliculus actively.
- The chloride is derived from sodium chloride in the blood. Now, the hydrogen ion combines with chloride ion to form hydrochloric acid.
- To compensate the loss of chloride ion, the bicarbonate ion from parietal cell enters the blood and combines with sodium to form sodium bicarbonate. Thus, the entire process is summarized as
- $CO_2 + H_2O + NaCl \rightarrow$ **$HCl + NaHCO_3$**

- ***Factors Stimulating the Secretion***
- ***of Hydrochloric Acid***
- 1. Gastrin
- 2. Histamine
- 3. Vagal stimulation.
- ***Factors Inhibiting the Secretion***
- ***of Hydrochloric Acid***
- 1. Secretin
- 2. Gastric inhibitory polypeptide
- 3. Peptide YY.

- Accordingly, gastric secretion occurs in three different
- phases:
- I. Cephalic phase
- II. Gastric phase
- III. Intestinal phase.

. **Each phase is regulated by neural mechanism** or hormonal mechanism or both.

Phases of digestion

- Digestive activities occur in three overlapping phases: the
- cephalic phase, the gastric phase, and the intestinal phase.
- **Cephalic Phase**
- During the **cephalic phase of digestion, the smell, sight,** thought, or initial taste of food activates neural centers in the cerebral cortex, hypothalamus, and brain stem. The brain stem then activates the facial (VII), glossopharyngeal (IX), and vagus (X) nerves.
- The facial and glossopharyngeal nerves stimulate the salivary glands to secrete saliva, while the vagus nerves stimulate the gastric glands to secrete gastric juice. The purpose of the cephalic phase of digestion is to prepare the mouth and stomach for food that is about to be eaten.

GASTRIC PHASE

Once food reaches the stomach, the **gastric phase of digestion begins.**

- Neural and hormonal mechanisms regulate the gastric phase of digestion to promote gastric secretion and gastric motility.

Neural regulation. Food of any kind distends the stomach and

- stimulates stretch receptors in its walls. Chemoreceptors in the stomach monitor the pH of the stomach chyme. When the stomach walls are distended or pH increases because proteins have entered the stomach and buffered some of the stomach acid, the stretch receptors and chemoreceptors are activated, and a neural negative feedback loop is set in motion

- From the stretch receptors and chemoreceptors, nerve impulses propagate to the submucosal plexus, where they activate parasympathetic and enteric neurons.
- The resulting nerve impulses cause waves of peristalsis and continue to stimulate the flow of gastric juice from gastric glands.
- The peristaltic waves mix the food with gastric juice; when the waves become strong enough, a small quantity of chyme undergoes gastric emptying into the duodenum.
- The pH of the stomach chyme decreases (becomes more acidic) and the distension of the stomach walls lessens because chyme has passed into the small intestine, suppressing secretion of gastric juice

- ***Hormonal regulation. Gastric secretion during the gastric*** phase is also regulated by the hormone **gastrin. Gastrin is** released from the **G cells of the gastric glands in response to** several stimuli: distension of the stomach by chyme, partially digested proteins in chyme, the high pH of chyme due to the presence of food in the stomach, caffeine in gastric chyme, and acetycholine released from parasympathetic neurons.
- Once it is released, gastrin enters the bloodstream, makes a round-trip through the body, and finally reaches its target organs in the digestive system. Gastrin stimulates gastric glands to secrete large amounts of gastric juice

- It also strengthens the contraction of the lower esophageal sphincter to prevent reflux of acid chyme into the esophagus, increases motility of the stomach, and relaxes the pyloric sphincter, which promotes gastric emptying.
- Gastrin secretion is inhibited when the pH of gastric juice drops below 2.0 and is stimulated when the pH rises.
- This negative feedback mechanism helps provide an optimal low pH for the functioning of pepsin, the killing of microbes, and the denaturing of proteins in the stomach.

- **Intestinal Phase**
- The **intestinal phase of digestion begins once food enters the** small intestine. In contrast to reflexes initiated during the cephalic and gastric phases, which stimulate stomach secretory activity and motility, those occurring during the intestinal phase have inhibitory effects that slow the exit of chyme from the stomach.
- This prevents the duodenum from being overloaded with more chyme than it can handle. In addition, responses occurring during the intestinal phase promote the continued digestion of foods that have reached the small intestine.
- These activities of the intestinal phase of digestion are regulated by.neural and hormonal mechanisms

- ***Neural regulation. Distension of the duodenum by the*** presence of chyme causes the **enterogastric reflex.**
- **Stretch** receptors in the duodenal wall send nerve impulses to the medulla oblongata, where they inhibit parasympathetic stimulation and stimulate the sympathetic nerves to the stomach.
- As a result, gastric motility is inhibited and there is an increase in the contraction of the pyloric sphincter, which decreases gastric emptying.

- ***Hormonal regulation. The intestinal phase of digestion*** is mediated by two major hormones secreted by the small intestine: cholecystokinin and secretin. **Cholecystokinin (CCK) is secreted by the CCK cells of the small intestinal** crypts of Lieberkühn in response to chyme containing amino acids from partially digested proteins and fatty acids from partially digested triglycerides. CCK stimulates secretion of pancreatic juice that is rich in digestive enzymes. It also causes contraction of the wall of the gallbladder, which squeezes stored bile out of the gallbladder into the cystic duct and through the common bile duct.
- In addition, CCK causes relaxation of the sphincter of the hepatopancreatic ampulla (sphincter of Oddi), which allows pancreatic juice and bile to flow into the duodenum. CCK also slows gastric emptying by promoting contraction of the pyloric sphincter, produces satiety (a feeling of fullness

- acting on the hypothalamus in the brain, promotes normal growth and maintenance of the pancreas, and enhances the effects of secretin. Acidic chyme entering the duodenum stimulates the release of **secretin from the S cells of the** small intestinal crypts of Lieberkühn. In turn, secretin stimulates the flow of pancreatic juice that is rich in bicarbonate ($HCO3$) ions to buffer the acidic chyme that enters the duodenum from the small intestine. Besides this major effect, secretin inhibits secretion of gastric juice, promotes normal growth and maintenance of the pancreas, and enhances the effects of CCK. Overall, secretin causes buffering of acid in chyme that reaches the duodenum and slows production of acid in the stomach.