7.1 Functional Anatomy and General Principles of Functions of Gastrointestinal System

FUNCTIONAL ANATOMY

FUNCTIONAL ORGANIZATION

The digestive system comprises gastrointestinal tract (GIT) and accessory organs of digestion like teeth, tongue, salivary glands, liver and exocrine part of pancreas.

Gastrointestinal tract also known as alimentary canal is basically a muscular tube extending from the mouth to the anus (Fig. 7.1-1). At either end the lumen is continuous with external environment. It measures about 10 metre (30 feet) and comprises following parts:

Mouth. Mouth is loosely used term to denote the external opening and for the cavity it leads to. Strictly speaking the term mouth should be applied only for the external opening which is also called oral fissure. The cavity containing anterior two-third of tongue and teeth is the *mouth cavity* or *oral cavity* or *buccal cavity* (Fig. 7.1-2). The oral cavity extends from the lips to the oropharyngeal isthmus, i.e. junction of the mouth with the pharynx. Oral cavity is subdivided into two parts: the vestibule and oral cavity proper (Fig.7.1-2).

- *Vestibule* lies between the lips and cheeks externally and the gums and teeth internally.

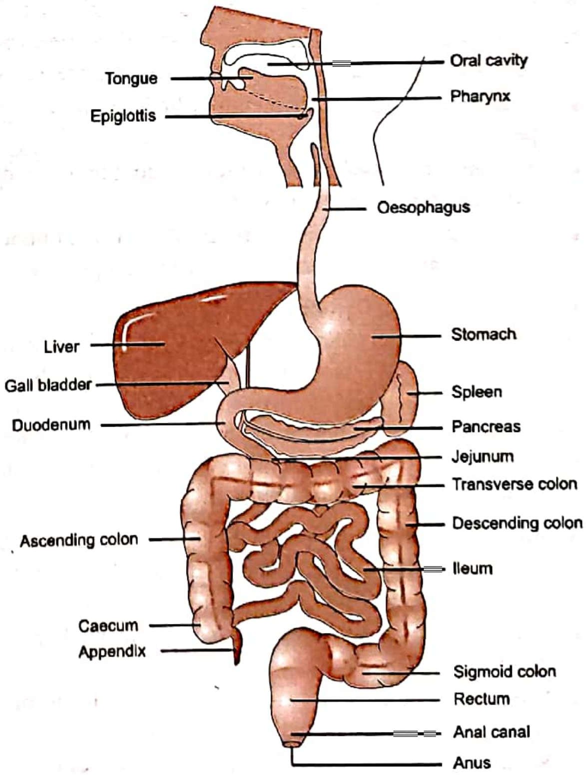

Fig. 7.1-1. The gastrointestinal system.

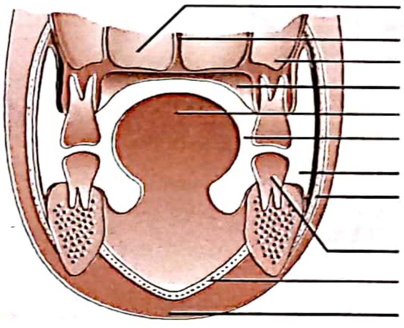

Fig. 7.1-2. Schematic coronal section through oral cavity.

- *Oral cavity proper* lies within the alveolar arches, gums and teeth.

Tongue, in the digestive system plays two important roles:
- Tells the taste of food, and
- Helps in chewing and swallowing of the food.

Teeth. Functions of different types of teeth in chewing are:
- *Incisors* provide strong cutting action,
- *Canines* are responsible for tearing action
- *Premolars and molars* have grinding action.

Pharynx. The pharynx is a median passage that is common to the gastrointestinal and respiratory systems. It is divisible, from above downwards, into three parts:
- *Nasal part* or *nasopharynx* into which nasal cavities open,
- *Oral part* or *oropharynx* which is continuous with posterior end of oral cavity, and
- *Laryngeal part* or *laryngopharynx* which is continuous in front with larynx, and below with oesophagus.

Oesophagus. It is a fibromuscular tube about 25 cm long. At its junction to the pharynx upper oesophageal sphincter is present and its junction with the stomach lower oesophageal sphincter is present. During swallowing upper oesophegeal sphincter opens and food passes into the oesophagus. The peristaltic movements of the oesophagus propel the food into stomach.

Stomach. It is a hollow muscular bag connected to the oesophagus at its upper end and to the duodenum at the lower end. It serves following motor functions:
- Storage of food till it can be accommodated in the duodenum,
- Mixing of food with gastric secretions to form a semiliquid mixture called chyme, and
- Slow emptying of food into the small intestine.

Small intestine. It is a long tubular structure which can be divided into three parts:
- *Duodenum* is the first part of small intestine. It is C-shaped and measures about 25 cm in length.
- *Jejunum,* the middle part of the small intestine is about 25 metre long, and
- *Ileum,* the last part of small intestine, is about 3.5 metre long.

Gastric chyme enters the duodenum where it meets with pancreatic juice, bile, and secretions of the small intestine (succus entericus). The partially digested foodstuffs in the gastric chyme are digested further and the final products of digestion are absorbed by the villi of small intestine. The movements of small intestine help in mixing, digestion and absorption of the food. The peristaltic activity of small intestine also helps in moving the undigested and unabsorbed food material to the large intestine.

Large intestine. It arches around and encloses the coils of the small intestine and tends to be more fixed than the small intestine. It is divided into following parts (Fig. 7.1-1):
- *Caecum* is a blind ended sac into which opens the lower end of ileum. The ileocaecal junction is guarded by the ileocaecal valve which allows on flow but prevents backflow of intestinal contents.
- *Appendix* is worm-shaped tube that arises from the medial side of caecum which in human being is a vestigial organ.
- *Ascending colon* extends upward from the caecum along the right side of the abdomen upto the liver. On reaching the liver it bends to the left, forming the *right hepatic flexure.*
- *Transverse colon* extends from the right hepatic flexure to the *left splenic flexure.* It forms a wide U-shaped curve.
- *Descending colon* extends from the left splenic flexure to the pelvic inlet below.
- *Sigmoid colon* begins at the pelvic inlet as continuation down of the descending colon and joins the rectum in front of the sacrum.
- *Rectum* descends in front of the sacrum to leave the pelvis by piercing the pelvic floor. Here it becomes continuous with anal canal in the perineum.
- *Anal canal* opens to the exterior through the anus, the opening which is guarded by two sphincters.

In large intestine there occurs absorption of water and electrolytes from the intestinal contents. The remaining material is called *faecal matter.* The mucus secreted from the wall of large intestine lubricates the faecal matter. The faecal matter is stored in the sigmoid colon (pelvic colon)

Muscles of mastication

- *Masseter* raises the mandible, *clenches* the teeth and helps to protract the mandible.
- *Temporalis* raises the mandible and helps to retract the mandible after protraction.
- *Internal and external pterygoids* protrude the mandible, depress the chin and, therefore, help in opening the mouth. Grinding movements are produced by these when right and left muscles are acting alternatively.
- *Buccinator*, is an accessory muscle of mastication which prevents accumulation of food between the cheek and teeth.

Functions of mastication

1. Breaking of food into smaller pieces increases the total surface area. As the digestive enzymes act mainly on the surface of food particles, so digestion rate is increased.
2. Undigestive cellulose membrane present around the nutrition portion of most fruits and raw vegetable is broken, making it easier for them to be digested.
3. Mixing of food with saliva initiates the process of starch digestion by salivary amylase, and lipid digestion by lingual lipase.
4. Swallowing becomes easy because of breaking of food into smaller pieces, and lubrication and softening of the food bolus by saliva.
5. Chewing brings food into contact with taste receptors and releases odour that stimulates the olfactory receptors. Stimulation of taste receptors and olfactory receptors increase the pleasure of eating and stimulate gastric secretions.

Net effect of mastication. The bolus of food becomes a homogenized mixture of small food particles, saliva and mucus, which is easy to swallow and digest.

LUBRICATION OF FOOD BY SALIVA

SALIVARY GLANDS

In addition to the chewing, another important physiological activity which takes place in the mouth is lubrication of food by saliva. The saliva is secreted by three pairs of major salivary glands:

1. Parotid glands

Location. Parotid glands are the largest salivary glands (each weighing 20-30 gm), located near the angles of jaw.

Acini. The parotid glands are purely serous glands (Fig.7.2-1) which secrete watery saliva containing more than 90% water. Parotid glands secrete 25% of the total salivary secretion (which is about 1500 ml/day).

Ducts. Ducts of the parotid glands open on the inner side of the right and left cheek and pour their secretions in the vestibule.

2. Sublingual glands

Location. The sublingual gland is the smallest of the three main salivary glands. It lies just below the mucosa on the floor of mouth. Each gland raises a ridge of mucosa which starts at the sublingual papilla and runs laterally and backwards. The ridge is called the sublingual fold.

Acini. The sublingual gland contains both serous and mucous acini (Fig.7.2-1), the latter predominating.

Ducts of sublingual gland are 8 to 20 in number. Most open into the mouth on the summit of sublingual fold but a few may open into the submandibular duct.

3. Submandibular glands

Location. The submandibular glands are large salivary

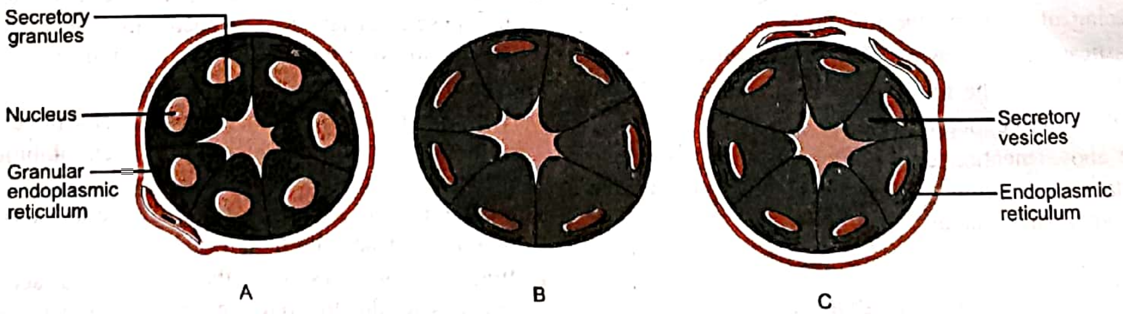

Fig. 7.2-1. Different types of acini in salivary glands: A, serous; B, mucous; and C, seromucous.

glands which lie (one on each side) partly under cover of the body of the mandible. Each gland is made up of a large superficial part and a small deep part.

Acini. The submandibular gland is composed of a mixture of serous and mucous acini, the former predominating (Fig. 7.2.1).

Ducts. S-shaped duct of each submandibular gland opens on the sublingual papilla located just lateral to the frenulum lingua.

Note. The sublingual and submandibular glands secrete a fluid that contains a higher concentration of proteins and so is more viscus as compared to watery secretion of parotid glands.

Smaller salivary glands

In addition to the three pairs of salivary glands described above, several smaller glands are located throughout the oral cavity. Those in the tongue secrete lingual lipase.

SALIVA

SECRETION AND COMPOSITION

Amount. Under normal circumstances the salivary glands secrete about 500 to 1500 ml of saliva every day. pH of saliva varies from 6 to 7.4.

Composition. Saliva is composed of:

Water 99%, and

Solids 1%, which include:

- Organic substances such as L-amylase (ptyalin), lingual lipase, kallikrein, lysozyme, small amounts of urea, uric acid, cholesterol and mucin.
- Inorganic substances are Na^+, Cl^-, K^+ and HCO_3^-.

Note. Composition of saliva varies with the salivary flow rate.

Mechanism of formation of saliva

Mechanism of formation of saliva involves two processes:

1. ***Primary secretion of saliva.*** The acinar cells of salivary glands secrete the initial saliva into the salivary ducts. The initial saliva is formed by transudation (pressure filtration) of plasma and therefore is isotonic, i.e. has the same Na^+, Cl^-, K^+ and HCO_3^- concentrations as plasma (Fig. 7.2-2). However, the initial saliva is soon modified by the salivary ducts.

2. ***Modification of saliva.*** The ductal cells that line the tubular portions of the salivary ducts change the composition of initial saliva by following processes (Fig. 7.2-2).

- *Reabsorption of Na^+ and Cl^-* occurs in the ductal cells, therefore, the concentration of these ions is lower than their plasma concentration.
- *Secretion of K^+ and HCO_3^-*, is caused by the ductal cells, therefore, the concentrations of these ions are higher than their plasma concentrations.
- *Modified saliva becomes hypotonic* in the ducts because the ducts are relatively impermeable to water. Because more solutes than water is reabsorbed by the ducts, the saliva becomes dilute relative to plasma.

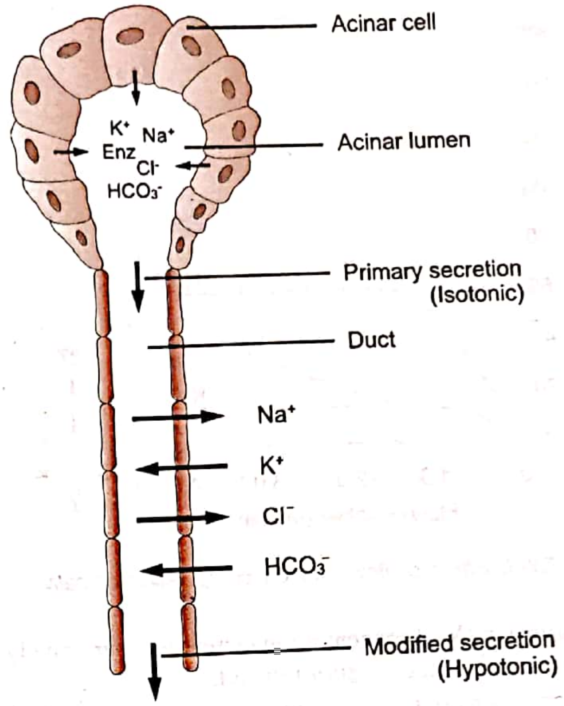

Fig. 7.2-2. Mechanism of formation of saliva.

Note. Aldosterone acts on the ductal cells to increase the reabsorption of Na^+ and Cl^- from salivary ducts (analogous to its actions on renal tubule). Thus a high Na^+ / Cl^- ratio is seen when aldosterone is deficient in Addison's disease (see page 765). Conversely, in presence of excess aldosterone the greatly increased sodium chloride concentration of saliva falls almost to zero and increases K^+ concentration equal to or higher than that of plasma.

Effects of flow rate on the composition of saliva

Effects of flow rate on the composition of saliva occur due to changes in the contact time available for reabsorption and secretion processes to occur in the ducts.

1. At high flow rates, there is less time for reabsorption and secretion, and therefore the saliva is most like the initial secretion by the acinar cells. Thus, with the increase in flow rate the concentration of ions changes (Fig.7.2-3):