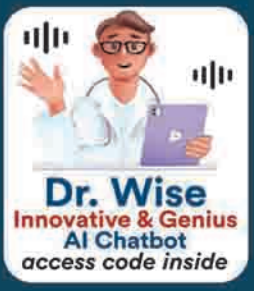
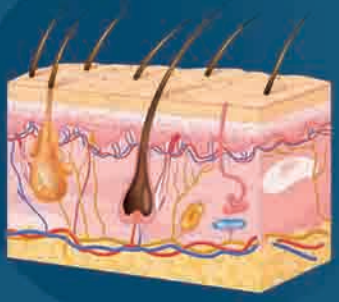
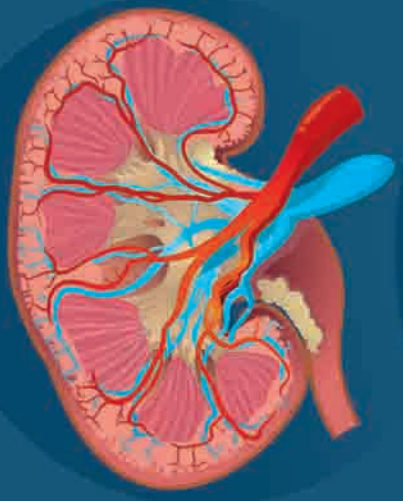
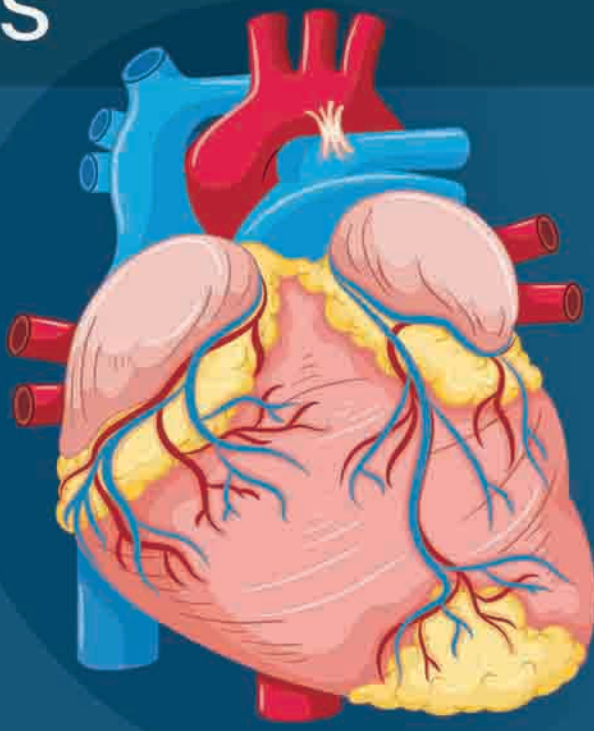
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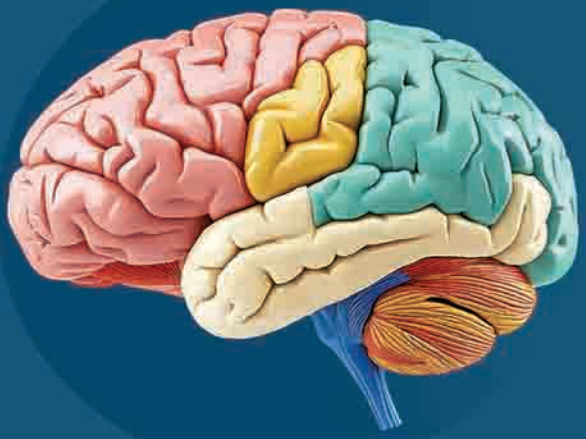
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7

CHAPTER

Digestive System

Chapter Outline

- Process of Digestion
- Innervation of Gastrointestinal Tract
- Parts of Digestive System
- Pharynx
- Salivary Glands

Gut

- Esophagus
- Stomach
- Small Intestine
- Large Intestine
- Accessory Organs of Digestion
- Gastrointestinal Hormones
- Peritoneum

INTRODUCTION

- The **purpose of digestion** is to change the foodstuffs by mechanical and chemical action to simple forms, which can be easily absorbed into blood and utilized by various tissues in the body.
- It is also involved in maintaining the water and electrolyte balance of the body.
- The gastrointestinal (GI) tract consists of an alimentary canal of 8–10 m length, extending from the mouth to the anus, salivary glands, liver and exocrine part of pancreas.

Gastrointestinal tract is formed by two types of organs:

1. Primary digestive organs
2. Accessory digestive organs.

Key Points

Primary digestive organs

Primary digestive organs are the organs where actual digestion takes place.

These organs are:

- Mouth
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine.

Accessory digestive organs

Accessory digestive organs help the primary digestive organs in the process of digestion. These organs are:

- Teeth
- Tongue
- Salivary glands
- Exocrine part of pancreas
- Liver
- Gallbladder.

PROCESS OF DIGESTION (FIG. 7.1)

Food is processed within the body in following steps:

- Ingestion
- Swallowing
- Digestion
- Absorption
- Excretion.

Ingestion

Ingestion or taking in of food and mastication (chewing) are functions performed by mouth and teeth, aided by tongue.

Swallowing

Pharynx and esophagus are concerned with swallowing.

Digestion

Digestion occurs in the stomach and upper part of small intestine.

Absorption

Absorption can occur from any part of alimentary canal (mainly from small intestine).

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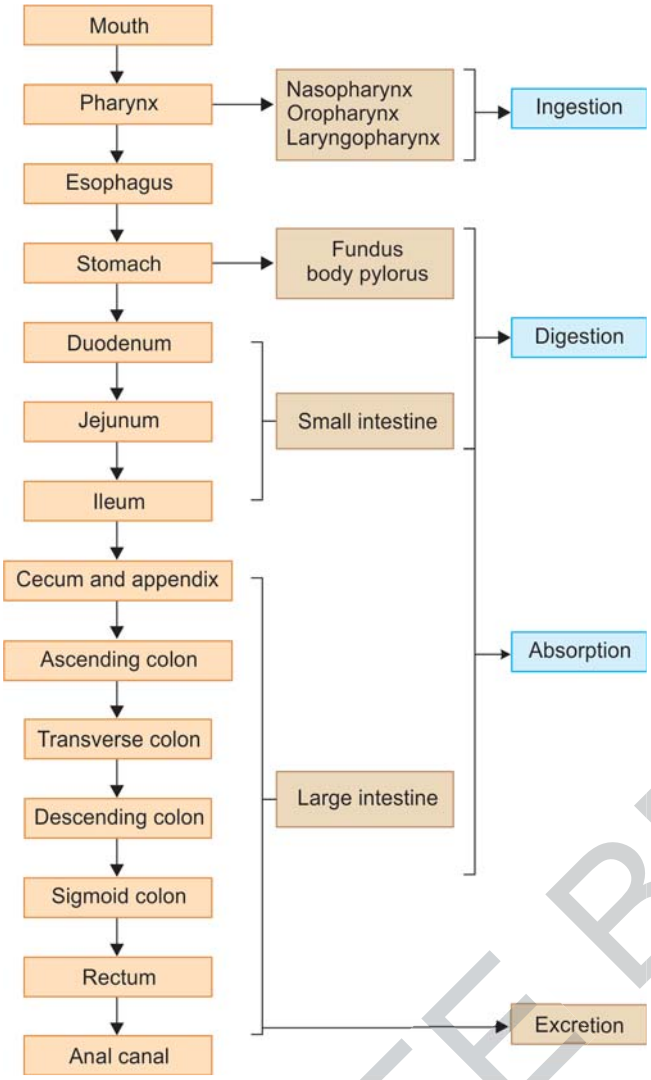


Fig. 7.1: Parts and process of digestion.

Excretion

Large intestine absorbs major quantity of water and the residue is excreted in the form of feces.

INNERVATION OF GASTROINTESTINAL TRACT

The special network of nerve fibers innervating the GIT consists of two groups of fibers:

1. Enteric nervous system or intrinsic nervous system **(Fig. 7.2)**
2. Extrinsic nervous system or autonomic nervous system.

Enteric Nervous System or Intrinsic Nervous System

Enteric nervous system (ENS) or intrinsic nervous system (INS) is formed by two different networks of nerve fibers **(Fig. 7.2)**:

- ***Myenteric (Auerbach's) plexus:*** Myenteric plexus lies between the longitudinal and circular muscle layers. They are responsible for the tone of the gut wall and the rhythmic contractions of gut. Thus, they control the peristalsis of the gut
- ***Meissner's (submucous) plexus:*** Meissner's plexus lies between submucous layer and inner layer of muscular layer. It is mainly sensory in function and is responsible for the control of exocrine and endocrine secretions from GIT.

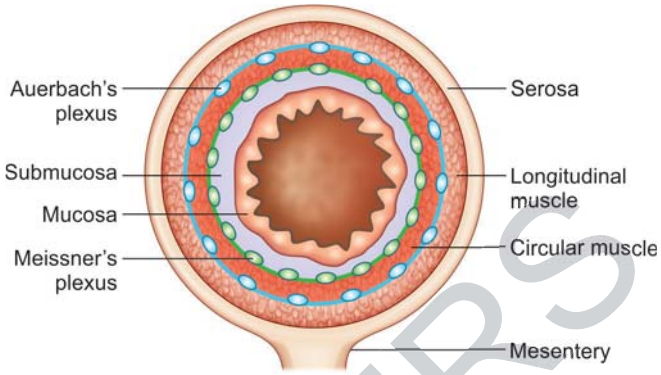


Fig. 7.2: Structure of intestinal wall with intrinsic nerve plexus.

Extrinsic Nervous System or Autonomic Nervous System

- Extrinsic nervous system is under the control of the parasympathetic and sympathetic nerves.
- Parasympathetic innervation to the gut arises from the vagus.
- The vagus nerve supplies the GIT up to the right two thirds of transverse colon.
- The rest of the gut tube receives parasympathetic supply from the pelvic splanchnic nerves.
- Stimulation of parasympathetic system results in an increase in the gastrointestinal secretions as well as the gastrointestinal motility.
- Sympathetic fibers to GIT arise from T8 to L2 segments of the spinal cord.
- Most of these fibers terminate on the ENS, but a few go along with the blood vessels of the gut.
- Their stimulation causes inhibition of peristalsis and vasoconstriction.

PARTS OF DIGESTIVE SYSTEM (FIG. 7.3)

Oral Cavity

The mouth or oral cavity is the first part of the digestive tube. It is divided into mouth proper and a vestibule. The vestibule is slit-like space between the lips and cheek externally, and the gums and teeth internally. The parotid duct opens into the vestibule. The vestibule is lined by mucous membrane, the lining epithelium of which is stratified squamous non-keratinizing.

Lips

Lips (labia) are fleshy folds lined externally by skin and internally by mucous membrane. Each lip is composed of skin,

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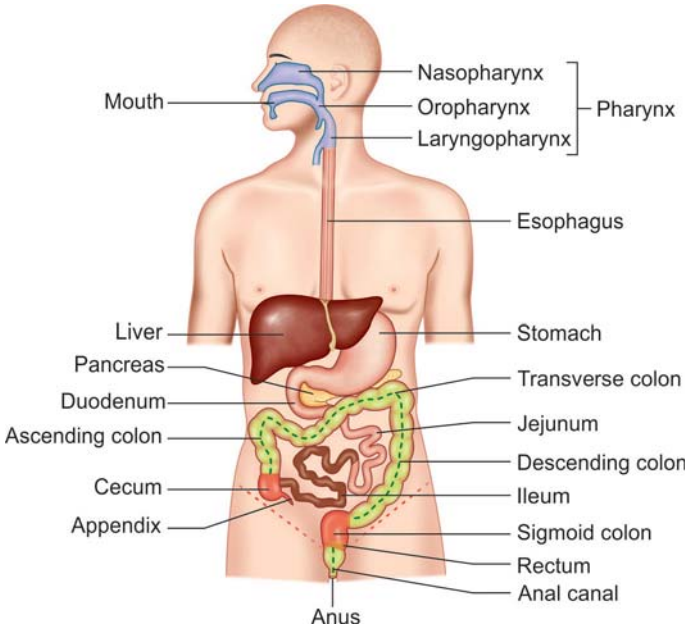


Fig. 7.3: Parts of digestive system.

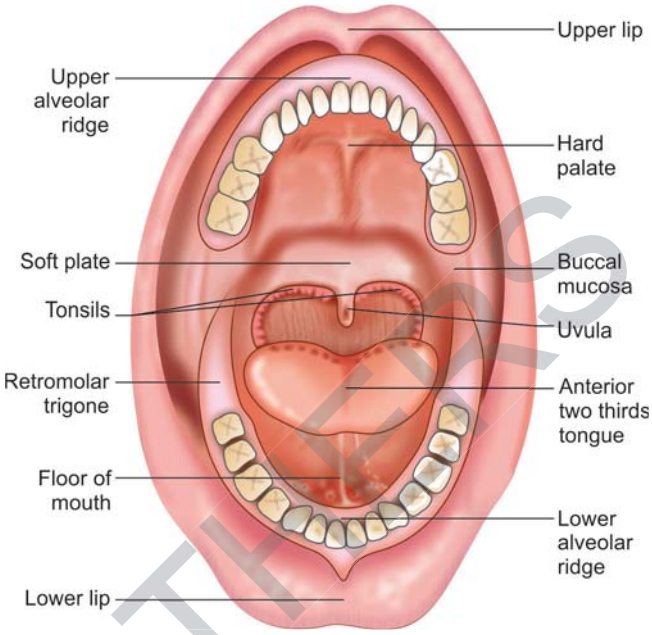


Fig. 7.4: Oral cavity.

superficial fascia and orbicularis oris muscle, submucosa and mucous membrane.

Cheeks

Cheeks (buccae) are fleshy flaps, forming a large part of each side of the face. The cheeks are composed of skin, buccinator muscle, parotid duct, vessels and nerves, mucous glands and mucosa. In infants, a well-developed buccal pad of fat lies on the buccinator.

Oral Cavity Proper (Fig. 7.4)

Boundaries

- Anterolaterally by teeth, gums and alveolar arches of jaws
- Roof is formed by hard and soft palates
- Floor is formed by the tongue and sublingual region
- Posteriorly the oral cavity communicates with the pharynx through the oropharyngeal isthmus.

Gums

Gums are the soft tissues, which cover the alveolar processes of the upper and lower jaws, and surround the necks of the teeth.

Teeth

Teeth constitute approximately 20% of the surface area of mouth, the upper teeth significantly more than the lower teeth. A tooth consists of a crown, which is exposed to oral cavity and single or multiple roots, lying in socket of jaw bones. The teeth are composed of the following tissues **(Fig. 7.5)**:

Enamel: It is the hardest tissue in a human body, covering the crown of the tooth. It is inert, acellular and formed from ectoderm. It is supported by the underlying dentin.

Dentin: It is less calcified, more resilient, vital, hard tissue forming the main bulk of the tooth. It is formed from and

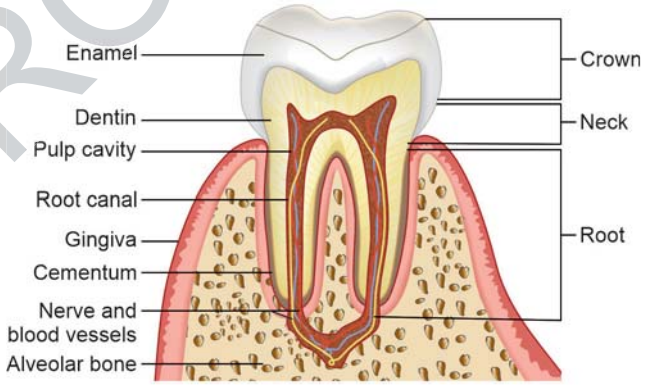


Fig. 7.5: Vertical section through a tooth.

supported by the dental pulp. In crown portion, it is covered by the enamel and in the root portion, it is covered by the cementum. The junction between enamel and dentin is known as dentino-enamel junction.

Cementum: It is less mineralized tissue, covering the radicular portion of the tooth. The junction between enamel and cementum is known as cervical line or cementoenamel junction.

Pulp: It is the soft, connective tissue in the central part of tooth enclosed by dentin. The pulp cavity in the crown part is known as pulp chamber and in the root portion, it is known as pulp canal or root canal.

Periodontium: The tissues (periodontal ligament, cementum, alveolar bone), which support the teeth in jaws are collectively termed as periodontium. The tooth is anchored to the socket of bone by periodontal ligament. The part of jaw bone, which supports the tooth is known as alveolar bone.

At birth, normally, no teeth is visible in the oral cavity. In postnatal period, teeth of various sizes and shapes are found

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in the jaws. The human beings are known as diphyodont as human dentition consists of two sets of teeth:

Key Points

- Primary, deciduous or milk dentition:
  - Total 20 in number
  - 10 in each jaw
  - 5 in each quadrant
  - Start erupting in oral cavity at the age of 6 months
  - Continue to erupt up to 2½–3 years.
- Secondary, permanent or succedaneous dentition:
  - Total 32 in number
  - 16 in each jaw
  - 8 in each quadrant.
- Start erupting in oral cavity at the age of 6 years.

The dentition in a human being can be divided into three stages:

1. ***Stage of primary dentition:***
   - It lasts for about 6 months to 6 years of age.
   - Only deciduous teeth are present in this phase.
2. ***Stage of mixed dentition:***
   - It lasts from 6 to 13 years of age.
   - Both deciduous and permanent teeth are present in the oral cavity.
3. ***Stage of permanent dentition:***
   - It lasts from 13 years onwards.
   - Only permanent teeth are present.
   - The permanent teeth replace deciduous teeth except permanent molars, which do not have any deciduous predecessors.

The teeth are arranged in two dental arches:

1. Maxillary or upper arch.
2. Mandibular or lower arch.

The arrangement of teeth is symmetrical in the right and left halves in each arch. In both dentitions, there are three basic tooth forms—incisiform, caniniform and molariform.

1. ***Incisors:***
   - Two in each quadrant of jaws.
   - They are flat, have cutting edges and are delicate.
2. ***Canines:***
   - One in each quadrant of jaws.
   - They have sharp-pointed cusp and are strong.
   - They are known as cuspids.
   - They are meant for piercing or tearing.
   - Eight incisors and four canines together are known as anterior teeth.
3. ***Premolars:***
   - They are two in each quadrant.
   - They replace deciduous molars.
   - They generally have two cusps and are known as bicuspids.
   - They are present only in permanent dentition.
4. ***Molars:***
   - There are two deciduous molars and three permanent molars in each quadrant.
   - The permanent molars do not have deciduous predecessors.
   - They are large and strong.
   - They have broad surface designed for grinding.
   - They are situated farthest back in the mouth.

Functions of Teeth

- Help in mastication (cutting of food by the incisors, tearing by the canines, chopping by the premolars and grinding by the molars).
- Help in articulation and speech.
- Give a definite shape and beauty to the face; vertical height of face is maintained by molars; help to maintain the personality of an individual.
- May be used for self-protection.
- Growth and development of jaws are dependent on tooth.

Vessels of teeth

The branches of maxillary artery supply the upper and lower set of teeth. The veins join the pterygoid venous plexus. Lymph vessels drain mainly into the submandibular nodes.

Nerves of teeth

The teeth of upper jaw are supplied by maxillary nerve; the lower (mandibular) set of teeth are supplied by inferior alveolar nerve, which is a branch of mandibular nerve.

Clinical Correlation

Dental caries

1. Dental caries is the most common disease of dental tissues, causing destruction of the calcified tissues of the teeth.
2. Caries occurs chiefly in the areas of pits and fissures, mainly of the molars and premolars, where food retention occurs, and in the cervical part of the tooth.
3. The earliest change is the appearance of a small, chalky-white spot on the enamel, which subsequently enlarges and often becomes yellow or brown and breaks down to form carious cavity. Eventually, the cavity becomes larger due to fractures of enamel. Once the lesion reaches enamel-dentine junction, destruction of dentine also begins.

Pulpitis

Pulpitis refers to the inflammation of the pulp. It may be acute, which is accompanied by severe pain and requires immediate intervention or it may be chronic where the pulp is exposed widely. It may protrude through the cavity forming polyp of the pulp.

Palate (Fig. 7.6)

Palate forms the arched roof of the oral cavity and the floor of the nasal cavities. It separates the nasal cavities and nasopharynx from the oral cavity.

Parts

The palate consists of **two regions**—the anterior two thirds or bony part called **hard palate** and the mobile, posterior one-third—**the soft palate.**

Hard palate:

- The hard palate is formed by the palatine processes of maxillae and the horizontal processes of palatine bones.
- Anteriorly and laterally, the hard palate is bounded by alveolar processes and gums.
- Medial to third molar tooth is the greater palatine foramen through which greater palatine nerve and vessels emerge from the greater palatine canal.
- The hard palate is covered by mucous membrane.

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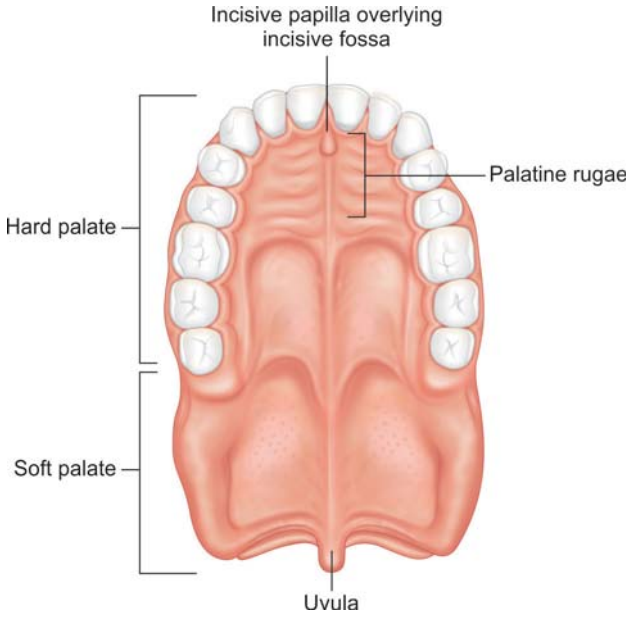


Fig. 7.6: Palate.

Soft palate:

- The soft palate is a movable, fibromuscular fold, that is attached to the posterior edge of the hard palate.
- The soft palate shows a conical process called uvula (L, uva means 'grape'), which hangs from its posterior, curved, free margin.
- Laterally, the soft palate is continuous with the wall of the pharynx and is joined to the tongue and pharynx by the palatoglossal and palatopharyngeal arches respectively.
- The palatine tonsil is located in the triangular interval between the palatoglossal and palatopharyngeal arches.

Muscles of soft palate:

- The **five pairs** of muscles of soft palate pass from the base of the skull to the palate.
- They are levator palati, tensor palati, palatoglossus, palatopharyngeus and musculus uvulae.
- The expanded tendon of tensor palati muscle forms the palatine aponeurosis, which strengthens the soft palate.

Nerves of the palate

- ***Sensor:*** Greater and lesser palatine nerves
- ***Motor:*** All the muscles of the palate are innervated by pharyngeal plexus formed by cranial part of accessory and vagus nerves; the **tensor palati is an exception,** which is supplied by mandibular nerve.

Tongue

The tongue (lingua, glossa) is a highly mobile muscular organ situated partly in the mouth and partly in the oropharynx.

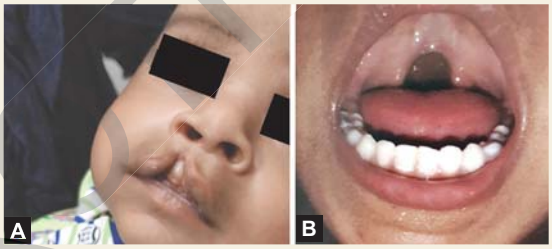
Parts

- Root
- Body
- Tip
- A dorsal surface
- A ventral surface
- Two lateral borders

Clinical Correlation

Cleft lip and cleft palate (Figs. 7.7A and B)

1. Cleft lip and cleft palate are congenital malformations (a cleft is a gap or opening).
2. A cleft lip is a split or separation of the two sides of the upper lip that appears as a gap in the skin of upper lip.
3. This gap can be on one side or both sides.
4. A cleft palate is a split or gap in the roof of the mouth. It can involve the hard palate and/or the soft palate.
5. Cleft lip and cleft palate can occur together or separately, and can be successfully corrected with surgery, if conducted soon after birth or in early childhood.
6. Paralysis of muscles of the palate leads to nasal regurgitation and gives a 'nasal sound' to the voice.



Figs. 7.7A and B: (A) Cleft lip; (B) Cleft palate.

Courtesy: Dr Prathap Somnath, Professor and Head, Department of Pediatric Surgery, Government Medical College, Kozhikode, Kerala, India.

Functions of Tongue

- Mastication (chewing)
- Taste
- Deglutition (swallowing)
- Articulation/speech
- Oral cleansing

Dorsal surface (Fig. 7.8): Important features

- The dorsal surface of tongue is covered by mucous membrane.
- A V-shaped groove, the **sulcus terminalis**, divides this surface into anterior two thirds or palatine part and posterior one-third or pharyngeal part **(Fig. 7.8)**.
- At the apex of the V is a small foramen cecum.
- A shallow median groove extends from the tip to the foramen cecum, dividing the anterior two thirds into right and left halves.
- The mucous membrane of anterior two thirds of dorsum of tongue is rough due to the presence of microscopic projections called **papillae.**
- Mucous membrane of posterior one-third of tongue shows collections of lymphoid tissue called **lingual tonsil.**

Ventral surface (Fig. 7.9):

- The ventral surface of the tongue is covered by smooth mucous membrane, devoid of papillae.

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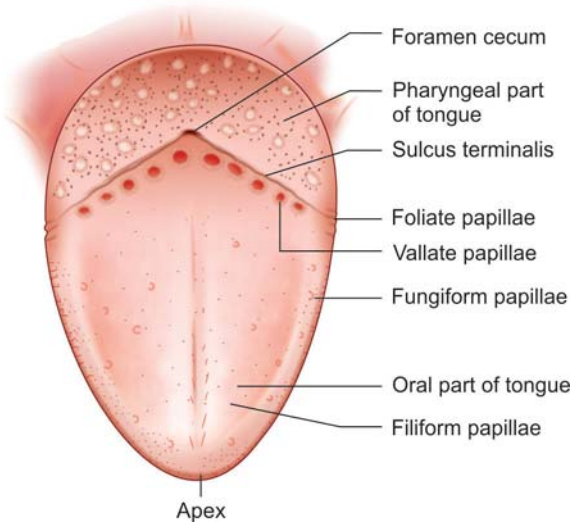


Fig. 7.8: Dorsal surface of tongue.

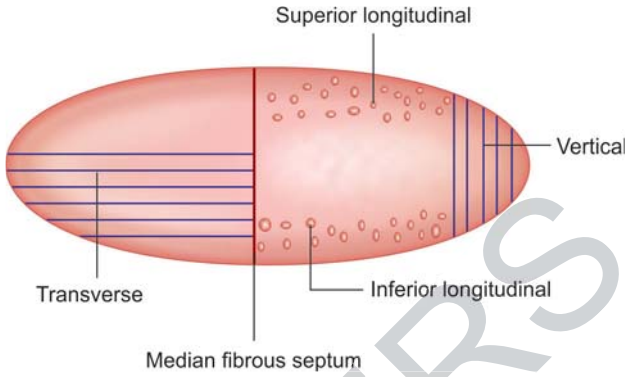


Fig. 7.10: Coronal section of tongue showing intrinsic muscles (diagrammatic).

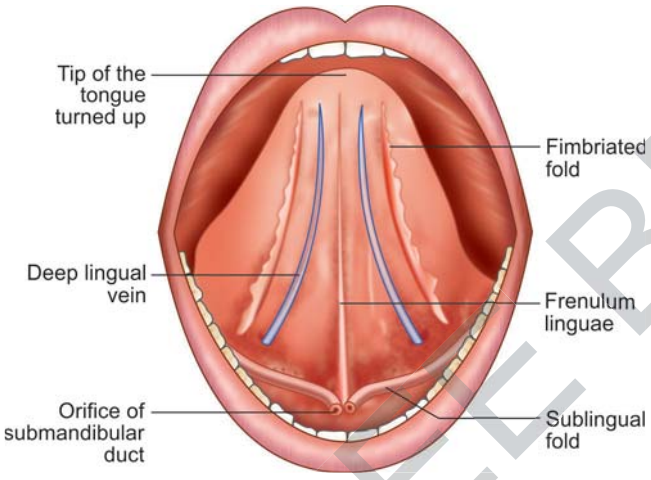


Fig. 7.9: Ventral or inferior surface of tongue and floor of mouth.

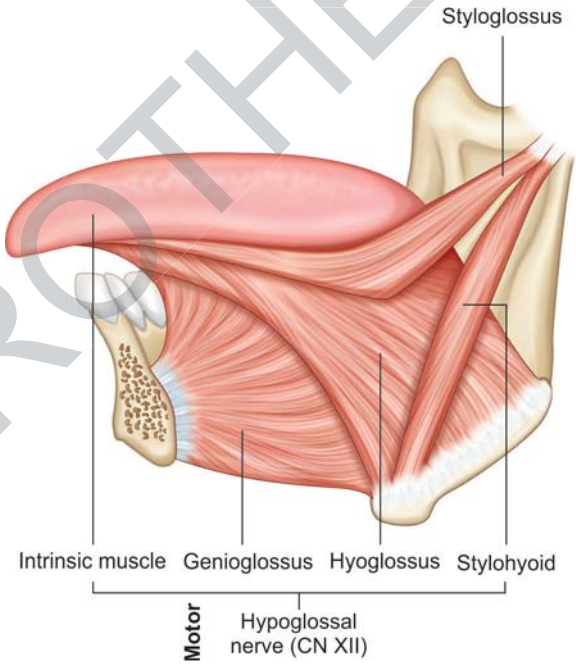


Fig. 7.11: Extrinsic muscles of the tongue.
(CN: cranial nerve).

- There is a median mucous fold, the **frenulum linguae,** stretching from this surface to the floor of the mouth.
- On either side of the frenulum, the **deep lingual vein** can be seen **(Fig. 7.9)**.

Muscles of the tongue (Figs. 7.10 and 7.11)

Muscles of the tongue are grouped into two parts— intrinsic muscles and extrinsic muscles are as follows:

1. ***Intrinsic muscles:*** A median fibrous septum divides the tongue into right and left halves. Each half has four intrinsic muscles **(Fig. 7.10)**:
   - Superior longitudinal muscle
   - Inferior longitudinal muscle
   - Transverse muscle
   - Vertical muscle.
2. ***Extrinsic muscles*** of the tongue **(Fig. 7.11)** are:
   - Genioglossus
   - Hyoglossus
   - Styloglossus
   - Palatoglossus.

Nerve supply

- Motor
- Sensory—general
- Special

Motor nerve supply (Fig. 7.12)

All the intrinsic and extrinsic muscles of tongue, except palatoglossus are supplied by the hypoglossal nerve. The palatoglossus is supplied by cranial accessory through vagus.

Sensory nerve supply (Fig. 7.12)

- Tongue is divided into anterior two thirds and posterior one-third by the sulcus terminalis.
- In the anterior two thirds of tongue, **general sensory** (pain, temperature, touch, pressure, etc.) supply is by the

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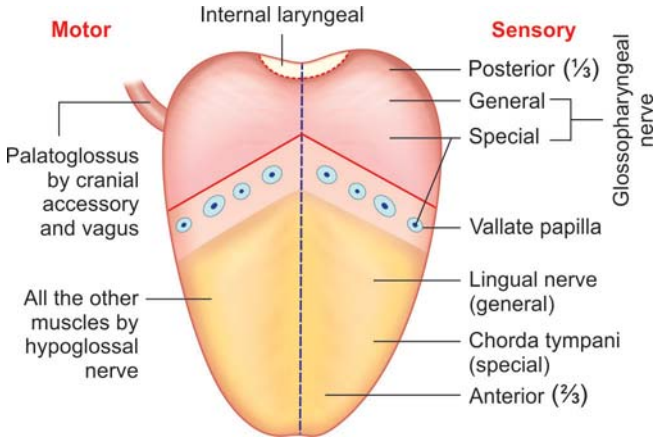


Fig. 7.12: Nerve supply of the tongue.

lingual nerve, a branch of mandibular nerve (a branch of trigeminal nerve).

- **Special sensory** (gustatory or taste) supply of anterior two thirds is by the **chorda tympani** branch of facial nerve (VII cranial nerve).
- Both the general and special sensations from the **posterior one-third** of the tongue are carried by the **glossopharyngeal nerve** (IX cranial nerve).
- The **posterior most** part is supplied by **internal laryngeal nerve**, a branch of vagus.
- The circumvallate papillae are supplied by glossopharyngeal nerve.

Blood supply

- The lingual arteries (branch of external carotid artery) supply blood to the tongue.
- The corresponding veins drain into the internal jugular veins.

Lymphatic drainage

Lymph from the tongue drains into the superior and inferior deep cervical lymph nodes (mainly into the jugulo-omohyoid).

Papillae

The papillae are of various types **(Figs. 7.13A to D)**:

1. ***Filiform papillae:*** They are the most numerous papillae. They are small and conical in shape.
2. ***Fungiform papillae:*** Mushroom-shaped fungiform papillae bear taste buds.
3. ***Circumvallate papillae:*** These are the largest papillae of the tongue. They are arranged in a row just anterior to the sulcus terminalis **(Fig. 7.14)** their walls have taste buds.
4. ***Foliate papillae:*** These are rudimentary in a human being. They can be seen along the posterior part of lateral margin of the tongue.

Histology of Tongue

- Tongue is covered by stratified squamous epithelium.
- The mucous membrane covering dorsal aspect of tongue has numerous papillae.
- There are three different types of papillae—filiform, fungiform and circumvallate.
- The fungiform and circumvallate papillae have taste buds.
- The mucous membrane covering ventral aspect is lined by non-keratinized squamous epithelium.
- The substance of the tongue is made up chiefly of skeletal tissue supported by connective tissue.

Taste buds (Fig. 7.14)

Taste buds are small, barrel-shaped structures, arranged along the sides of the grooves that surround the vallate or fungiform papillae. A taste bud has a layered appearance (similar to an onion) under the microscope. There is a pit, called inner taste pore, near the surface of the bud. Any substance to be tasted gets dissolved in saliva and passes through the taste pore into the pit of the taste bud, where it stimulates the neuroepithelial cells. These cells are richly innervated. So, a nerve impulse is set up.

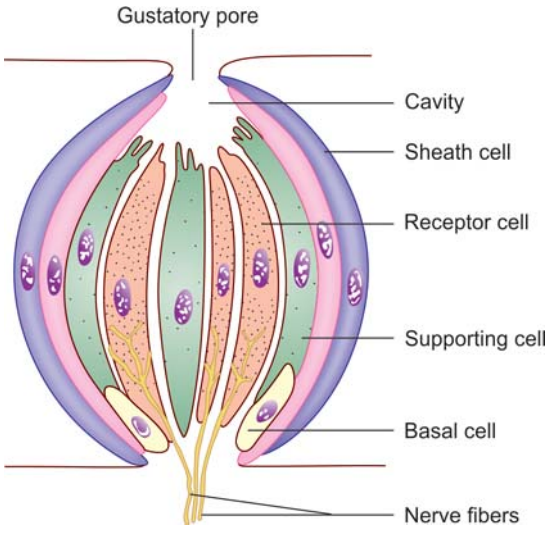
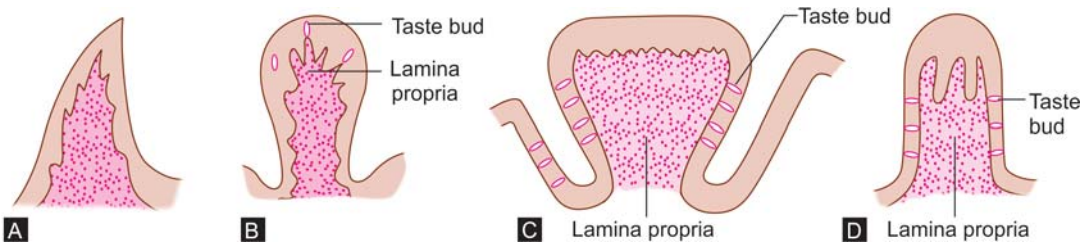


Fig. 7.14: Structure of a taste bud.



Figs. 7.13A to D: Papillae. (A) Filiform; (B) Fungiform; (C) Circumvallate; (D) Foliate.

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Clinical Correlation

- ***Congenital anomalies:***
  - *Macroglossia:* Large tongue
  - *Microglossia:* Small tongue
  - *Ankyloglossia or tongue tie:* In this condition, the frenulum linguae extends up to the tip of the tongue, interfering with its protrusion. It may require surgical correction.
- Injury to hypoglossal nerve leads to paralysis of muscles on the side of the lesion. When the patient is asked to protrude the tongue, which deviates to the side of the lesion.
- ***Referred pain:*** In case of cancer of the tongue, the lingual nerve may be involved. In such cases, pain is referred to the ear (pain radiates along the mandibular nerve and its auriculotemporal branch).

Nursing Implications

- When quick absorption of a drug is required, for example, Nitroglycerin , a vasodilator used in angina pectoris, the tablet is placed under the tongue , where it dissolves in saliva and enters the deep lingual vein in less than a minute. This is called the sublingual route of administration of drugs.
- In unconscious patients, the tongue may fall back and obstruct the air passage. So, the patient can be made to lie on one side with head down.
- Carcinoma of tongue is common in people who use tobacco. **(Fig. 7.15)**



Fig. 7.15: Carcinoma of tongue.

Pharynx (Fig. 7.16)

- The pharynx is a wide muscular tube, situated behind the nose, mouth and larynx.
- It is about 13 cm long. Its upper part is the widest (3.5 cm) and lower part is the narrowest part of gastrointestinal tract (except the appendix).
- Inferiorly it continues with the esophagus through pharyngoesophageal junction.

Parts of Pharynx

The cavity of pharynx is divided into three parts:
1. Nasopharynx
2. Oropharynx
3. Laryngopharynx.

Nasopharynx

- Nasopharynx is situated behind the nose.
- It is respiratory in function; it is lined by ciliated columnar epithelium.
- Anteriorly, it communicates with the nasal cavities, through the posterior nasal apertures. Inferiorly, it becomes continuous with the oropharynx.
- The lateral wall of the nasopharynx shows the pharyngeal opening of the auditory tube or Eustachian tube.
- This opening is bounded by a tubal elevation (torus tubarius).
- Behind this, there is a narrow vertical slit called pharyngeal recess or fossa of Rosenmüller.

Clinical Correlation

The fossa of Rosenmüller is a common site of nasopharygeal carcinoma.

- Near the junction of the roof and posterior wall of the nasopharynx, there is a collection of lymphoid tissue called **pharyngeal or nasopharyngeal tonsil.**
- It is well developed in children.
- A pathologically enlarged pharyngeal tonsil is called **adenoid**.
- Another collection of lymphoid tissue is present in the nasopharynx, behind the opening of the auditory tube—it is **called tubal tonsil**.

Functions of Nasopharynx

1. ***Airway:*** Conduction of air to the larynx and trachea.
2. ***Middle ear ventilation:*** Eustachian tube ventilates the middle ear and equalizes air pressure on both sides of the tympanic membrane. Dysfunctions of Eustachian tube can affect the middle ear.
3. ***Resonance:*** It is a part of resonating chamber for voice production. Nasopharyngeal obstruction produces changes in voice.
4. ***Drainage:*** It is a drainage channel for nasal and nasopharyngeal mucus secretions.
5. ***Nasopharyngeal isthmus:*** It cuts off the nasopharynx from the oropharynx during swallowing, vomiting, gagging and delivering of speech.

Oropharynx

- Oropharynx is the middle part of the pharynx situated behind the oral cavity.
- Superiorly it communicates with oral cavity through the oropharyngeal isthmus (isthmus of fauces).
- Inferiorly, it opens into the laryngopharynx.

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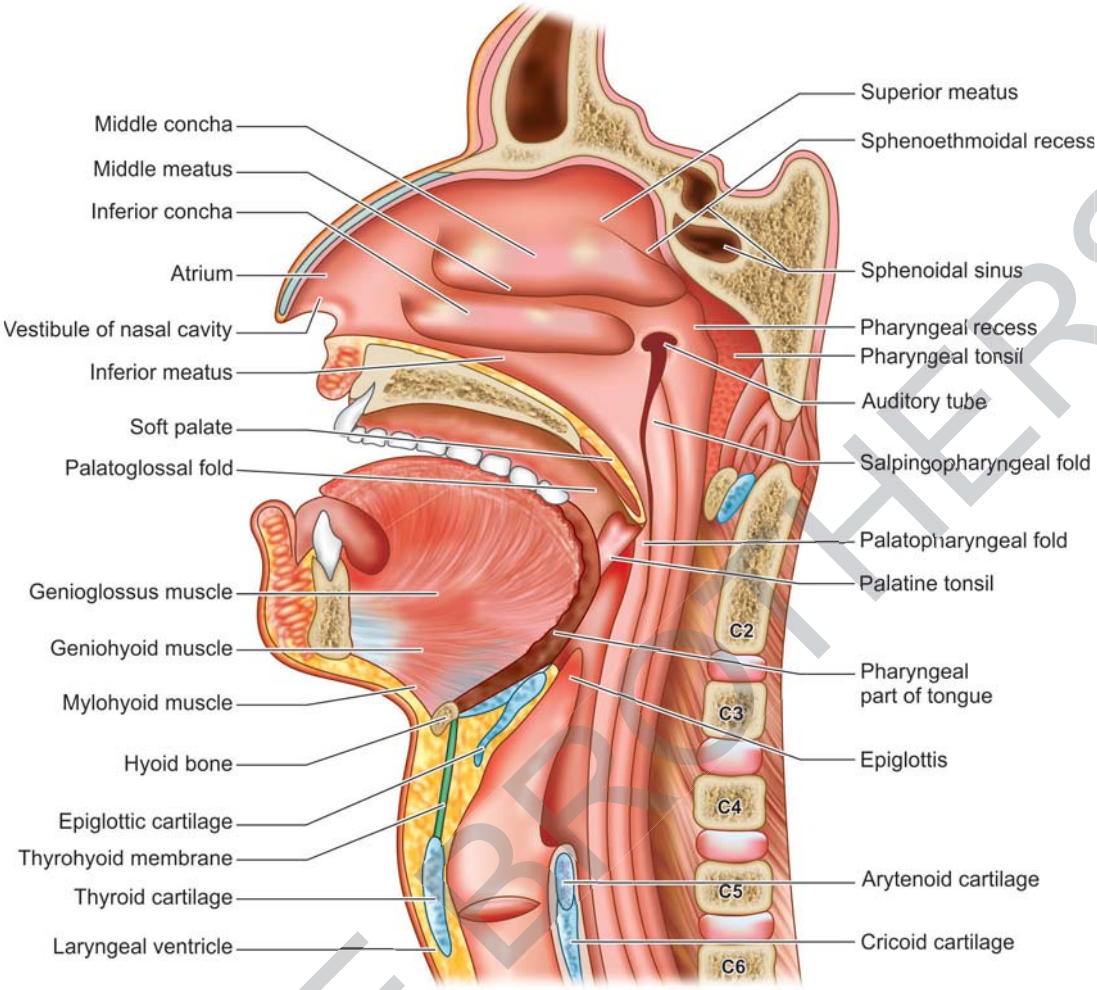


Fig. 7.16: Paramedian section of the pharynx showing different parts.

- The lateral wall of oropharynx presents the palatine tonsil, lying between the palatoglossal and palatopharyngeal arches.
- 'Palatine tonsils' are discussed in detail in **Chapter 5: Lymphatic System**.

Functions of Oropharynx

- A common passage of both air and food.
- Oropharyngeal phase of deglutition.
- ***Taste:*** The base of tongue, soft palate, anterior pillars and posterior pharyngeal wall contain taste buds.
- Local defense and immunity.

Laryngopharynx (Fig. 7.17)

- Laryngopharynx is situated behind the larynx.
- It extends from the upper border of epiglottis to the lower border of cricoid cartilage.
- The lateral wall of laryngopharynx shows a depression called piriform sinus.
- This shallow depression is bounded by the aryepiglottic fold medially; by thyroid cartilage and thyrohyoid membrane laterally.

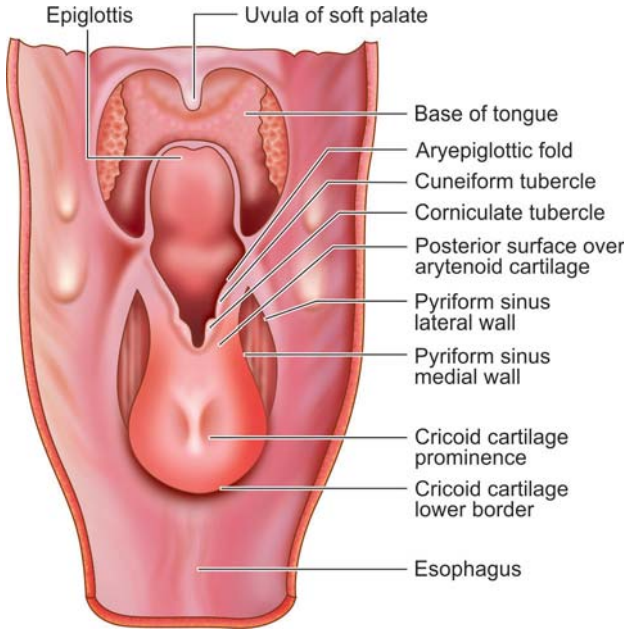


Fig. 7.17: Posterior view of laryngopharynx.

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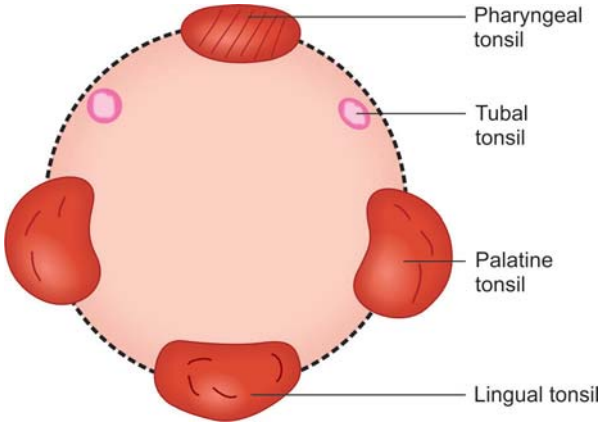


Fig. 7.18: Waldeyer's ring.

- The internal laryngeal nerve lies deep to the mucosa lining this fossa.
- Piriform fossa is a common site where foreign bodies can get arrested.

Waldeyer's Ring (Fig. 7.18)

Mucosa-associated lymphoid tissue (MALT) in subepithelial layer of pharynx is aggregated at the entrance of aerodigestive tract and are collectively called Waldeyer's ring.

Waldeyer's Ring

Waldeyer's ring consists of:
- Nasopharyngeal tonsil
- Tubal tonsils
- Palatine tonsils
- Lingual tonsils.

Functions of Tonsils and Adenoids

- ***Immunology and host defenses:*** The lymphocytes provide cell-mediated immunity against various viruses, bacteria and fungi.
- ***Sentinels at the portal of aerodigestive tract:*** Lymphoid tissues of Waldeyer's ring, act as protective sentinels against harmful intruders into the air and food passages.
- ***Antibody production.***

Muscles of Pharynx

There are **three pairs of constrictors:**
- Superior, middle and inferior constrictors.
- Other muscles of the pharynx are stylopharyngeus, salpingopharyngeus and palatopharyngeus.

Nerve Supply of Pharynx

- The pharynx is supplied by the pharyngeal plexus of nerves, formed by motor fibers of cranial accessory nerve, sensory fibers from glossopharyngeal nerve and branches from sympathetic chain.
- All the muscles of pharynx are supplied by the pharyngeal plexus except stylopharyngeus, which is supplied by glossopharyngeal nerve.
- Inflammation of pharynx is called pharyngitis. Swallowing becomes painful.

SALIVARY GLANDS (FIG. 7.19)

The secretions of these glands help to keep the mouth moist, and provide a protective and lubricant coat of mucus.

Classification of Salivary Glands

Based on the presence or absence of duct the salivary glands are classified as follows:

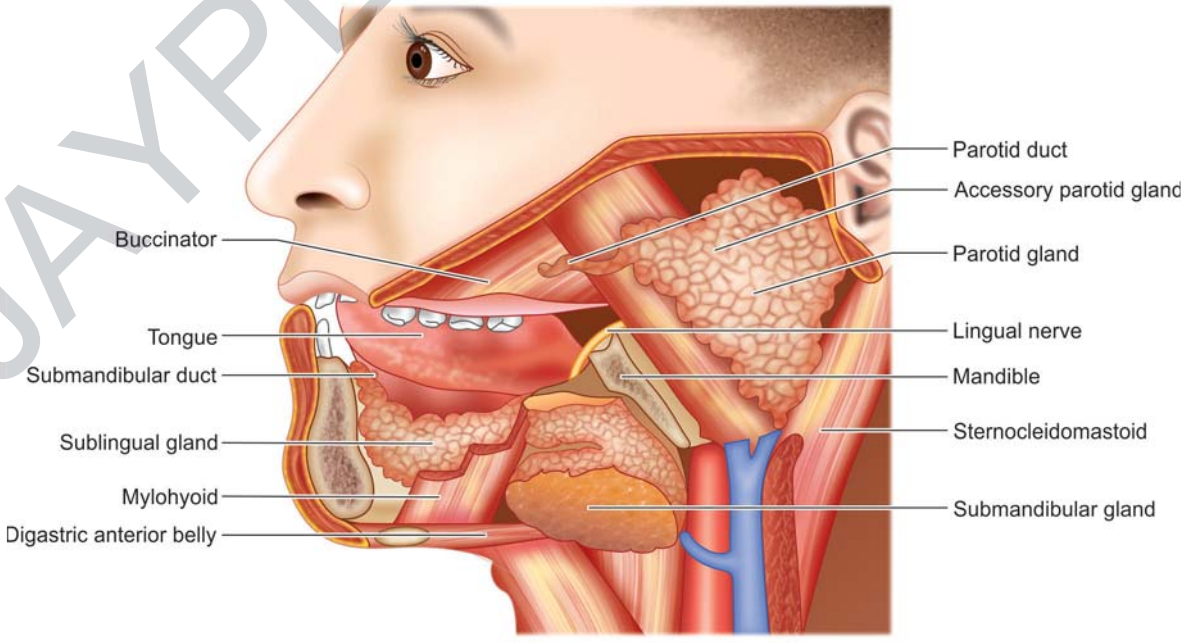


Fig. 7.19: Salivary glands (parotid, submandibular and sublingual) and their relations.

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Table 7.1: Ducts of major salivary glands.

Gland	*Duct*
Parotid gland	Stensen's duct
Submandibular gland	Wharton's duct
Sublingual gland	Ducts of Rivinus

Major Salivary Glands

Major salivary glands are those glands, which discharge their secretions into the oral cavity through a duct.

Major salivary glands (paired) are **(Table 7.1)**:

- Parotid
- Submandibular
- Sublingual.

Parotid gland

- Parotid glands ('para' means near, 'otis' means ear) are paired glands.
- They are the largest among the salivary glands.
- This gland is wedged between mandible and sternocleidomastoid muscle.
- It occupies the side of the face anterior and inferior to the auricle.
- The parotid duct or Stensen's duct passes horizontally from the anterior edge of the gland. T
- This duct is 5 cm long and 5 mm in diameter and opens in mouth opposite to the crown of the upper second molar tooth.
- It is closely related to the facial nerve and its branches, termination of external carotid artery and retromandibular vein.
- **Important relations**

Superficial or Lateral Surface

- Skin
- Superficial fascia
- Fibers of platysma, superficial lamella of parotid sheath
- Facial branches of great auricular nerve
- Superficial parotid lymph nodes

Anteromedial Surface

- Ramus of mandible, masseter and medial pterygoid on its outer and inner sides from above downwards
- Zygomatic branch of facial nerve
- Transverse facial vessels
- Parotid duct
- Buccal and mandibular branches of facial nerve

Posteromedial Surface (Fig. 7.20)

- Mastoid process, sternomastoid, posterior belly of digastric
- Styloid process and styloid group of muscles
- Deep to styloid—internal carotid artery, internal jugular vein, last four cranial nerves
- Facial nerve
- External carotid artery

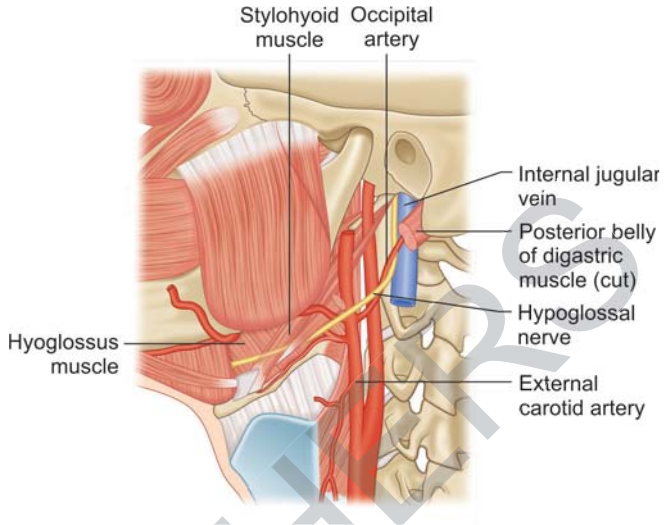


Fig. 7.20: Parotid relations of posteromedial surface.

Anterior Border (Figs. 7.21 and 7.22)

- Thin
- Rests on masseter: Structures radiating deep to this border are:
  - Zygomatic branch of facial
  - Transverse facial vessels
  - Upper buccal branch of facial
  - Accessory parotid gland and its duct, when present
  - Parotid duct
  - Lower buccal branch of facial nerve
  - Marginal mandibular branch of facial nerve

Facial Nerve and Parotid Gland (Figs. 7.21 and 7.23)

- Emerges from stylomastoid foramen
- Passes downward and forward for 1 cm
- Pierces posteromedial surface of parotid
- Runs forward 1 cm on retromandibular vein and external carotid artery
- Then divides into two:
  1. Temporofacial
  2. Cervicofacial

Temporofacial

- Temporal
- Zygomatic

Cervicofacial

- Buccal, marginal mandibular, and cervical

The branches of facial nerve in the face resemble the webbed foot of a goose. So it is described as "Pes Anserius" **(Fig. 7.21)**.

External Carotid Artery

- Deep
- Divides into two terminal branches—superficial temporal, maxillary artery
- Transverse facial artery arises from superficial temporal artery
- Sometimes posterior auricular artery also arises from external carotid artery within parotid gland **(Fig. 7.24)**.

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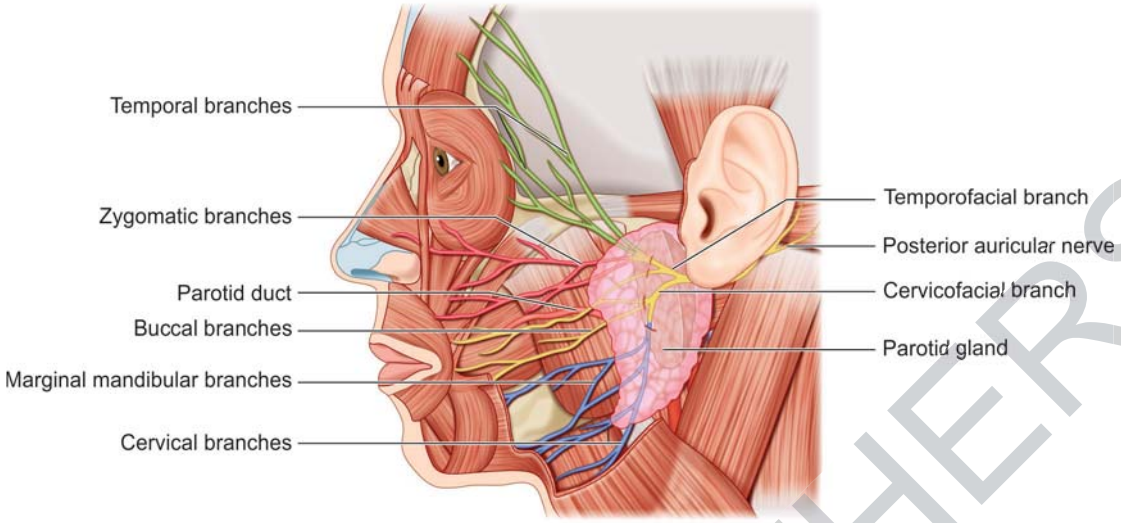


Fig. 7.21: Relations of anterior border of parotid gland.

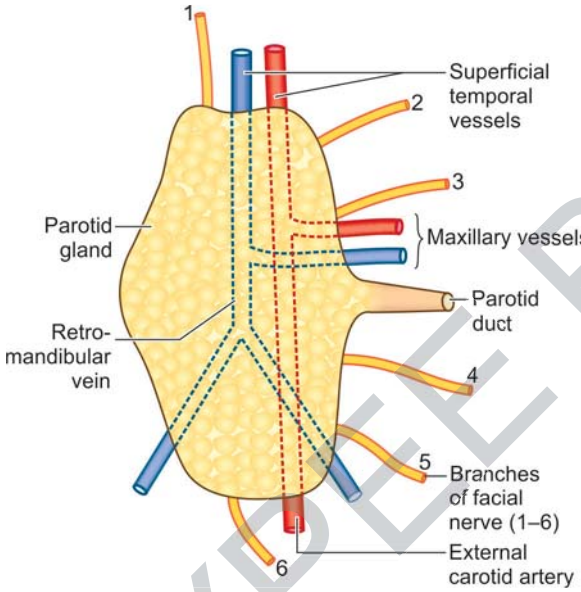


Fig. 7.22: Parotid gland and its relations.

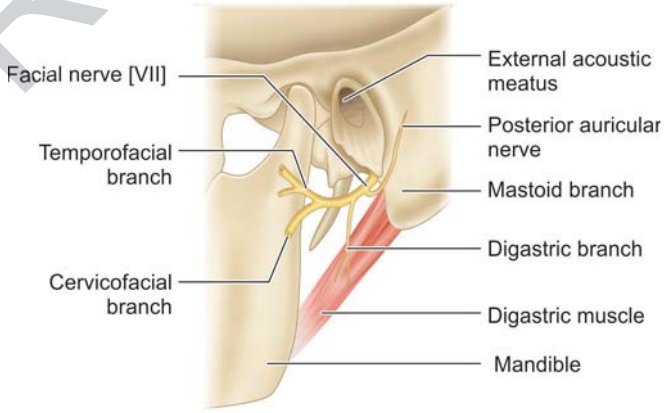


Fig. 7.23: Division of facial nerve within the parotid gland.

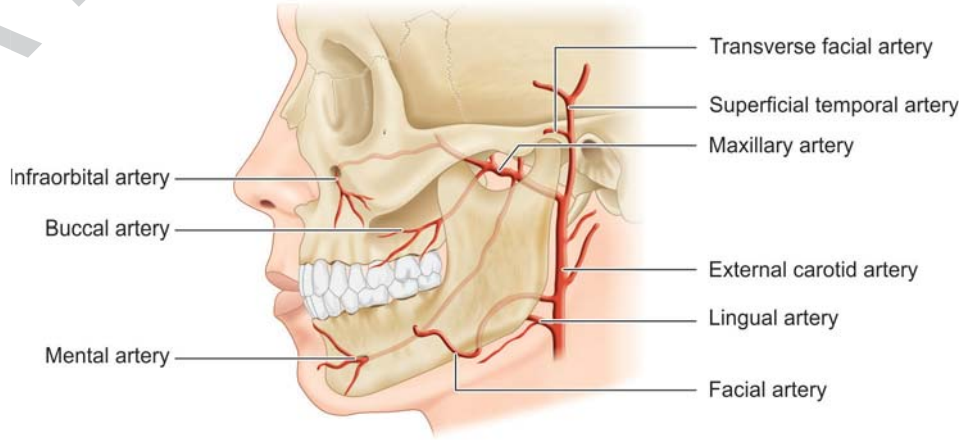


Fig. 7.24: External carotid artery—branches in the face.

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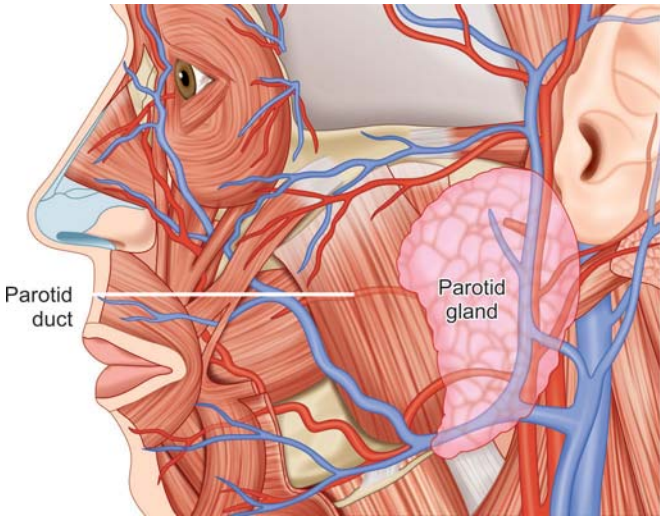


Fig. 7.25: Parotid duct.

Parotid Duct (Fig. 7.25)

- Stenson's duct, 5 cm long, 3 mm wide
- Formed within the gland by the union of smaller ducts
- Emerges at anterior border
- Lies on masseter, between upper and lower buccal branches
- Passes obliquely between buccinator and mucous membrane of cheek
- Opens in the vestibule of mouth on a papilla opposite the crown of upper second molar tooth
- Oblique submucosal course acts as a valve
- Prevents inflation of duct during blowing

Arterial supply: The parotid gland is supplied by branches of external carotid artery.

Nerve supply: It is innervated by sympathetic and parasympathetic fibers. Stimulation of parasympathetic fibers results in copious, watery secretion; whereas sympathetic stimulation, as in fright, decreases the secretion and the mouth turns dry. Sensory nerve fibers pass to the gland through the great auricular and auriculotemporal nerves.

APPLICATIONS AND IMPLICATIONS IN NURSING

1. Mumps is an infectious disease caused by mumps virus, which affects the parotid gland.
2. Parotid swellings are very painful due to the unyielding nature of the parotid fascia. The pain radiates to the ear along the great auricular nerve.
3. Parotidectomy is the surgical removal of parotid gland. The facial nerve is preserved by removing the gland in two parts (superficial and deep) separately.
4. A tumor of parotid gland may infiltrate the facial nerve or its branches resulting in paralysis of muscles of facial expression on that side **(Figs. 7.26 and 7.27)**.

Submandibular gland (Fig. 7.19)

- Submandibular gland is a large salivary gland, roughly J shaped, situated along the body of the mandible.



Fig. 7.26: Parotid tumor.
Courtesy: Dr Sreejayan MP, Professor, General Surgery, Government Medical College, Kozhikode, Kerala, India.



Fig. 7.27: LMN palsy.
Courtesy: Dr Sreejayan MP, Professor, General Surgery, Government Medical College, Kozhikode, Kerala, India.

- It is closely related to the facial artery, lingual and hypoglossal nerves.
- The duct (Wharton's duct), is about 5 cm long, opens on the floor of the mouth, on the summit of the sublingual papilla, at the side of the frenulum of the tongue.

APPLICATIONS AND IMPLICATIONS IN NURSING

1. ***Acute infections:*** May be viral or bacterial. Mumps is the usual viral infection affecting all the salivary glands.
2. ***Salivary calculi:*** Submandibular calculi (stones) are most common and can be demonstrated easily by plain radiography. The duct may be obstructed by the calculus. The characteristic symptom is recurrent painful swelling of the affected gland at meal times. The calculus can be palpated by a 'bidigital' examination **(Fig. 7.28)**.

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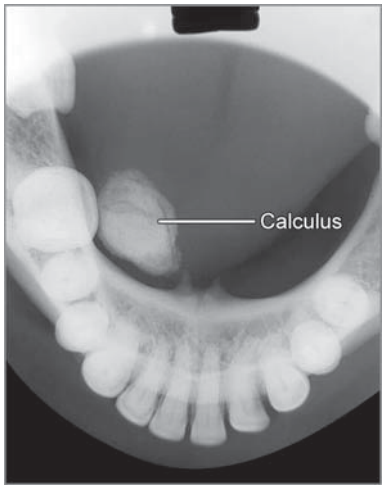


Fig. 7.28: Submandibular calculus seen in intraoral radiograph. *Courtesy*: Department of Oral Medicine and Radiology, Government Dental College, Kozhikode, Kerala, India.

Sublingual salivary gland (Fig. 7.19)

- Sublingual salivary gland is the smallest of the three major salivary glands.
- It lies below the mucosa of the floor of the mouth.
- About 15 ducts emerge from the gland—some of them open directly into the floor of the mouth.
- A few of them join the submandibular duct.

Sialogram

The parotid and submandibular salivary glands may be examined radiographically following injection of a contrast medium into their ducts. This special type of radiograph is called a sialogram due to the small size of sublingual ducts, injection of contrast medium cannot be made into them.

Minor Salivary Glands

There are about **450** minor salivary glands in oral cavity situated in the mucosa of lips, cheeks, palate, floor of mouth and retromolar region. They are present, though in small numbers, in sinuses, oropharynx, larynx and trachea. The highest number (250) of minor salivary glands is situated in the hard palate. **A malignant tumor can occur in any of these small glands.**

These open directly in oral cavity. Minor salivary glands are labial glands (lips), buccal glands (cheeks), lingual glands (tongue) and palatine glands (palate).

Based on types of cells

Serous glands: These types of glands secrete thin and watery saliva. Parotid glands and lingual glands are of serous variety.

Mucus glands: These glands secrete thick, viscous saliva with high mucin content, e.g., lingual glands, buccal glands and palatal glands.

Mixed glands: These glands are made up of both serous and mucus cells. Submandibular, sublingual and few labial glands are mixed glands.

Saliva

- Total amount of saliva secreted is 1,500 mL/day
- Contribution of each major salivary gland is:
  - *Parotid glands:* 25%
  - *Submandibular gland:* 70%
  - *Sublingual glands:* 5%.

Composition of Saliva

Saliva contains 99% water and 1% solids. Solids include organic and inorganic constituents:

1. The organic constituents are, the enzyme ptyalin or salivary amylase, lingual lipase and mucin. Mucin is responsible for the viscosity of saliva, which helps in the lubrication of food in mouth.
2. The inorganic constituents in saliva include Na^+, K^+, Ca^{++}, HCO_3^- and Cl^-. Apart from the above substances, saliva also contains lysozyme and immunoglobulin A.

Functions of Saliva (Fig. 7.29)

Lubrication and speech: Saliva helps in easy swallowing of food, as it lubricates food. Mucin is responsible for this action. Lubricating action of saliva also helps in speech.

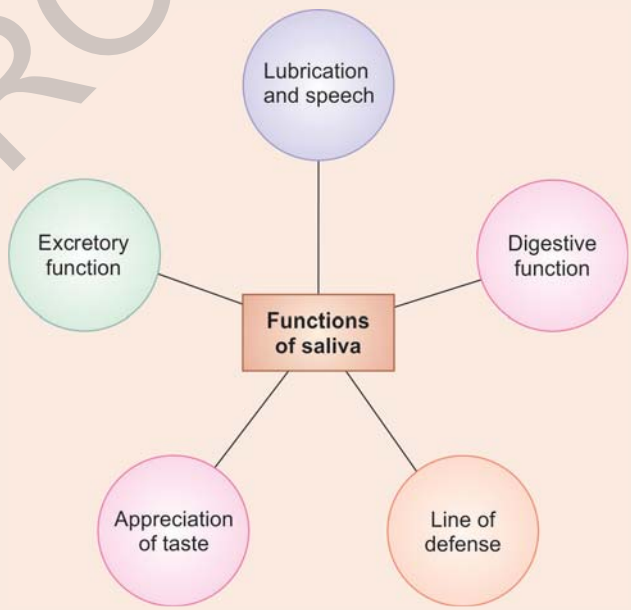


Fig. 7.29: Functions of saliva.

Appreciation of taste: Only foods, which are dissolved in the saliva can stimulate the taste buds.

Digestive function: Saliva contains salivary amylase or ptyalin, which mainly acts on cooked starch and converts it into maltose. After chewing, the food mixed with ptyalin is swallowed and its action continues in the stomach for some time. Lingual lipase has a weak action on fat digestion.

Defense: Saliva contains many substances such as lysozyme, immunoglobulin A, etc. which can attack the microorganisms such as bacteria, which are present in food.

Excretory function: Many substances, both organic and inorganic are excreted in saliva. It excretes substances such as

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mercury, potassium iodide, lead and thiocyanate. Saliva also excretes some viruses such as those causing rabies and mumps. In some pathological conditions, saliva excretes certain substances, which are not found in saliva under normal conditions, such as glucose in diabetes mellitus. In certain conditions, some of the normal constituents of saliva are excreted in large quantities. For example, excess urea is excreted in saliva during nephritis and excess calcium is excreted during hyperparathyroidism.

Regulation of Salivary Secretion

There can be spontaneous as well as stimulated secretion of saliva. Spontaneous secretion or basal secretion of saliva occurs without any stimulus and is always present. It is of small quantity (0.5 mL/min) and is mucinous in nature. Stimulated secretion or reflex secretion of saliva is controlled by nervous stimulation, via unconditioned reflex and conditioned reflexes.

Unconditioned Reflex (Inherent Reflex)

Unconditioned reflex is present since birth and needs no previous experience. Here, salivation occurs when food is placed inside the mouth. The receptors involved are the mechanoreceptors and taste receptors in the oral cavity.

Conditioned Reflex (Acquired Reflex)

Conditioned reflex is developed by previous experiences of the subject. Sight, smell or even thought of familiar food substances can initiate salivary secretion. This reflex is mediated by cerebral cortex. Stress, nausea, irritation of stomach and upper small intestine can also cause increased salivation by this reflex.

Clinical Correlation

1. ***Sialorrhea:*** It is increased salivation that can occur in pregnancy or due to some irritation in the oral cavity, esophagus or stomach.
2. ***Hyposalivation:*** It is decreased salivation, which can occur due to fever, anxiety or drugs such as atropine.
3. ***Xerostomia:*** It means dry mouth. It is due to hyposalivation or absence of salivary secretion (aptyalism). The causes of xerostomia can be dehydration, radiotherapy, injury to salivary glands or their ducts, side effects of drugs such as antihistamines, antidepressants and antiparkinsonian drugs.

GUT

Histology of Gut

General structure of gut wall

Histologically the entire gut consists of four layers (from inside to outside) are mucosa, submucosa, muscularis externa and serosa or adventitia **(Fig. 7.30)**.

Mucosa

Mucosa consists of lining epithelium, lamina propria and muscularis mucosa.

Epithelium

- It performs three functions: Protection, absorption and secretion.
- It gets modified according to the function it has to perform.

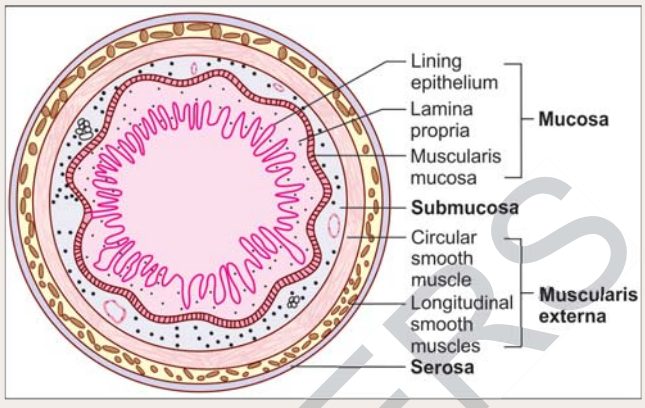


Fig. 7.30: Layers of the gut.

Lamina propria

- It supports the overlying epithelium.
- It is composed of loose connective tissue.
- It is rich in blood supply and lymphatics; the digested food enters the blood in this layer.
- It may also contain glands and lymphoid follicles.

Muscularis mucosa

- It separates mucosa from submucosa.
- It consists of inner circular and outer longitudinal layers of smooth muscles.
- It produces localized movements of the mucous membrane.

Submucosa

- It is present between mucosa and muscularis externa.
- It consists of loose connective tissue.
- Apart from blood vessels and lymphatics, it also has a plexus of autonomic nerves, the submucosal plexus, also called Meissner's plexus.
- It may also contain glands.

Muscularis externa

- It consists of two layers of smooth muscles—the inner circular and the outer longitudinal layers.
- In between these two layers of smooth muscles lies a plexus of autonomic nerves called Auerbach's or myenteric plexus.
- Contraction of this layer propels the food contents.

Serosa and adventitia

- The outermost layer of gastrointestinal tract (GIT) is either serosa or adventitia.

ESOPHAGUS (FIG. 7.31)

The esophagus is a narrow part of the alimentary canal extending from the lower end of pharynx to the cardiac orifice of stomach.

Dimensions

- Length is 25 cm
- Diameter is 1.5 cm.

Parts

Esophagus has three parts:
1. Cervical
2. Thoracic
3. Abdominal.

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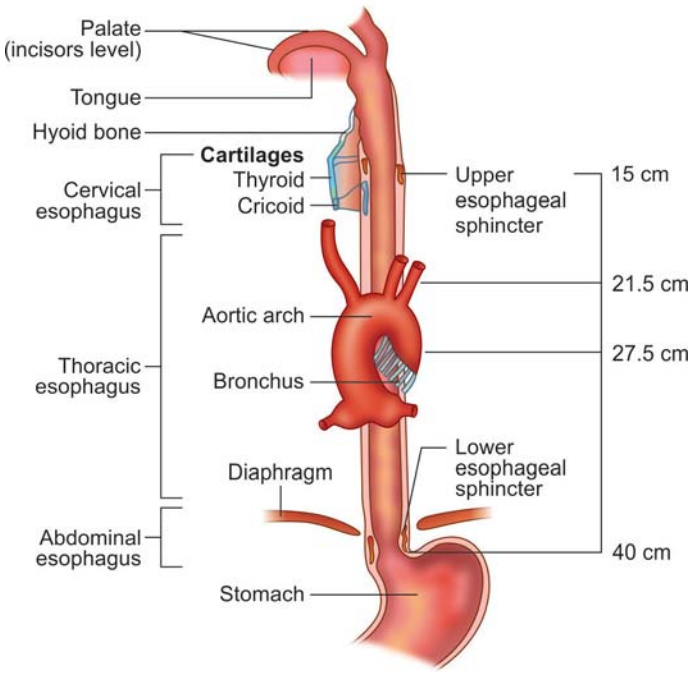


Fig. 7.31: Esophagus and its relations.

External Appearance

Esophagus is a tubular structure, which remains collapsed anteroposteriorly. It shows anteroposterior curvatures, which are similar to those of the vertebral column in the neck, it is convex forward; in the thorax, it is convex backward.

Constrictions of Esophagus

The esophagus presents four constrictions:

1. At the pharyngoesophageal junction—15 cm away from the lower incisors.
2. At the point where it is crossed by the arch of the aorta—21.5 cm away from the lower incisors.
3. At the point where it is crossed by the left bronchus—27.5 cm away from the incisors.
4. At the point where it passes through the diaphragm—40 cm away from the incisors.

Added Information

Important relations (Fig. 7.32)

Cervical part

- Posteriorly—vertebral column
- Laterally—carotid sheath and its contents
- Anteriorly—trachea.

The recurrent laryngeal nerves ascend in the groove between trachea and esophagus.

Thoracic part

- Posteriorly—vertebral column
- Anteriorly—from above downwards:
  - Trachea
  - Left bronchus
  - Right pulmonary artery
  - Left atrium
  - Diaphragm.

  The esophageal plexus of nerves surrounds the esophagus on all sides.
- On either side: Mediastinal pleura of the lungs.

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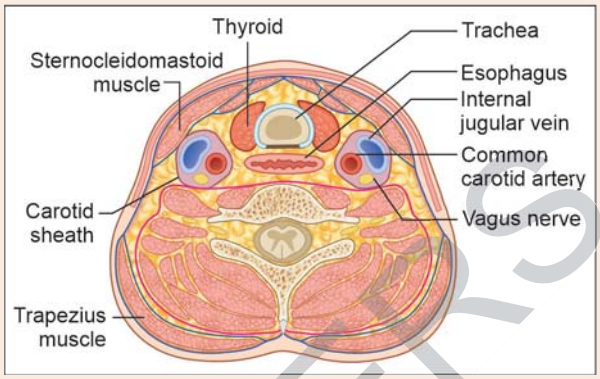


Fig. 7.32: Relations of esophagus.

Abdominal part

This short segment of esophagus lies in a groove on the posterior surface of the left lobe of the liver.

Blood Supply

- ***Arteries***: Esophagus is supplied by esophageal branches of descending thoracic aorta and esophageal branches of left gastric artery.
- ***Veins*** from the upper part drain into azygos venous system and veins from the lower end drain into left gastric vein, which drains into portal vein.

Key Points

Esophageal Varices

- In the submucous venous plexus at the lower end of esophagus, the systemic and portal veins meet.
- In cases of portal obstruction, due to the back flow of blood, esophageal varices are formed (i.e. the veins become dilated and tortuous).
- These varices may burst into the lower end of esophagus. Patient vomits blood (hematemesis).

Nerve Supply

Nerve supply to esophagus is by autonomic nervous system. Parasympathetic fibers arise from vagus nerve and sympathetic fibers arise from splanchnic nerves.

Histology of Esophagus (Fig. 7.33)

- Histology of esophagus is the same as the general histology of GIT
- The epithelial lining of esophagus is non-keratinized stratified squamous epithelium.

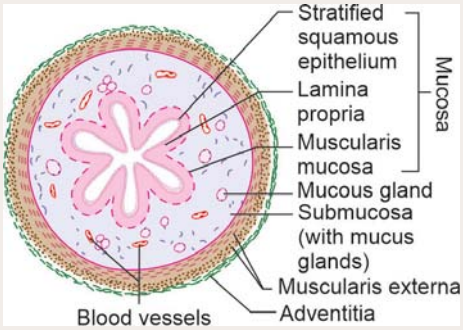


Fig. 7.33: Transverse section of esophagus showing all the four layers of wall. The lumen of esophagus is star shaped.

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Clinical Correlation

1. ***Heartburn (pyrosis)*** refers to the feeling of substernal burning and is highly specific of gastroesophageal reflux disease (GERD).
2. ***Achalasia (cardiospasm):*** The achalasia of the esophagus is a neuromuscular dysfunction in which the cardiac sphincter fails to relax during swallowing and results in progressive dysphagia (difficulty in swallowing) and dilatation of the esophagus (megaesophagus).
3. ***In esophagoscopy, an endoscope is introduced into the esophagus:*** Foreign bodies can be removed, biopsy can be taken from a tumor in the esophagus.

STOMACH

- Stomach is the most dilated part of the alimentary tract.
- It extends from the cardiac end to the pyloric end.
- At its upper end, it is continuous with esophagus and at the lower end, it is continuous with the duodenum.

Functions of Stomach (Fig. 7.34)

- It acts as a reservoir of food
- By its peristaltic activity, it makes the food particles smaller and softer and mixes the food thoroughly with gastric juice
- The gastric enzymes, have an important role in digestion
- The hydrochloric acid secreted by gastric glands destroys many organisms present in food and drink
- Stomach secretes the intrinsic factor necessary for the absorption of vitamin B_{12}
- Some substances are absorbed in the stomach, e.g., some drugs, alcohol, glucose, etc.

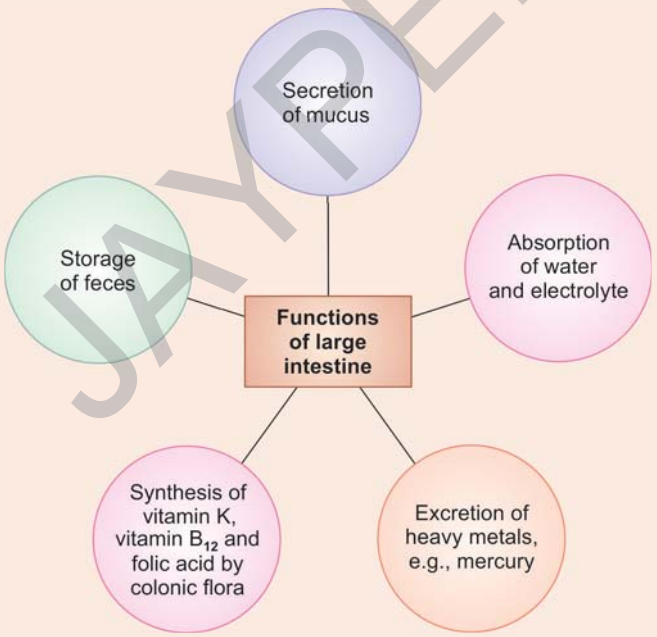


Fig. 7.34: Functions of stomach.

Position

In the supine position, the stomach occupies parts of the epigastric, umbilical and left hypochondriac regions.

Shape

- Stomach is J shaped, the upper part is broader than the lower part.
- It has two ends—upper cardiac and lower pyloric; two surfaces—anterior and posterior; two borders or curvatures—right border or lesser curvature and left border or greater curvature **(Fig. 7.35)**.
- The greater curvature is four to five times longer than the lesser curvature.

Capacity

A newborn infant's stomach can hold up to 30 mL of milk (it is about the size of a lemon). In adults, stomach is capable of considerable expansion, it can hold up to 2–3 L of food.

Parts of Stomach (Fig. 7.35)

For descriptive purposes, stomach can be divided into:

- Cardiac part
- Fundus
- Body of the stomach (or corpus)
- Pyloric region.

Cardiac Part

The cardiac part or cardia lies around the cardiac orifice, which receives the opening of the lower end of esophagus (it was given this name because it lies near the diaphragm where the pericardial sac containing the heart rests).

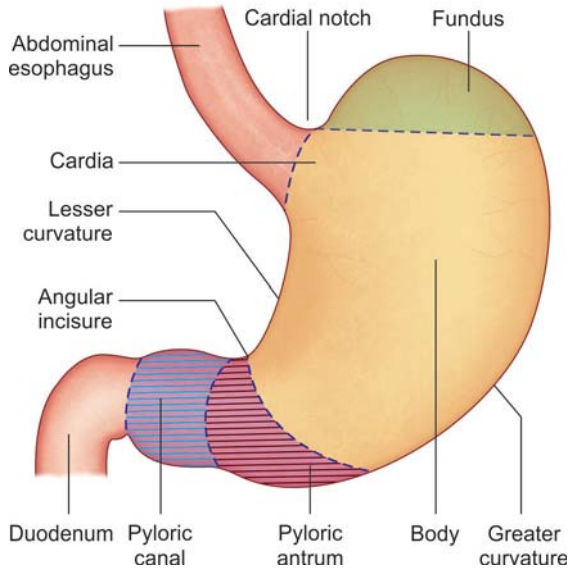


Fig. 7.35: Parts of stomach.

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Fundus

- The fundus of the stomach is the dilated portion, to the left and superior to the cardiac orifice.
- This is the most superior part of the stomach, which is related to the left dome of diaphragm.
- It usually contains a bubble of gas, which can be seen in X-rays.

Body of the Stomach or Corpus

The body of the stomach is the major portion of the stomach. It lies between the fundus and pyloric antrum.

Pyloric Region

- The pyloric region has two parts, antrum and pyloric canal.
- The body of the stomach ends in antrum.
- The junction between body and antrum is marked by an angular notch called incisura angularis or angular incisure.
- 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 the duodenum.

Curvatures

Stomach has two curvatures. The one on the right side is lesser curvature and the one on the left side is the greater curvature.

Lesser Curvature

Lesser curvature gives attachment to a double fold of peritoneum called the lesser omentum **(Fig. 7.36)**, which stretches towards the liver.

Greater Curvature

- Greater curvature gives attachment to the following peritoneal folds from above downwards, as shown in **Figure 7.36**—gastrophrenic, gastrosplenic and greater omentum.
- Between the two layers of lesser omentum at the lesser curvature is the anastomosis between left gastric and right gastric vessels.

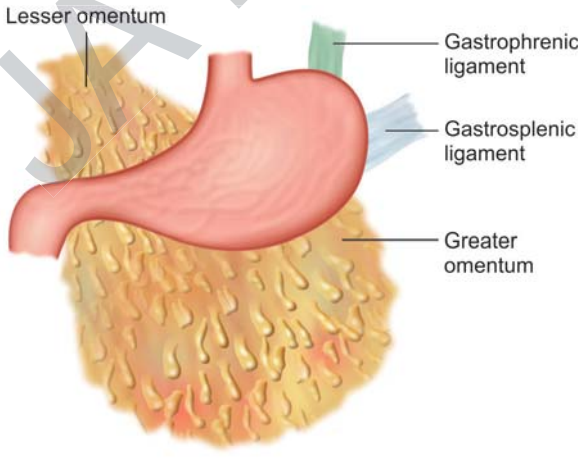


Fig. 7.36: Peritoneal folds.

- Between the two layers of greater omentum at the greater curvature are the right and left gastroepiploic vessels.

Added Information

Relations of anterior surface of stomach

- Left lobe of liver
- Diaphragm
- Anterior abdominal wall.

Relations of posterior surface of stomach—'The stomach bed' (Fig. 7.37).

- Anterior surface of pancreas
- Transverse mesocolon and transverse colon
- Anterior surface of upper part of left kidney
- Left suprarenal
- Splenic artery
- Left crus of diaphragm
- Gastric surface of spleen.

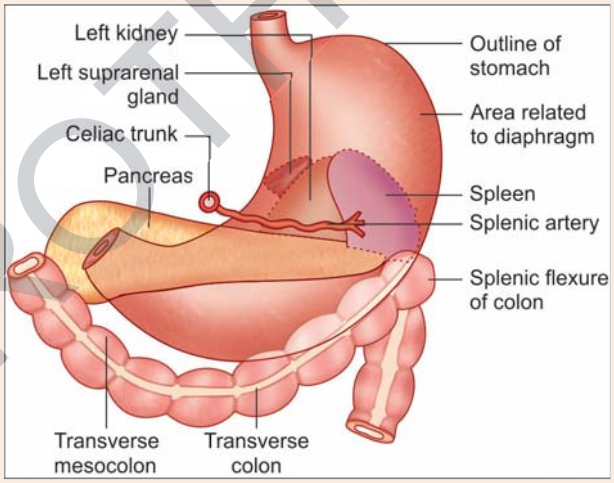


Fig. 7.37: Stomach bed.

Blood Supply of Stomach (Fig. 7.38)

Arterial Supply

Arterial supply from the branches of celiac trunk.

- ***Left gastric artery:*** It is a branch of the celiac trunk, which descends along the lesser curvature.
- ***Right gastric artery:*** It is a branch of hepatic artery and runs along the lesser curvature; it anastomoses with the left gastric artery and supplies blood to the right half of the stomach.
- ***Left gastroepiploic artery:*** It is a branch of splenic artery; it descends along the greater curvature.
- ***Right gastroepiploic artery:*** It is a branch of gastroduodenal artery, which goes along the greater curvature and anastomoses with the left gastroepiploic artery.
- ***Short gastric arteries:*** These are five to six in number; they arise from the splenic artery and supply blood to the fundus of stomach.

Venous Drainage

- Right and left gastric veins end in the portal vein.
- Short gastric and left gastroepiploic vein drains into the splenic vein.

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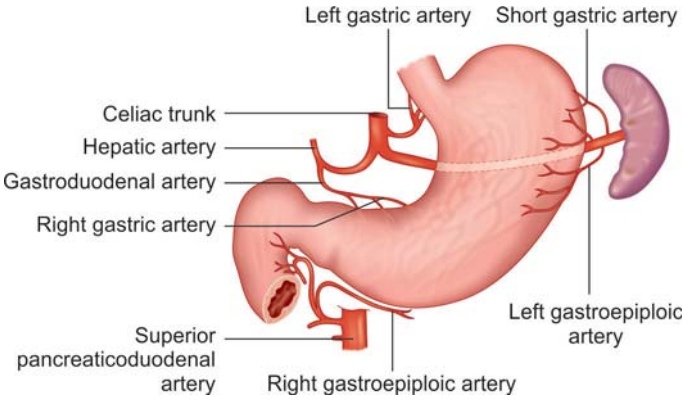


Fig. 7.38: Stomach-arterial supply.

- Right gastroepiploic vein drains into the superior mesenteric vein.
- The **prepyloric vein of Mayo** connects the right gastric and right gastroepiploic veins and crosses the anterior surface of pylorus. So, it forms an important landmark for surgeons in the identification of location of pylorus.

Lymphatic Drainage

The stomach is divided into four zones as shown in **Figure 7.39**. All the nodes finally drain into the celiac nodes.

Nerve Supply

- Nerve supply to stomach is by **autonomic nervous system**.
- Parasympathetic fibers come from the vagus. Parasympathetic stimulation increases the motility of stomach and increases the secretion of gastric juice rich in pepsin and hydrochloric acid.
- Sympathetic fibers arise from the celiac plexus. Sympathetic nerves are vasomotor and motor to pyloric sphincter and the main pathway for pain impulses from the stomach.

Interior of Stomach

Mucosa of stomach is thrown into folds called gastric rugae, which disappear when the stomach distends.

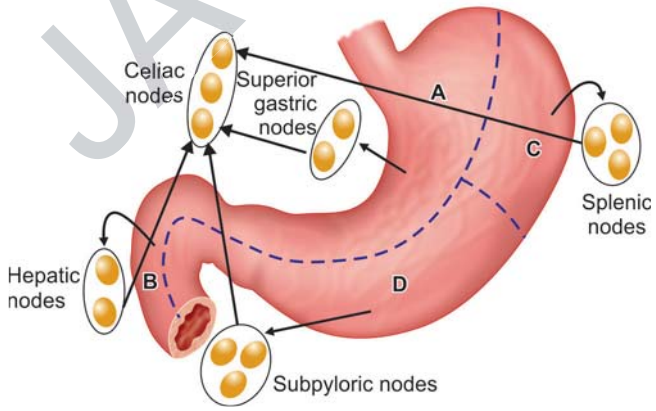


Fig. 7.39: Lymphatic drainage of stomach.

Histology of Stomach (Fig. 7.40)

Stomach has four layers:

1. Mucosa is very thick; lined by simple columnar epithelium. The lamina propria contains gastric glands.
2. The glands open by ducts into pits, which open on the mucosa, releasing their secretions into the lumen of stomach.
3. The gastric glands are long and numerous in the fundus and body.
4. They are lined by different types of cells as given below.

Cell type	*Secretions*
Chief cells	Pepsinogens, lipase, rennin
Parietal (oxyntic) cells	Hydrochloric acid, intrinsic factor of Castle
Mucous cells	Mucus
Endocrine cells or APUD cells	Hormones such as gastrin, somatostatin, VIP
Enterochromaffin cells	Histamine, serotonin

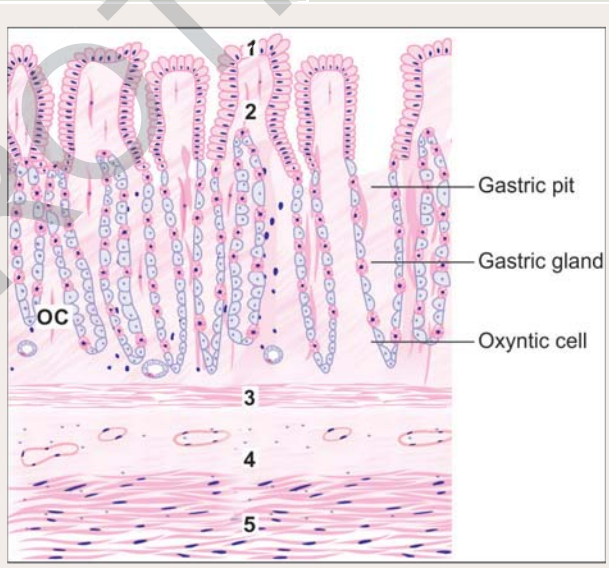


Fig. 7.40: Internal structure of stomach (1, columnar epithelium lining; 2, lamina propria; 3, muscularis mucosa; 4, submucosa; 5, muscularis externa; OC: oxyntic cells).

Clinical Correlation

1. ***Congenital hypertrophic pyloric stenosis:*** First born male infants are commonly affected. The musculature of pyloric antrum is hypertrophied. The symptoms are vomiting, visible peristalsis, constipation and loss of weight. Obstruction is relieved by Ramstedt's operation.
2. ***Peptic ulcer:*** Ulcer means the erosion of the surface of any organ due to shedding or sloughing of inflamed necrotic tissue that lines the organ. Peptic ulcer means an ulcer in the wall of stomach or duodenum caused by digestive action of gastric juice. If peptic ulcer is found in stomach, it is called gastric ulcer and if found in duodenum, it is called duodenal ulcer—occurs in conditions such as infection by *Helicobacter pylori* bacteria, alcohol, vinegar, long-term treatment with non-steroidal anti-inflammatory drugs, e.g., aspirin, etc.

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3. ***Gastric pain:*** It is felt in the epigastrium, because the stomach and skin of upper part of abdominal wall are supplied by T6-T10 segments of spinal cord.
4. ***Carcinoma of stomach:*** The cancer may spread directly to neighboring structures such as pancreas, liver, transverse colon or esophagus; cancer cells can spread to other parts of the body along the lymph vessels or blood vessels. The cells can sometimes pass from the stomach into the peritoneal cavity (transperitoneal implantation). In females, the cells get deposited on the ovaries, giving rise to Krukenberg's tumors.
5. ***Vagotomy:*** Stimulation of vagus nerve is known to cause increased secretion of HCl. So, as a method of treatment in ulcers, vagus nerve section is done.
6. ***Achlorhydria:*** It occurs when a stomach cannot produce juice with a pH of less than 7.1 even after maximal stimulation. Achlorhydria is associated with pernicious anemia because the parietal cell is responsible for the production of both HCl and intrinsic factor.
7. ***Gastrectomy:*** Refers to removal of stomach, as in carcinoma.

Gastric Juice (Fig. 7.41)

The cells of gastric glands secrete about 2,500 mL of gastric juice daily. It has a pH of 1-2 at the luminal surface; i.e., it is strongly acidic. It contains 99% water and 1% solids. The important constituents of gastric juice are pepsinogen, hydrochloric acid, mucus, intrinsic factor, HCO_3^-, etc.

Hydrochloric Acid

Hydrochloric acid (HCl) is secreted by the parietal (oxyntic) cells of the fundic glands.

Functions of HCl

- Activation of pepsinogen to pepsin
- Provides a medium necessary for the action of pepsin on proteins
- Has antiseptic and antibacterial actions
- Helps in absorption of iron and calcium by making them soluble
- Stimulates.

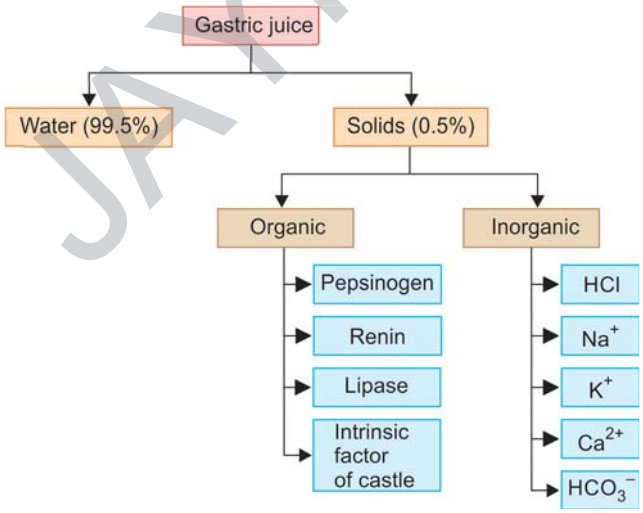


Fig. 7.41: Composition of gastric juice.

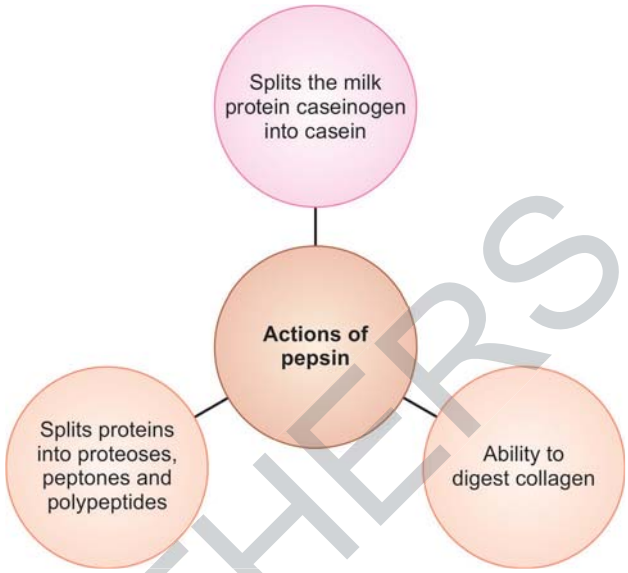


Fig. 7.42: Actions of pepsin.

Pepsinogen

The chief cells secrete pepsinogen. This is an inactive precursor of pepsin, which is stored in the zymogen granules. Hydrochloric acid converts inactive pepsinogen into active pepsin by cleaving a peptide from the molecule. Actions of pepsin are summarized in **Figure 7.42**.

Mucus

Mucus is secreted by the neck mucus cells of fundic gland, cells of pyloric gland and cardiac gland. Mucus forms a viscid, gel-like coat over the mucosa. It is alkaline in nature and forms an extremely important protective layer, saving the stomach from the destructive action of HCl. Substances such as alcohol, vinegar, aspirin, etc., can erode this barrier and produce gastritis.

Phases of Gastric Secretion (Fig. 7.43)

There are three phases of gastric secretion—cephalic, gastric and intestinal.

Cephalic Phase

Cephalic phase is the psychic secretion that occurs even before food enters the stomach. Presence of food in the mouth, sight, smell or thought of food, etc., may stimulate gastric acid secretion, which is mediated via vagus nerve. This secretion is called appetite juice.

Gastric Phase

The presence of food in the stomach initiates this phase causing more than two thirds of total gastric secretion. Gastric distension is a potent stimulus for the secretion of parietal and chief cells. Gastrin can also stimulate HCl production. When the pH of gastric contents becomes less than two, there is a feedback inhibition of gastrin hormone and HCl. This protects the gastric mucosa from damage due to increased acidity.

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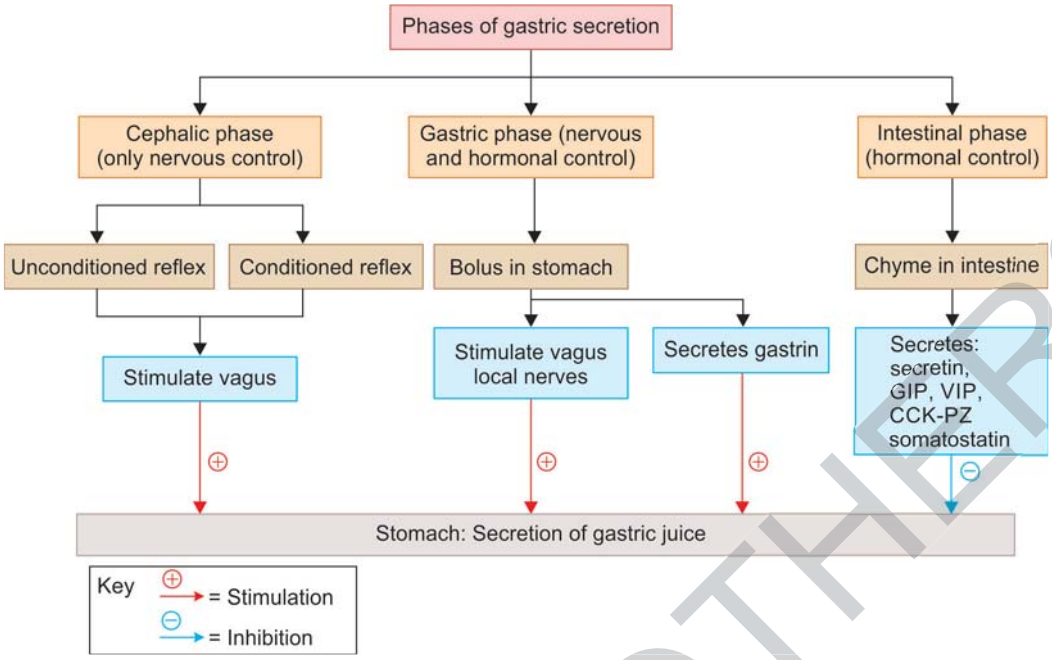


Fig. 7.43: Phases of gastric secretion.
(CCK-PZ: cholecystokinin-pancreozymin; GIP: gastric inhibitory peptide; VIP: vasoactive intestinal peptide)

Intestinal Phase

In contrast to the excitatory cephalic and gastric phases, the intestinal phase of gastric secretion is chiefly inhibitory in nature. The presence of acid or fat in duodenum causes release of hormones such as secretin, cholecystokinin-pancreozymin (CCK-PZ), vasoactive intestinal polypeptide (VIP), gastric inhibitory polypeptide (GIP), somatostatin, etc., which inhibits gastric acid secretion.

SMALL INTESTINE

Extent

- The small intestine extends from the pylorus to the ileocecal junction.
- It is about 6 m long. Its structure is adapted for digestion and absorption.

Parts

Small intestine is divided into:

- An upper fixed part called duodenum, approximately 25 cm long (10 inches)
- A lower (distal) mobile part.
- The proximal two fifth of this long convoluted tube is continuous with the duodenum and is known as jejunum.
- The distal three fifth is called ileum.
- The coils of jejunum and ileum are suspended by a fold of peritoneum called **mesentery** from the posterior abdominal wall.

Important Features

The structure of small intestine is adapted for digestion and absorption. For absorption of digested food, a very large surface area is required. This is achieved by the following modifications:

1. Great length of small intestine (5½–6 m).
2. Presence of circular mucous folds or plicae circulares or valves of Kerckring. They are permanent mucous folds; absent in the first part of duodenum and last part of the ileum. These folds help to increase the surface area for absorption, and digestion and also help in slowing down the passage of food.
3. ***Presence of villi and microvilli:*** The intestinal villi are finger-like projections of mucous membrane, which give the intestinal surface a velvety appearance.
4. ***Structure of villus:*** Each villus is covered by a layer of tall columnar cells. The surface of each cell is provided with numerous microvilli or the brush border, which increase the surface area of absorption. The connective tissue core of the villus contains a plexus of capillaries, a lymphatic vessel called lacteal and a few smooth muscle fibers. The lacteals absorb the products of digestion of fat. The products of digestion of carbohydrates and proteins reach the capillaries, which ultimately reaches the portal vein. The smooth muscle fibers help in the movement of the villi.
5. ***Intestinal glands or crypts*** of Lieberkühn are simple tubular glands, which open into the lumen, on the surface of mucous membrane, between the villi. They secrete enzymes and mucus.

Note: The duodenum has special glands in the submucosa—the duodenal glands or Brunner's glands, which secrete alkaline mucus to neutralize the hydrochloric acid.

Duodenum

- The duodenum is the shortest, widest and most fixed part of small intestine.

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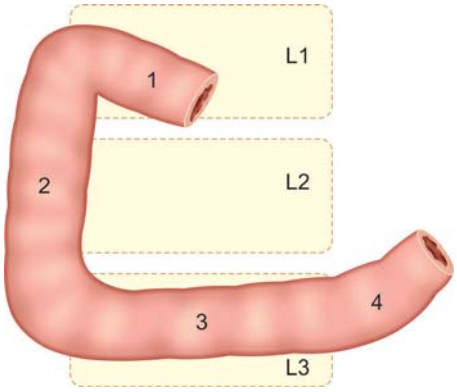


Fig. 7.44: Position of duodenum and its parts.

- The term 'duodenum' is derived from a Greek word 'do deka daktulos,' meaning 12 fingers (the duodenum has 12-finger breadth—approximately 10 inches/25 cm).

Extent

It extends from the pylorus to the duodenojejunal flexure. It is closely related to the head of the pancreas.

Position

The duodenum is mostly retroperitoneal, lies above the level of umbilicus, opposite to the vertebrae L1, L2 and L3.

Parts (Fig. 7.44)

Duodenum has four parts:
1. Superior or first part (5 cm)
2. Descending or second part (7.5 cm)
3. Horizontal or third part (10 cm)
4. Ascending or fourth part (2.5 cm).

Superior or first part

First part begins at the pylorus and passes upwards, backwards and to the right to meet the second part at the superior duodenal flexure.

Descending or second part

Second part is about 7.5 cm long. It begins at the superior duodenal flexure, descends up to L3 level and becomes continuous with the third part at the inferior duodenal flexure. It is retroperitoneal.

Interior of second part **(Fig. 7.45)**

- About 8–10 cm distal to the pylorus, there is an elevation called major duodenal papilla.
- The hepatopancreatic ampulla of Vater opens on the summit of the papilla.
- The minor duodenal papilla is present 6–8 cm distal to the pylorus; the accessory pancreatic duct, when present, opens on this papilla.

Horizontal or third part

- Third part is about 10 cm long.
- It begins at the inferior duodenal flexure, to the right of L3 vertebra, runs horizontally and ends by joining the fourth part.

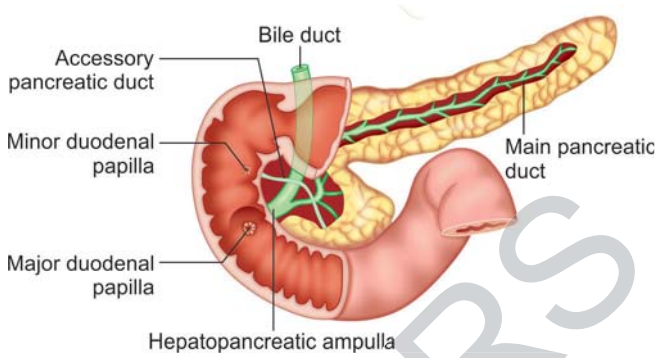


Fig. 7.45: Interior of second part of duodenum.

Ascending or fourth part

- Fourth part is only 2.5 cm long.
- It runs upwards to the left of the aorta up to L2 level.
- It becomes continuous with the jejunum at the duodenojejunal flexure.

Organs related to duodenum (Fig. 7.46)

Anteriorly: Liver and gallbladder (to first part), transverse colon (to second part) and superior mesenteric vessels (to third part).

Posteriorly: Gastroduodenal artery, bile duct, portal vein (to first part), right kidney and ureter (second part) right abdominal vessels, inferior vena cava and abdominal aorta (third part).

Arterial supply

- ***First part:*** Branches from right gastric artery
- ***Second part:*** Up to the major duodenal papilla, by superior pancreaticoduodenal artery
- ***Rest of the duodenum:*** Inferior pancreaticoduodenal artery.

Venous drainage

Corresponding veins drain into the superior mesenteric and portal veins.

Nerve supply

- Sympathetic nerve supply is by T9-T10 segments
- Parasympathetic supply is by vagus nerve.

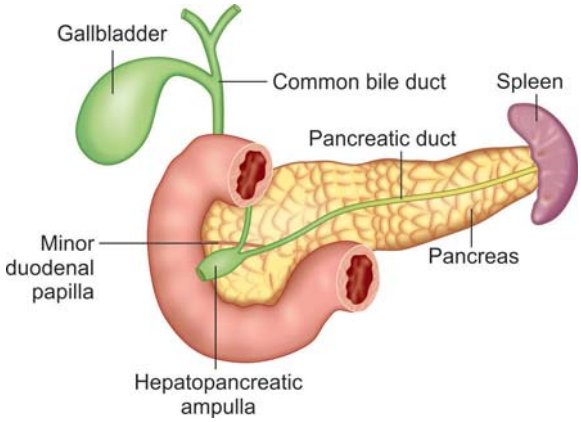


Fig. 7.46: Relations of duodenum.

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Clinical Correlation

1. Duodenal ulcers are more common in the first part of duodenum due to the following reason—stomach empties its acid chyme into the first part of duodenum.
2. A perforated duodenal ulcer may erode the gastroduodenal artery, producing severe bleeding.

Jejunum and Ileum (Table 7.2)

- The coils of jejunum and ileum are suspended by the mesentery (a fan-shaped fold of peritoneum) from the posterior abdominal wall; so they are freely mobile.
- The jejunum begins at the duodenojejunal flexure.
- Together, the jejunum and ileum are about 5½–6 m long (jejunum forms two fifth and ileum three fifth).
- The ileum ends at the ileocecal junction in the right iliac fossa.

Mesentery of jejunum and ileum (Figs. 7.47A and B)

- The jejunum and ileum are suspended from the posterior abdominal wall by a fan-shaped mesentery.
- The pleated, fan-shaped mesentery has two layers of peritoneum.
- Between these layers, there are jejunal and ileal vessels, lymphatics, nerves and extraperitoneal fatty tissue.
- **The root of the mesentery** is about 15 cm long. It is directed obliquely; runs downwards and to the right.
- It extends from the left side of L2 vertebra to the right sacroiliac joint.

Structures crossed by the root of the mesentery:

- Horizontal part of duodenum
- Aorta
- Inferior vena cava
- Psoas major muscle
- Right ureter
- Right gonadal vessels.

Table 7.2: Differences between jejunum and ileum.

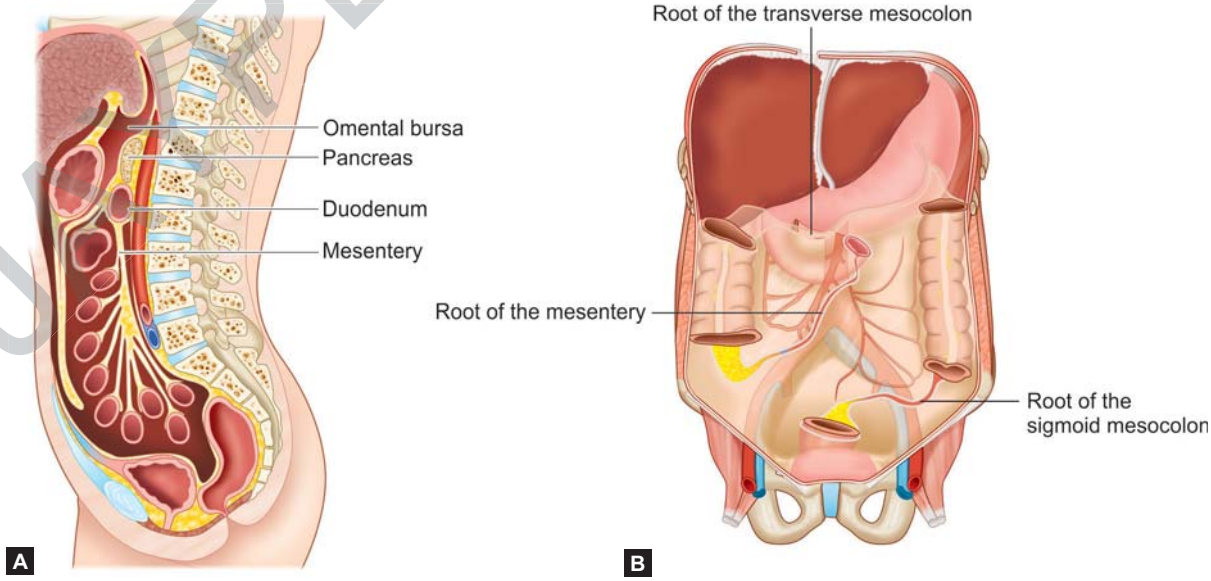
Feature	*Jejunum*	*Ileum*
Cavity	Usually empty (In Latin jejunus means 'empty')	Loaded
Thickness of wall	More	Less
Color	Red, due to increased vascularity	Paler
Position	Coils occupy the umbilical region	Hypogastric and right iliac fossa
Plicae circulares	Large and well developed, more in number	Small in the superior part and absent in the terminal part
Presence of fat in the mesentery	Less	More
Presence of lymph nodes in the mesentery	Less	More
Arteries in the mesentery	Vasa recta longer and less in number	Shorter, closely placed and numerous
Villi	Long and abundant	Short, thin and less numerous
Peyer's patches	Absent	Present

Arterial supply

They are supplied by branches of superior mesenteric artery, a branch of abdominal aorta.

Nerve supply

By superior mesenteric plexus (an autonomic plexus) containing sympathetic fibers and parasympathetic fibers from vagus.



Figs. 7.47A and B: (A) Mesentery and coils of small intestine; (B) Root of the mesentery.

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Lymphatic drainage

Lymphatics in the intestinal villi called **lacteals** empty their milk-like fluid into a plexus of lymph vessels in the walls of jejunum and ileum. From here they pass to inferior mesenteric lymph nodes and ultimately into the superior mesenteric lymph nodes.

Clinical Correlation

1. **Volvulus (L, volvo means 'to roll'):** Twisting of intestines and superior mesenteric vessels often occurs. This may lead to deficiency in blood supply (ischemia) to the intestines, leading to necrosis and gangrene (death of tissue).
2. An ileal diverticulum (**Meckel's diverticulum**) is the most common malformation of the digestive tract.
   - It is a blind sac or finger-like pouch arising from the antimesenteric border of ileum about 2 ft proximal to ileocecal junction, it is approximately 2 inch long and present in 2% of population.
   - It is of clinical significance because it may get inflamed (ileal diverticulitis) and the symptoms mimic acute appendicitis
   - Ileal diverticulum is the remnant of proximal part of embryonic yolk stalk.

Functions of Small Intestine (Fig. 7.48)

Helps in digestion

- Segmental contractions in the small intestine help in mixing the chyme coming from stomach with pancreatic juice, bile and intestinal juice for proper digestion

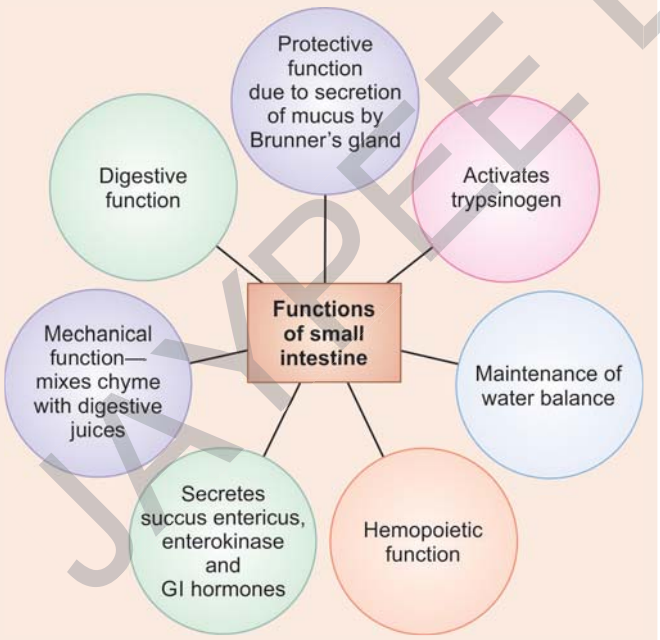


Fig. 7.48: Functions of small intestine.
(GI: gastrointestinal)

- End stages of digestion occur in the small intestine
- Final products of digestion, vitamins, minerals, water, etc. are absorbed in the small intestine

Contd...

Contd...

- Has antiseptic and antibacterial actions
- Helps in absorption of iron and calcium by making them soluble
- Stimulates.

Secretes hormones

A large number of hormones are secreted by the APUD cells present in the small intestine. Enterogastrone, secretin and CCK control the secretory activity of pancreas, small intestine and also control gastrointestinal movements. Other hormones secreted by the intestine are gastroinhibitory peptide and motilin. Activation of trypsinogen occurs by enterokinase secreted by small intestinal mucosa.

Protective function

The mucus present in the succus entericus protects the intestinal wall from the acid chyme, which enters the intestine from stomach; thereby it prevents the intestinal ulcer. Mucus secreted by the Brunner's gland and goblet cells protects intestinal mucosa. Paneth cells of intestinal glands secrete defensins, which are the antimicrobial peptides.

Water balance

Amount of juice presented to the small intestine comes to about 9 L. But only 1-2 L of fluid reach the colon. Rest is reabsorbed in the small intestine.

Hematopoietic function

Vitamin B is absorbed from small intestine in the presence of intrinsic factor. Deficient absorption of B_{12} leads to pernicious anemia.

Small Intestine Juice (Succus Entericus)

Small intestine juice is the characteristic alkaline fluid secreted by the crypts of Lieberkuhn. The composition of succus entericus is given in **Figure 7.49**. About 2 L of fluid is secreted per day, which is rapidly reabsorbed by the intestinal villi. The digestive enzymes in the succus entericus are present in the brush border or microvilli of the epithelial cells. The enzymes include the following.

Disaccharidases

They are chiefly sucrase, maltase and lactase enzymes. They act on the carbohydrates and split the disaccharides into monosaccharides.

Proteolytic Enzymes or Peptidases

They bring about the final breakdown of polypeptides into amino acids.

Intestinal Lipase

Intestinal lipase splits neutral fats into diglycerides, monoglycerides, fatty acids and glycerol.

Enterokinase

Enterokinase enzyme activates the conversion of trypsinogen into trypsin. Enterokinase is secreted in response to bile acids, secretin or CCK-PZ.

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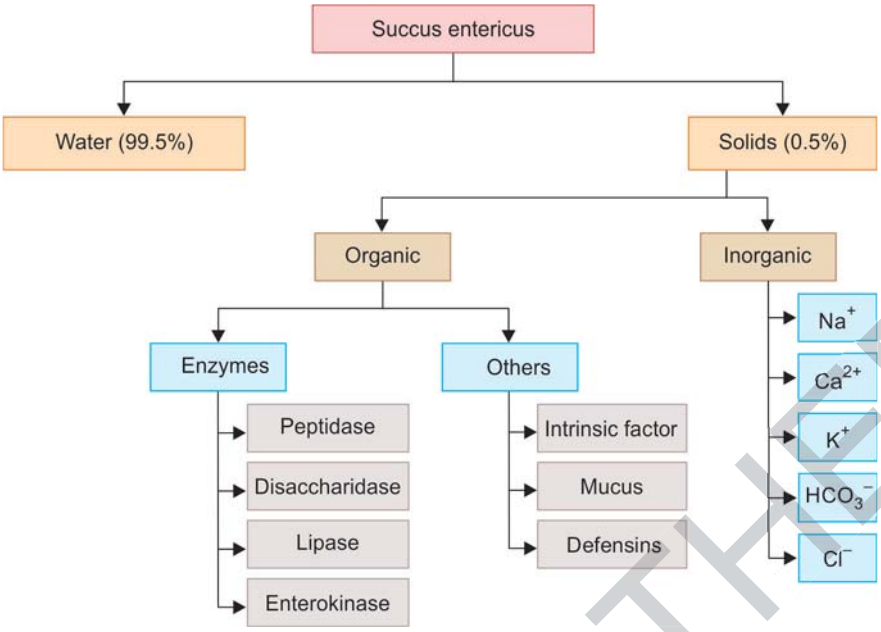


Fig. 7.49: Composition of succus entericus.

Clinical Correlation

Malabsorption refers to difficulty in the digestion or absorption of nutrients from small intestine. It may be the failure to absorb either the specific substances such as proteins, carbohydrates, fats and vitamins or some general non-specific substances of food. Malabsorption affects growth and development of the body.

LARGE INTESTINE

The large intestine extends from the ileocecal junction to the anus. It is about 1.5 m long. Differences between large intestine and small intestine are given in **Table 7.3**.

Table 7.3: Differences between small and large intestines.

Large intestine	*Small intestine*
It has a greater diameter; the caliber decreases gradually towards the rectum	It is smaller in diameter
Greater part of it is fixed; only the transverse colon, sigmoid colon and appendix are provided with mesocolon and are free to move	Greater part of it is mobile (except duodenum)
The longitudinal muscle coat forms three ribbon-like bands called taenia coli	*Taenia coli* absent
Presence of appendices epiploicae—they are small pockets of peritoneum filled with fat and attached to the walls of large intestine	Appendices epiploicae absent
Haustrations are present (they are circular constrictions followed by saccular dilatations)	Haustrations are absent
Villi are absent	Villi are present

Parts

The large intestine has:

- The cecum
- The ascending colon
- Transverse colon
- Descending colon
- Sigmoid colon
- Rectum and anal canal.
- In the angle between cecum and terminal ileum, there is a narrow diverticulum called Vermiform appendix.

Position

The rectum and anal canal are situated in the pelvis; the remaining parts are in the abdomen.

Cecum (Fig. 7.50)

- The cecum is the first part of the large intestine.
- It is a broad, blind pouch *(caecus* means blind) about 5–7 cm in length.
- It is situated in the right iliac fossa. It is continuous with the ascending colon.
- The ileum opens into the superior part of cecum.
- About 2.5 cm inferior to this ileocecal junction, the vermiform appendix opens into its medial aspect.

Vermiform Appendix

- Vermiform appendix (L, vermis means 'worm'; forma means 'form') narrow, worm-like, blind tube joins the cecum about 2.5 cm inferior to the ileocecal junction.
- Appendix is longer and narrower in children.

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