The digestive system includes:-

I. The alimentary (digestive) canal (tract):

A- Oral cavity:

a- Lips b- cheeks c- Palate d. Tongue e- Teeth

B- Pharynx.

C- Esophagus.

D- Stomach.

E- Small intestine (Duodenum, jejunum and ileum).

F- Large intestine (colon, caecum, vermiform appendix and rectum).

G- Anal canal.

II. Glands associated with digestive tract:-

A – Salivary glands

- Major "proper" salivary glands (parotid, lingual and submandibular).
- Minor "accessory" salivary glands (labial, buccal, palatine and lingual).

B- Pancreas.

C- Liver and gall bladder.

Functions of the digestive system:

1) The main functions of the digestive system are processing, digestion and absorption of food.

2. In the mouth, mechanical breakdown by teeth and tongue and mixed with saliva (mastication and swallowing).

3. in the stomach, digesion of swallowed food by gastric enzymes.

4. In small intestine, the digested food is absorbed in the form of its macromolecular basic units, amino acids, monosaccharides, glycerides, ….. etc.

5. Metabolism of the absorbed food by liver.

6. Elimination of the residue from the body through the anus.

A. Oral cavity

(Mouth)

- The oral cavity is the entrance of the digestive tract housing the tongue.
- **The boundaries of oral cavity:-**

* Anteriorly: teeth, gingiva and lips. * Posteriorly: the oro-pharynx.

* Laterally: the teeth and cheeks. * dorsally: the hard palate.

*ventrally: the tongue and floor of the mouth.

a) The Lips

The lip is formed of a central striated muscular mass (Orbicularis oris muscle) covered externally by thin skin and internally by cutaneous mucous membrane.

1- Skin: The lips are covered by thin skin (hairy skin) with hair follicles, sweat and sebaceous glands.

2- Muscular layer: striated muscle called orbicularis oris housing Fibroelastic connective tissue and some glands.

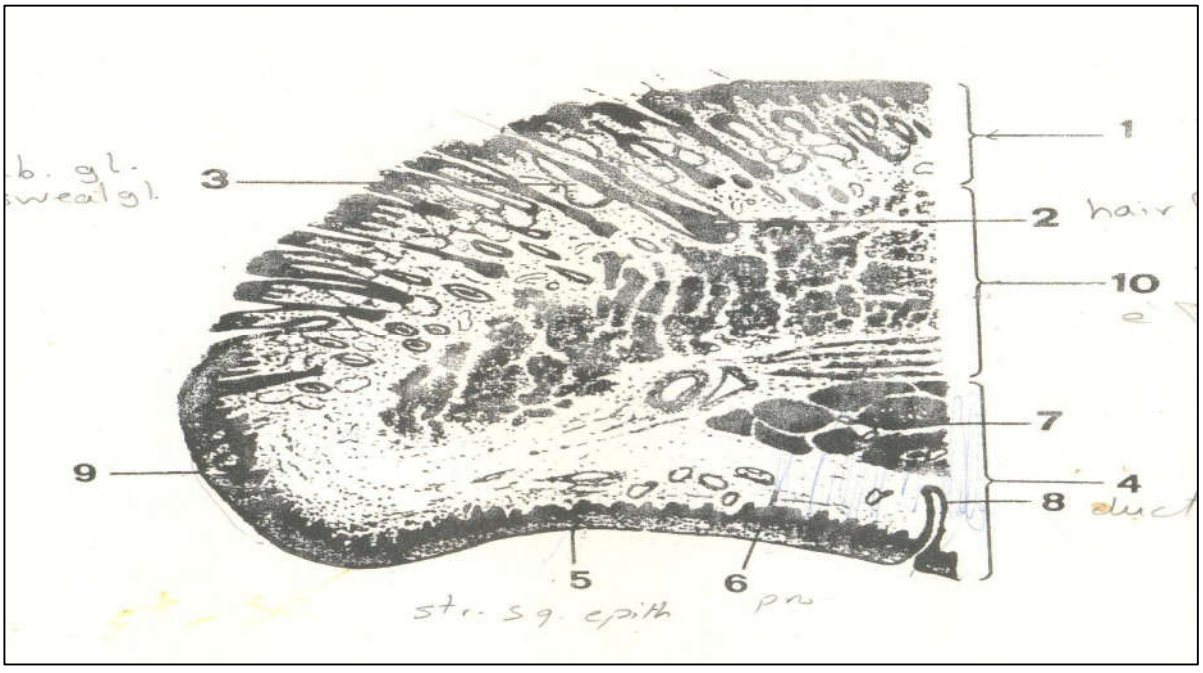
3- Submucosa: It consists of loose C.T containing nerves and arterio-venous anastomoses and labial glands.

4- Mucosa: (cutaneous mucous membrane)

a. Lamina epithelialis: The lips are lined by keratinized stratified squamous epithelium (ruminants and horses) or non-keratinized (pigs, dogs and other carnivores). i.e., the type of linning epithelium differ according to type of food and species of animal

b. Lamina propria or cornium: It consists of dense C.T showing numerous large papillary bodies.

- In ruminants the mucosa shows large cornified coniform macroscopic papillae.



1- Skin
2-hair follicles
3- sebaceous gland

4- Cutaneous mucous membrane 5-st. sq. epithelium
6- Lamina propria 7- labial glands
8- Duct of labial gland 9-junction between skin and cutaneous membrane
10- central striated muscular mass.

Functions:-

1- Prehension of food (small ruminants).
2- Speaking in human and phonation in animals.
3- Wetness and lubricant of food.

b- Cheeks

- It is formed of a central striated muscular mass (Massetter buccinator muscle) covered externally by skin and internally by cutaneous mucous membrane.
- The submucosa contains mixed, serous or mucous buccal glands.

NB:- 1- in ruminants, Mucosa of both lips and cheeks shows coniform papillae. 2- The submucosa consists of loose C.T containing buccal glands.

Functions:-

1- Mechanical direction of food by caudally directed conical papillae.
2- Help in mastication of food by contraction of muscle.
3- Wetness and lubricant of food by buccal gland secretion.

c) The palate

- It forms the roof of the oral cavity.

- It is composed of an anterior hard part (anterior 2/3) called the **hard palate** and posterior soft part (posterior 1/3) called **soft palate**.

i. Hard palate:

► It constitutes the anterior part of the roof of the oral cavity.

► It is formed of

- Lamina propria :- stratified squamous keratinized epithelium
- Lamina propria :- C.T (dense irregular collagen fibers) which is strongly bound to the periosteum of the maxilla and palatine bone.

- Its anterior part contains cavernous blood spaces and its caudal part contains seromucoid glands.

ii. <u>Soft palate</u>:

► It represented the posterior continuation of the hard palate and the posterior part of the roof of the oral cavity.

► It is a mucosal fold directed caudoventrally in the oropharynx, connected anteriorly with the hard palate and posterioly with the nasal mucosa.

► **has two surfaces**:-

- Oropharyngeal (ventral) surface:-
- Naspharyngeal (dorsal) surface:-

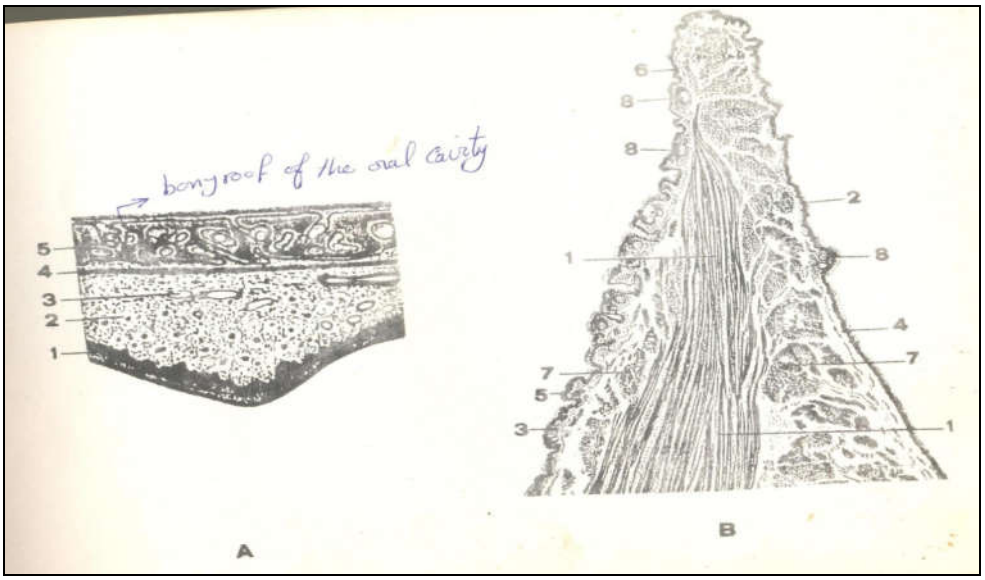
It is strong and movable so that it can be drawn upward during swallowing. This action closes off the nasopharynx and prevents food from being pushed up into the nasal cavity.

► The ventral (oropharyngeal) of the soft palate is covered with non-keratinized stratified squamous epithelium.

► The dorsal surface (nasopharygeal) of the soft palate is covered with pseudo-stratified columnar ciliated epithelium with goblet cells.

► the propria-submucosa of both surfaces consists of dense CT. containing seromucoid glands (palatine glands) and nodular and diffuse lymphoreticular tissue.

► Central longitudinal muscular bands.



A. hard palate: 1-keratinized lamina epithelialis 2-propria-submucosa 3-cavernous blood spaces 4-periosteum 5-bony roof of oral cavity
B. soft palate: 1-striated muscle 2-cutaneous mucous membrane (oral surface) 3-aboral surface (respiratory mm) 4- seromucoid glands in both surfaces XXXX

d) The tongue

- It is a fibromuscular movable organ present in the oral cavity.

- It consists of a thick striated central muscular mass arranged in different directions (longitudinal, transverse and vertical) to allow wide range of movement of the tongue that help in mastication, speaking or phonation and swallowing..

- It covered on both surfaces by mucosa and submucosa

1- <u>Mucosa</u>:

a. Lamina epithelialis:

- Dorsally: Cornified stratified squamous epithelium with lingual papillae
- Ventrally: smooth Stratified squamous non keratinized epithelium.

b. Lamina propria: dense fibrous C.T with papillary bodies dorsally.

2- <u>Submucosa</u>:

It continuous with the lamina propria and consists of dense fibrous C.T containing blood vessels lymphatics, nerves and seomucoid lingual glands

<u>The lingual papillae:</u>

- The lingual papilla is a little projection of the mucous membrane. It is formed of **a central core** of C.T covered with **cap** of stratified squamous epithelium.

* **There are two types:**

A) Mechanical papillae:

- They are consisting of C.T core, derived from the lamina propria and covered with an epithelial cap carrying a heavy stratum corneum.

- **According to their shape they are classified into:-**

1) Filiform papillae:

- **Site:** They are numerous in number present over the anterior 2/3 of the dorsum of the tongue.
- **Shape**: Each papilla is a thread-like projection of the mucous membrane.

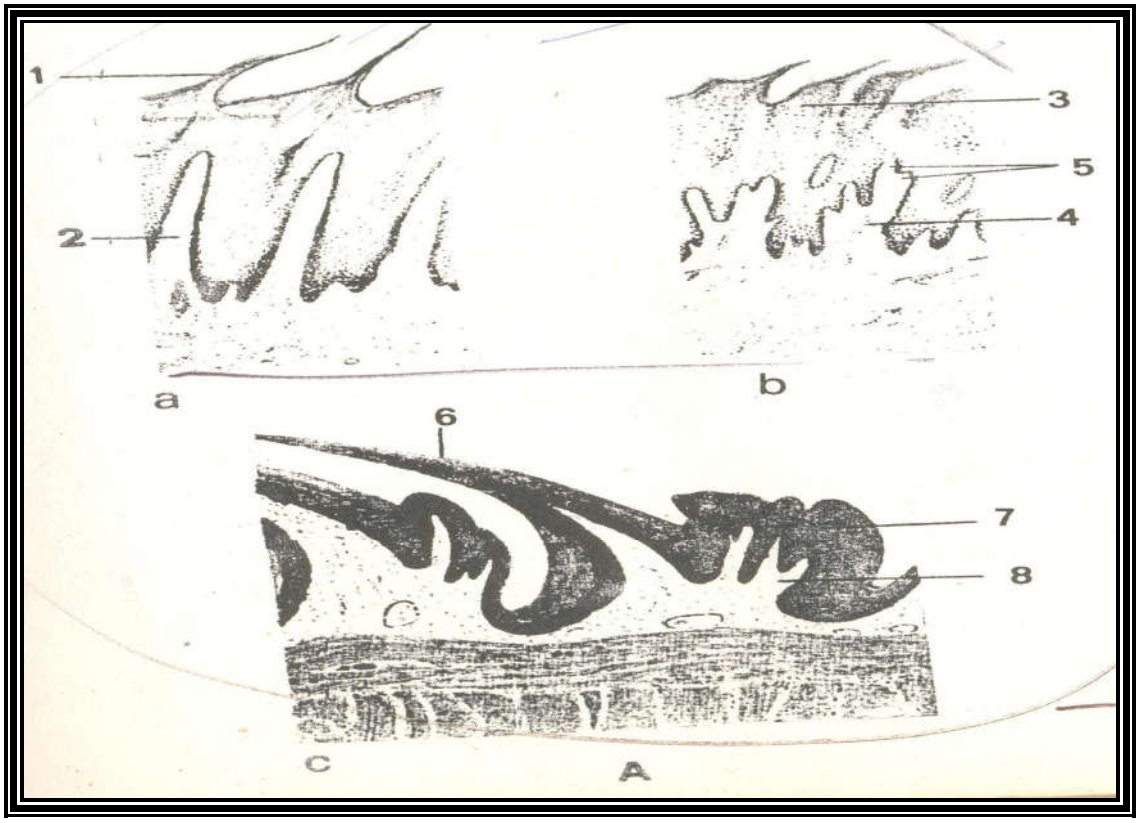
A - In the horse and pigs: The papilla has a simple elongated C.T core not extend above the surface epithelium. It is covered by heavy keratinize lamina epithelialis.

B - In ruminants: it is formed of primary and secondary papillary bodies not extend above the surface epithelium and covered by heavy keratinized epithelium.

- In dogs and cats: The papilla consists of two unequal parts:

a) ***oral or rostral or supporting part***: It is the smaller, rounded or flattened in shape formed of CT core has primary and secondary papillary bodies and covered by less keratinized epithelium

b) ***aboral or Caudal or main part*****:** It is the largest one, directed caudally. It is a claw or spine-like, highly cornified and The C.T core extends above the epithelial surface.



a- filiform papilla of horse:-
1- cornified cap 2- core of CT.
b- filiform papilla of ruminants:
3- Keratinized cap 4-core of CT. 5- Secondary papillae
c- filiform papilla of cat:
6-caudal (aboral) part 7-rostra (oral) part 8- core of CT.

2) Corniform papillae:

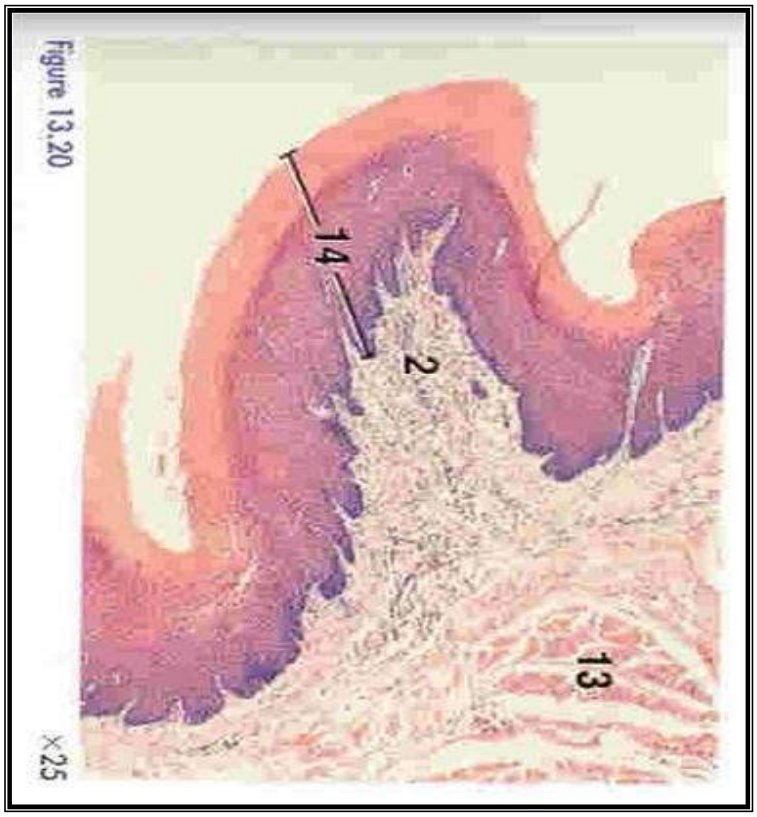
- **Site:** They are found at the root of the tongue and on the inner surface of the lips and cheeks of ruminants.
- **Shape**: They are conical in shape and are directed caudally. It consists of cap of less keratinized stratified squamous epithelium covering C.T which carries secondary papillae.

3) Lentiform papillae:

- **Site**: They are present at the caudal part of the tongue of ruminants.
- **Shape**: They are flattened lentil-shaped branched C.T core (core of dense irregular C.T) covered by cornified epithelial cap, having thin sharp edges.

❖ **Functions of mechanical papilla**e:-

Mixing, directing and pushing of food toward the esophagus**.**



Conical papilla

B) Gustatory papillae:

- They consist of C.T core, derived from the lamina propria forming primary and secondary papillae covered with a cap of lamina epithelialis. They are characterized by the presence of **taste buds**.
- **According to their shape they are classified into:-**

1) ***Fungiform papillae:***

- **Site**: They are present over the anterior 2/3 of the tongue among the rows of filiform papillae.
- **Shape**: They are Mushroom (fungus)-like short, broad. The C.T corium

forms small secondary papillae under the covering epithelium. Their covering epithelium is red in colour non-keratinized stratified squamous

- **Taste buds**: They may contain taste buds in the epithelial cap which is soft. The taste buds are few in horses and cattle and numerous in dogs.
- **Number:** They are few in number, but they are more numerous at the tip of the tongue.

2) ***Circumvallate or vallate papillae:***

- **Site**: They are present in the caudal part of the tongue along and deeply to the v-shaped sulcus terminalis.
- **Shape**: They are large papillae with broad tops and completely surrounded by deep furrow or moat. The covering epithelium on the lateral surface of the circumvallate papillae is non-keratinized. The C.T corium forms small secondary papillae under their covering epithelium.
- **Taste buds:** Several taste buds are present at the lateral sides of the papillae.
- There are serous glands beneath the papillae (Ebner's glands) which empty their products into the gustatory furrow.
- **Number:** 2 – 3 in horse, 8 – 17 in bovines and caprines and 18 – 24 in ovines (8 – 12 in human).

3) ***Foliate papillae:***

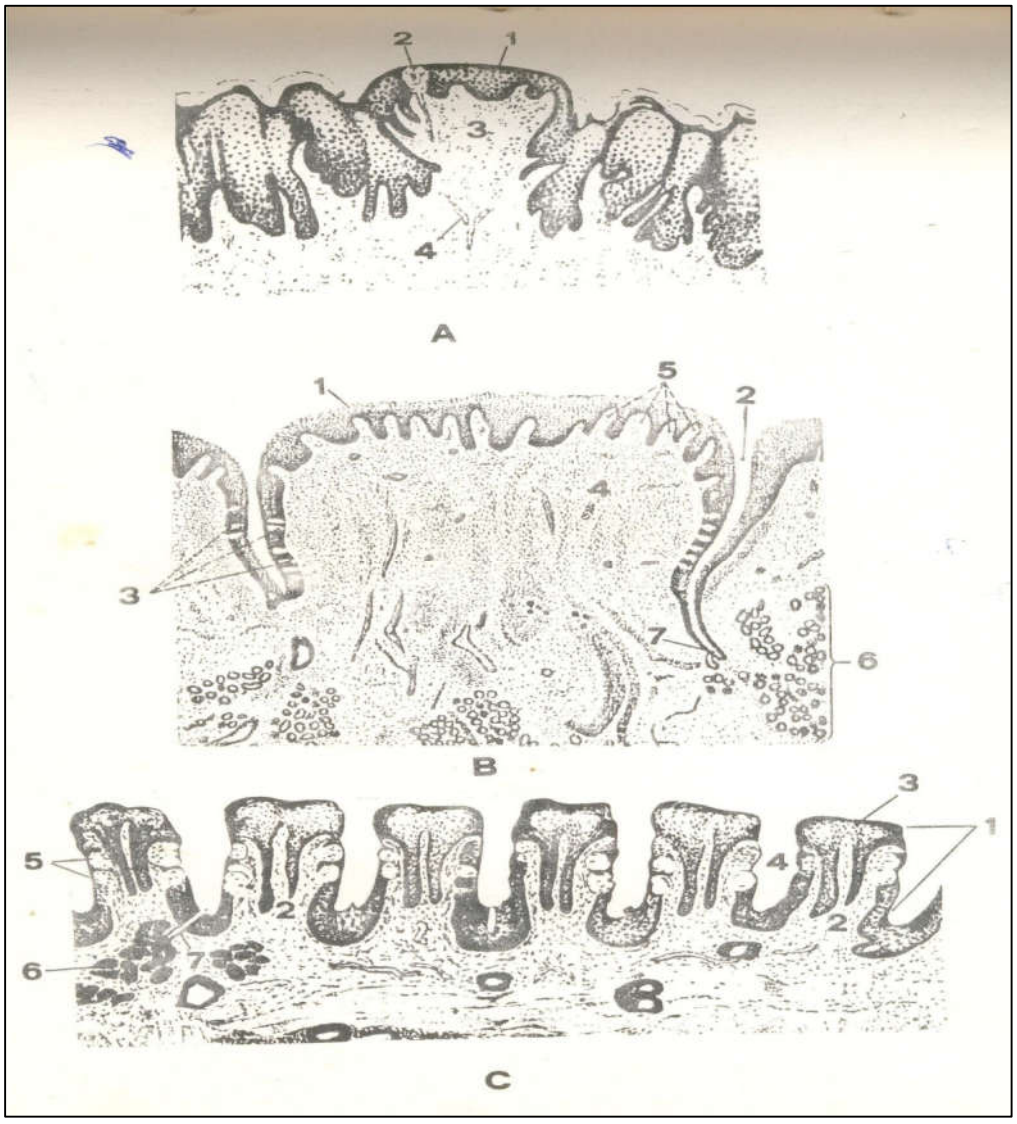
- **Site**: They are found on each side at the root of the tongue. They are well developed in the posterior part of the tongue of rabbit. They are rudimentary in man.They are 2 in horses (one on each side) and absent in ruminants.
- **Shape**: They are consisted of leaf-like projections, separated by gustatory furrows. Each papilla is formed of parallel ridges and grooves of C.T covered with stratified squamous epithelium. Deeply in its C.T corium, there are striated muscles and serous glands secreting saliva.
- **Taste buds:** Several taste buds are found at the lateral sides of each leaf.

- There are serous glands beneath the papillae (Ebner's glands) which empty their products into the gustatory furrow.

Functions of tongue papillae:

1- They are highly developed in animal to help them in thickening of solid and semisolid materials.

2- In man, tongue papillae permit children to lick milk and ice cream easily. They contain taste buds which are neuro-epithelial structure responsible for taste sensation.



A- fungiform papilla

1- non keratinized epithelium
2-taste buds
3- core of CT.
4-blood vessel and nerves

B- Circumvallate papilla

1- keratinized epithelium
2-cleft or moat
3-taste buds
4-C.T core
5-

secondary papillae
6- gustatory glands 7-ducts of gustatory glands

C-foliate palilla
1-papillary projection 2-C.T core 3-keratinized epithelium 4- gustatory furrow 5-gustatory glands 7-duct of gustatory gland

Special lingual structures:

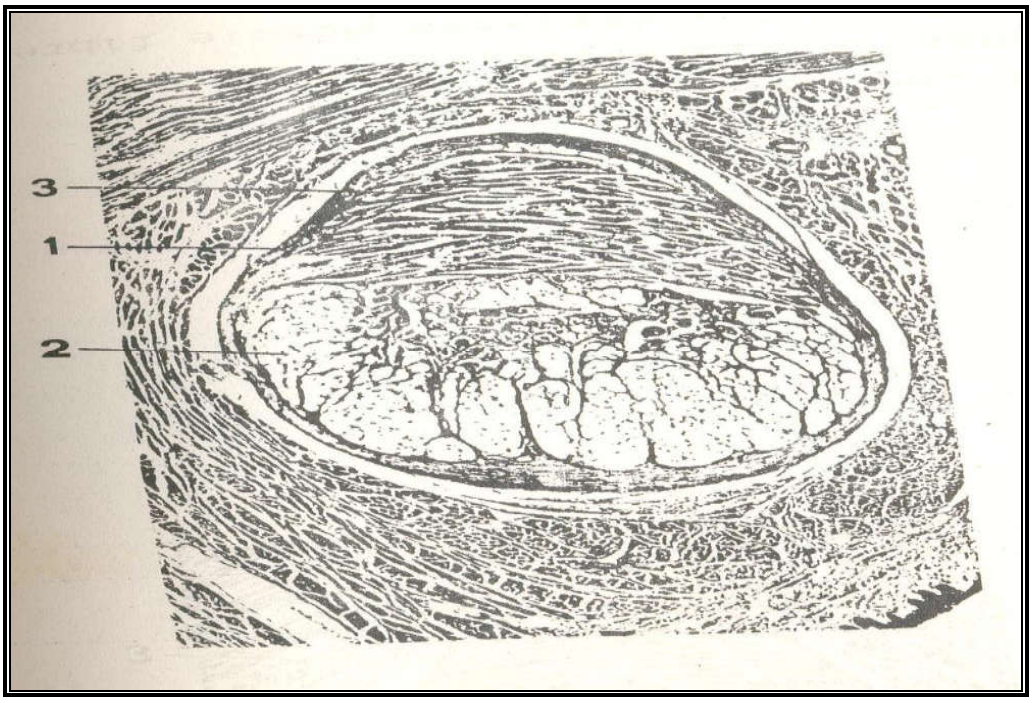
1) Lingual lyssa:

- It is present in carnivores (dogs and cats).

- It consists of rod-shaped hard structure enveloped with a collagenous sheath present mid ventrally

- **In dogs**: - its middle portion consists of fat cells, striated muscles, blood vessels and nerve fibers. Its posterior portion contains cartilaginous islands.

- In cats:- the middle portion contains only fat cells.



1-capsule of collagen fibers 2-fat cells 3-striated muscle

- **Functions**:- 1- Support for liking.

2- Attachment of muscular masses and fixation.

The taste buds:

- **Definition: -** They are onion like neuro-epithelial, pale staining ellipsoidal small sensory organs responsible for perception of taste.
- **Site:**

- **On the tongue**, they are accompanied by the gustatory lingual papillae; circumvallate, fungiform and foliate papillae.
- They are also present on the **soft palate**, **epiglottis**, **pharynx** (posterior wall) and **vocal cords**.

Structure:

- They are onion-like structures formed of 3 types of cells:

1) Neuro-epithelial taste cells or gustatory cells or receptor cells or hair cells:

► They are banana-shape modified columnar bipolar cells

► **Number and site**:- about six centrally arranged cells.

► Ctoplasm:- lightly stained.

►Nucleus:- darkly-stained elongated centrally situated.

► **The superficial part** (free surface) of these cells is provided with short hairs (hairlets) which are microvilli project into the taste pore.

► **The basal pa**rt of the taste cell is closely associated with sensory nerve fibers, which carry the impulses of taste sensation to the brain.

►their function is tasting of different substances (sweat, salt, bitter, astringent ……. etc).

2) Supporting or sustentacular cells:

► They are peripheral in position forming the outer wall of the taste bud.

► They are elongated columnar cells with **dark cytoplasm** but **lightly-stained oval nuclei.**

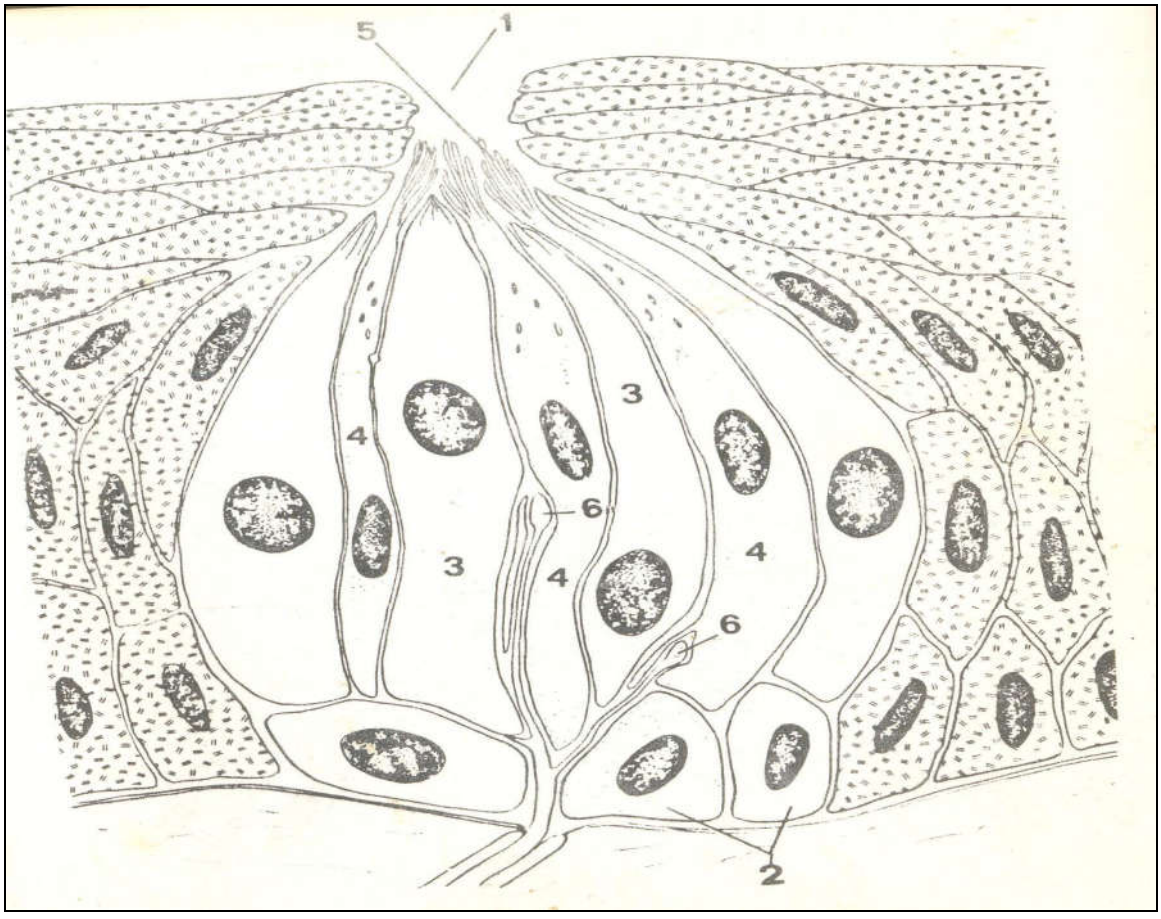
►Their function is support the gustatory cells.

3) Basal cells:

► They are short cells basally located.

► They act as stem cells for renewal of taste cells and supporting cells.

N.B: food substance to be tasted must become dissolved in saliva and passed to the taste pores where it affects the microvilli of the taste cells (hairlets) initiate a nerve impulse which transmitted along the sensory nerve fibers to the brain.



Taste bud

1-taste pore 2-basal cells 3-supporting cells 4-sensory cells 5-taste hairs 6-nerve fiber terminal

B. The pharynx (oropharynx)

- It is the connection between the oral cavity and the esophagus.
- The wall of the pharynx is composed of mucosa, musclosa and adventitia.

- ***Mucosa****:* It is formed of stratified squamous epithelium rest on fibroelstic C.T containing seromucoid glands and lymphoid tissue.
- ***Musclosa:*** It is formed of several layers of circularly arranged skeletal muscle fibers with some longitudinal.
- ***Adventitia****:* It is formed of fibro-elastic areolar connective tissue.

II. The digestive tract

- The digestive tube (digestive tract or GIT) includes esophagus, stomach and small and large intestine.

General structure of the digestive tract

➢ The wall of all parts of the digestive tube is formed of four tunics (from the lumen outwords):

1) Mucosa: (mucous membrane)

It is the inner most layer and consists of 3 parts:

a. <u>Epithelial lining</u>: (Lamina epithelialis)

- It is **stratified squamous epithelium**, extending from the mouth to the end of non-glandular stomach also in the rectoanal junction to the anus.
- It is **simple columnar epithelium**, extending from the glandular stomach to the end of the intestine.

- **<u>Functions</u>**:- The epithelium may be for **protection** as in the oesophagus, for **secretion** as in the stomach, or for **absorption** as in the intestine.

b. <u>Lamina propria</u>: (Corium or C.T layer)

- Dense connective tissue layer, rich in blood vessels, lymphatic, nerves and mucosl glands in stomach and intestine (lamina propria is subepithelial C.T layer).
- It connects the epithelium with the muscularis mucosa.

c. <u>Muscularis mucosa</u>: (may be present or absent)

- A thin layer of smooth muscles, arranged as an inner circular and outer longitudinal layers.
- It is responsible for the movement and folding of the mucosa.
- Present in esophagus, omasum, glandular stomach and intestine.

2) The submucosa: (Tela submucosa):-

- It is found between the mucosa and muscularis.
- It is formed of areolar C.T (dense fibroelastic C.T layer).
- It contains blood vessels, Meissner's plexus of nerves and some lymphatics.
- Mucous glands are present in the submucosa of oesophagus, duodenum some parts of large intestine.
- Some parts contain lymphoid tissue (diffuse, nodular or aggregation) as in ileum (peyer's patches).

3) The musculosa: (Muscularis externa or Tunica muscularis):-

- It is formed of involuntary smooth muscles usually arranged as inner circular and outer longitudinal layers.
- There is a plexus of nerves and ganglia called Auerbach's plexus or Myentric nerve plexus in between the two muscle layers.
- There are striated muscle fibers in the upper part of esophagus in some animals in form a mixture of striated and smooth muscle fibers.
- These muscles perform peristaltic contractions which propel the gut contents towards the anus.
- In glandular stomach there are three muscle layers; inner most oblique, middle circular and outer longitudinal SMFs.

4) The serosa or the adventitia:

- The outermost layer of the alimentary tract.

- It is called tunica serosa if the organ is intraperitoneal and composed of loose C.T. (lamina subserosa) that may be surrounded by simple squamous epithelium (lamina epithelialis serosa).
- It is called adventitia in **cervical part of the esophagus** and **the last part of the rectum.** It is formed of loose C.T without mesothelial covering and blends with the surrounding tissue.

C. The esophagus

- It is a musculomembranous tube extending from the pharynx to the stomach. Its wall consists of :-

1) Mucosa: ***a. Lamina epithelialis:***

- **stratified squamous keratinized epi.**:- in ruminants, horse and pig.
- **stratified squamous non- keratinized epithelium**:- in carnivores.
- It is thick to protect the oesophagus against the swallowed rough materials

b. Lamina propria: a layer of dense collagen fibers with abundant elastic fiber, blood vessels, lymph vessels and nerves.

c. Muscularis mucosa:

- It is formed of longitudinal smooth muscle fibers.
- **In ruminants, horse and cat**:- it forms isolated bundles near the pharynx and increase in thickness near the stomach to form a continuous layer.
- **In dog**: - it is absent at the cranial part and interrupted in the middle.
- **In pigs**: - it is absent in the cranial end and well developed in the caudal end.

2) Submucosa:

- It consists of loose connective tissue containing blood vessels, lymphatics and Meissner's plexus of nerves as well as **oesophageal glands**.
- in **horses, ruminants and cat**:- the oesophageal glands are present only at the pharyngo-oesophageal junction.

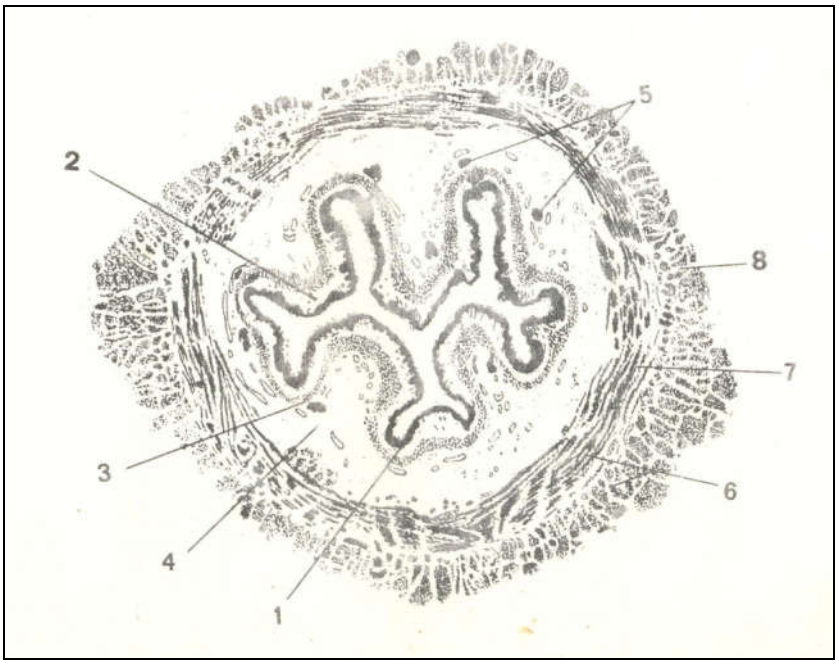
- **In pigs**:- the glands are more abundant in the cranial than the caudal half.
- **In dogs**:- the oesophageal glands extend throughout the length of oesophagus and for some distance into the stomach.

3) Musculosa: It includes two layers of muscle fibers interwoven in the anterior end while at the caudal end they arranged as inner circular and outer longitudinal.

- **In ruminants and dogs**:- It is made of either entirely striated fibers
- **In horse**:- the transition from striated to smooth occurs in the caudal third.
- **In pigs**:- the cranial third is striated, the middle is mixed and the caudal is smooth.
- **In cats:-** the anterior 4/5 of oesophagus is striated while the last 1/5 is smooth
- N.B.:- in all animals especially horse the inner circular layer become thicker toward the stomach forming **cardiac sphincter**.

4) Serosa (fibrosa) or adventitia:

- It is formed of C.T containing blood vessels, nerves and lymphatics.
- Adventitia in the cervical region or serosa at the thoracic and abdominal region.



Oesophagus of dog

1- lamina epithelialis 2-lamina propria 3-lamina muscularis mucosa 4-tunica mucosa 5-seromucoid glands 6-tunica muscularis 7-inner circular layer 8-outer longitudinal layer

Functions:- 1- conduction of food to the stomach.

2. Vomition in carnivores and rumination (due to extension of skeletal MFs)

D. The stomach

- It is the expanded part of the tubular digestive tract.
- It is classified according to Number of compartments into**:**-

1- Monolocular stomach:

It consists of a single compartment e.g. in dogs, cats, pigs and horses.

2- Mutilocular stomach:

It consists of more than one compartment e.g. in ruminant.

- It is also classified according to **the nature of the mucosa** into:-

1- Simple stomach: it is lined by one type of mucous membrane (glandular mucous membrane) in dogs and cats.

2- Compound stomach: It is lined by cutaneous non-glandular membrane and glandular mucous membrane. e.g., horses, pigs and ruminants.

Types of stomach:

1) Monolocular simple stomach in dogs and cats.

2) Monolocular compound stomach in horses and pigs.

3) Multilocular compound stomach in ruminants.

I. Non-glandular stomach of ruminants

(Fore-stomach or false stomach or pars proventriculus)

- It is formed of the first three compartments which are rumen, reticulum and omasum.

1- The rumen

- The wall of the rumen is composed of:

a. Mucosa: Thrown into tongue-shaped ruminal large and small papillae

- It consists of:

Lamina epithelialis*:* stratified squamous keratinized epithelium.

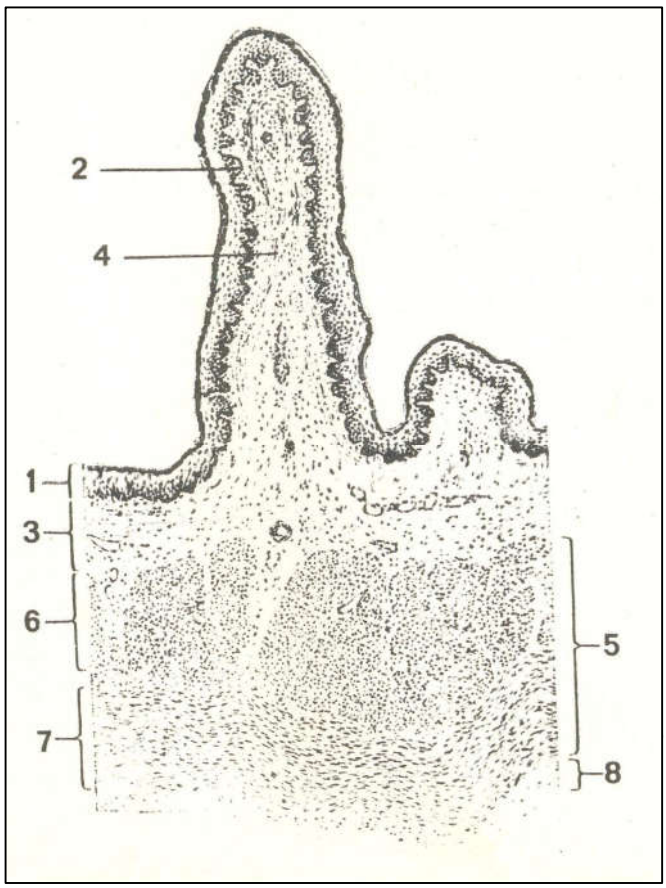
Lamina propria: A layer of dense connective tissue with many elastic fibers.

b. Musclosa: It is composed of two layers of smooth muscle fibers inner circular layer and outer longitudinal layer.

c. Serosa: It is a thin layer of loose connective tissue, which becomes thick and rich in fat in the ruminal grooves. It is covered externally by a mesothelium.

- **The ruminal papillae:**

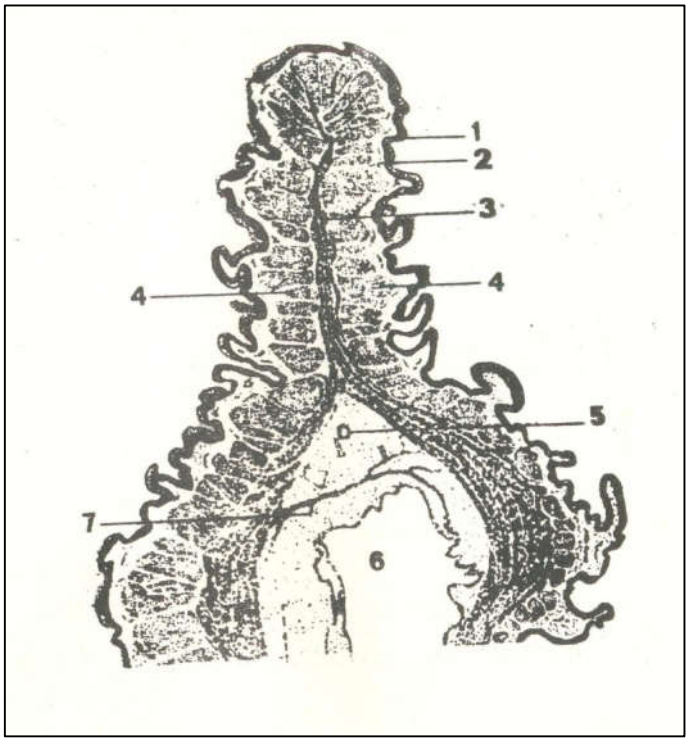
- Tunica mucosa forms large and small, conical or tongue-shaped papillae, formed of a core of fibro-elastic connective tissue derived from the lamina proria submucosa covered by stratified squamous epithelium
- **Functions:-** protective, metabolism and absorption.
- There are small and large conical ruminal papillae, the large ones are absent in the dorsal ruminal sac.



1- lamina epithelialis
2-ruminal papilla
3-propria-submucosa
4-CT core of ruminal papilla
5-tunica muscularis
6-inner circular layer
7-outer longitudinal layer
8-tunica serosa

The ruminal pillar:

- The inner surface of the ruminal cavity is demarcated by ruminal pillars into ruminal sacs. On the outer surface of the rumen and opposite to the ruminal pillars there are number of ruminal grooves.
- The ruminal pillar is covered by the ordinary ruminal epithelium that rests on a narrow layer of fibro elastic propria-submucosa.
- It has a muscular mass formed of a central band of longitudinally cut smooth muscle fibers derived from the outer longitudinal muscle layer of the ruminal muscular tunic and two outer bands of crossly smooth muscle bundles derived from the inner circular muscle layer of the ruminal musculature.
- The lamina subserosa of the ruminal pillar that faces the ruminal groove is rich in fat cells.



1-ruminal epithelium
2-propria-submucosa
3-central band of longitudinal smf
4-two outer muscular bands
5-lamina subserosa
6-ruminal groove

Reticulum

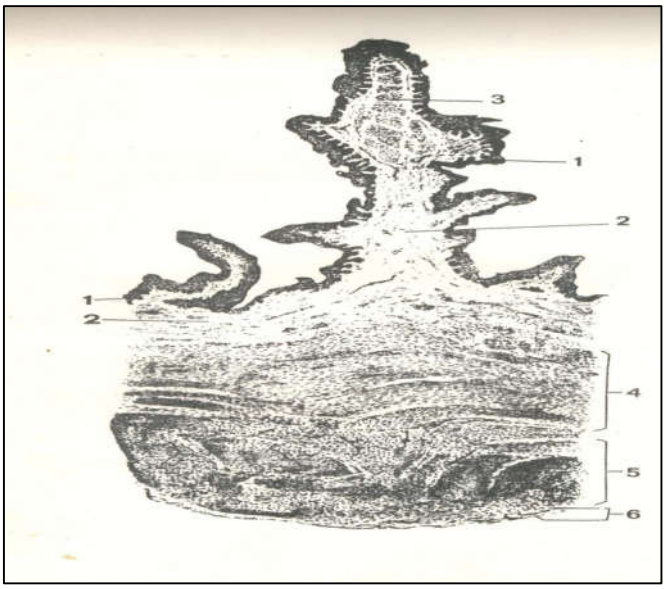
- It is the second non glandular compartment of the ruminant stomach thrown into reticular folds. The wall of the reticulum is composed of:

a. Mucosa: The mucosa of the reticulum forms characteristic permanent folds which join each other enclosing spaces, the reticular cells, giving the appearance of honeycomb-shaped with five or six side's reticular cells.

- The large cells are subdivided into smaller areas by secondary and tentiary smaller folds.
  - ***Lamina epithelialis*:** Stratified squamous keratinized type that forms on the sides and free ends of reticular folds conical horny papillae projecting into the lumen.
  - ***Lamina propria*:** A layer of dense C.T with abundant elastic fibers and forms the core of the reticular fold
- **In large folds of the reticulum**, there is a band of smooth muscle fibers which are **continuous with the muscularis mucosae of the oesophagus**.
- At the point of intersection between three reticular folds (cut near the free edges), the muscle bundles run from one fold to the other form continuous network and also muscular ring for each reticular cells.

b. Submucosa: It is a network of fibrous CT rich in elastic fibers containing blood vessels, lymphatics and nerves

c. Muscularis: It is composed of two thick layers of smooth muscle fibers inner circular layer and outer longitudinal layer.



The inner layer runs into the muscles of the lip of the ventricular groove and the external layer forms up the transverse muscle of the floor of the groove.

d. Serosa: It covers the reticulum externally

1-lamina epithelialis
2-prpria-submucosa
3-band of smooth muscle
4- inner circular muscle layer
5-outer longitudinal muscle layer
6-tunica serosa

2- Omasum

- The cavity of the omasum is occupied by about hundred omasal laminae (folds) of different sizes; the largest of them are 12 in number.
- There are secondary small short omasal lamina, beside shorter smaller tertiary ones and the shortest and smallest are quaternary ones.
- The long primary omasal lamina are studed with macroscopic papillae.
- The wall of the omasum is composed of:

a. Mucosa: Thrown into omasal laminae. which arise from the greater curvature and sides. The largest of these are about a dozen (دستة -12) in number.

Lamina epithelialis*:* The omasum is lined with cornified stratified squamous epithelium.

Lamina propria: A layer of dense C.T rich in elastic fibers.

Muscularis mucosae*:* It consists of longitudinally disposed smooth muscle fibers, which form 2 bands, extending laterally within the core of the omasl lamina.

The omasal lamina is studded by macroscopic keratinized papillae containing mucous CT.

b. Submucosa:

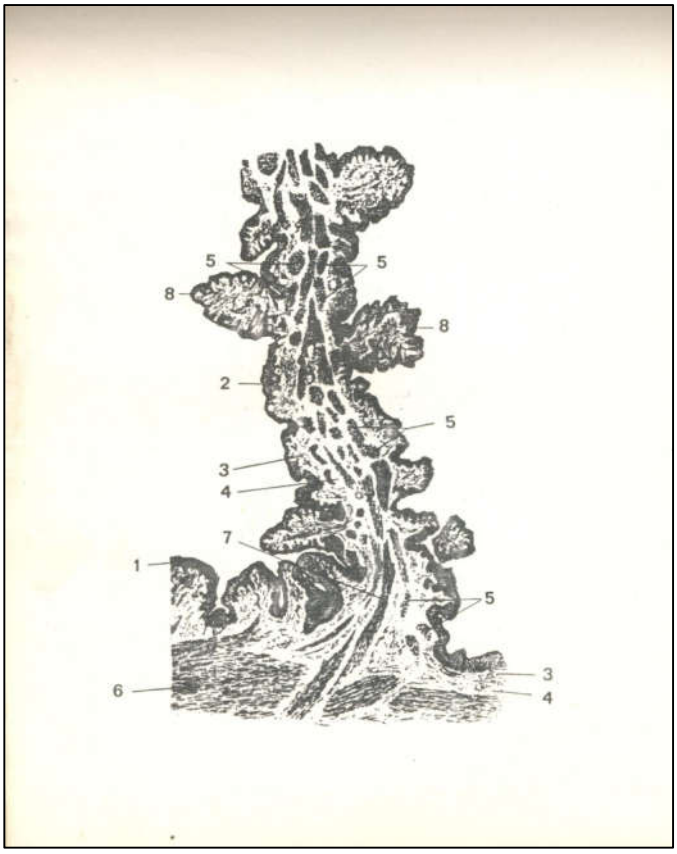
A loose C.T rich in elastic fibers containg blood vessels, lymphatics and nerves

c. Muscularis:

- Smooth muscle fibers oriented into:

- **Inner circular layer:-**forms a single central band which arises between the 2 bands of the muscularis mucosa within the omasal lamina and fuse together near the free edge of the omasal lamina.
- **Outer longitudinal layer**.

d. Serosa: It is formed of C.T layer with a single layer of endothelium derived from the peritoneal covering.



1- lamina epithelialis 2- omasal lamina
3- Lamina propria 4- tunica submucosa
5- two muscular bands of muscularis mucosa 6-inner layer of tunica muscularis
7- central muscular layer
8- macroscopic papillae

<u>The omaso-abomasal fold or vela terminalis</u>.

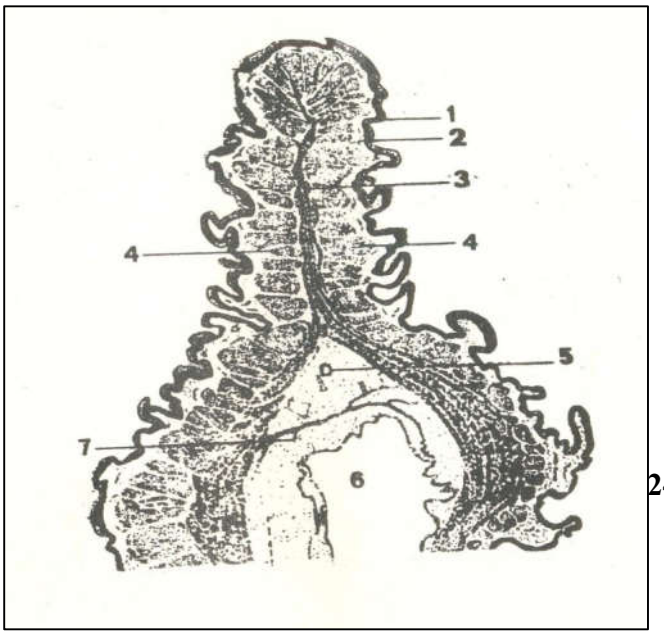
- It is a mucosal fold between the omasum and abomasum.
- **On this fold:-** the epithelium changes abruptly from stratified squamous to simple columnar so this fold has two surfaces; omasal and abomasal surfaces.

- In ox: its omasal surface is covered by cutaneous mucous membrane as the change from cutaneous to glandular mucous membrane take place at the free end (apex) of the fold.
- In case of sheep and goat, both surfaces carry glandular mucous membrane.
- At the point of junction between the cutaneous and glandular mucous membranes, lymph nodules are always present.
- The core of the fold is derived from the lamina propria.

The ruminal pillar:

- The inner surface of the ruminal cavity is demarcated by **ruminal pillars** which divide it into dorsal and ventral ruminal sacs. On the outer surface of the rumen and opposite to the ruminal pillar there are a number of ruminal grooves.
- The ruminal pillar is covered by the stratified squamous epithelium keratinized that rests on a narrow layer of fibro elastic propria-submucosa.
- It has a muscular mass formed of:-
  - Two outer (peripheral) bands of crossly smooth muscle bundles derived from the inner circular muscle layer of the rumen.
  - A central band of longitudinally cut smooth muscle fibers derived from the outer longitudinal muscle layer of the rumen.
- The tunica serosa composed of lamina subserosa and lamina epithelialis serosa.

- N.B., the lamina subserosa that faces the ruminal groove is rich in fat cells.



1-Ruminal epithelium

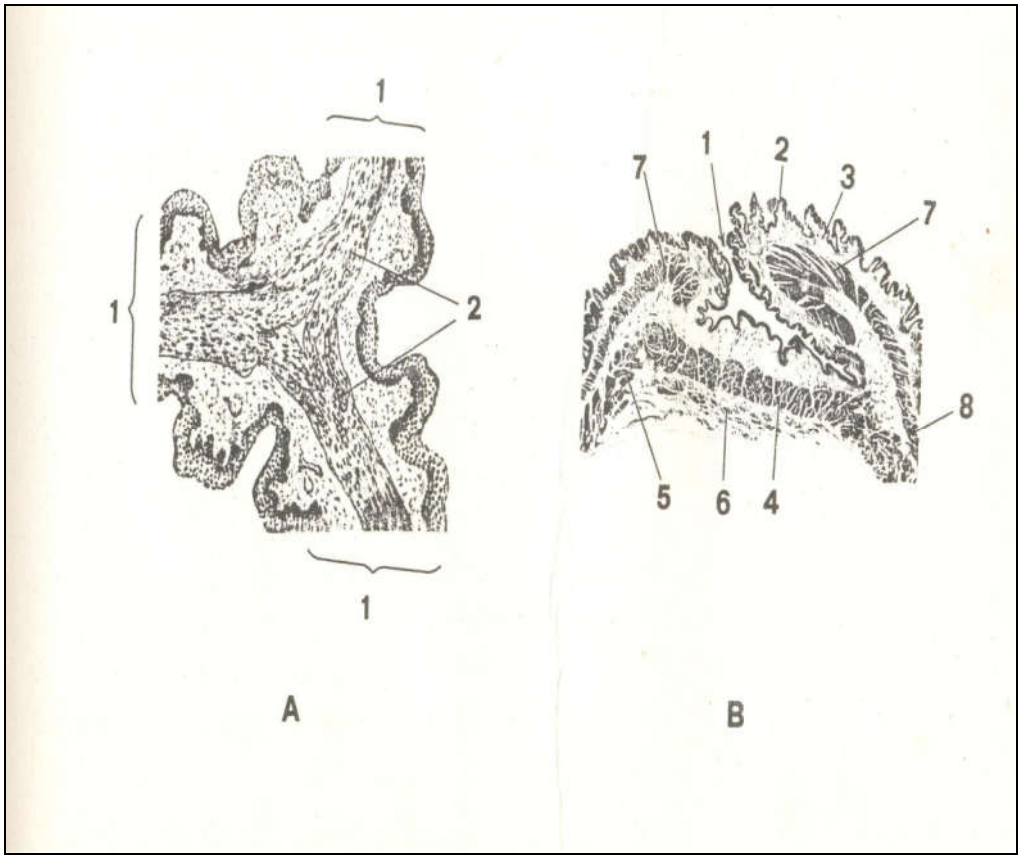
2-Propria-submucosa
3-Central band of longitudinal SMF
4-Two outer muscular bands
5-Lamina subserosa
6-Ruminal groove

The gastric groove (ventricular groove or esophageal groove):

- It is a tube like structure begins from the esophageal opening of the rumen passing through the lesser curvature of rumen, reticulum and omasum and terminates at the beginning of the abomasums.
- It contract reflexly during suckling to form a tube (in calves and lambs) to conduct the milk directly to the aboasum without passing to fore stomach as it still functionless. So, the the gastric groove could defined as the shortest pathway between esophagus and abomasum.
- It has a similar structure to that part of the fore stomach (rumen, reticulum and omasum) in each part it passes.
- It composed of **two lips** and **floor**.
- Histologically has the following structure:-
- **The lamina epithelialis mucosae:-** stratified squamous keratinized epithelium that rests on a dense connective tissue lamina propria.
- **The tunica submucosa:-** loose C.T that shows simple branched tubulo-acinar seromucoid at the bottom of the groove of sheep.
- **The muscularis mucosa** is incomplete. It is mostly conspicuous in the groove and forms a complete layer near the omasum.
- **Tunica musclosa**:- each lip contains
    - Two thick longitudinal smooth muscles, derived from the inner circular muscle layer of the forestomach.
    - A central (intermediate) layer of circular SMF derived from outer longitunal layer of fore stomach.
- **On the floor**:- the groove is a short shet of transverse muscle fibers, derived from the outer longitudinal muscle layer of the forestomach.

- N.B., Outside it, there is a longitudinal layer containing both smooth fibers and bundles of striated fibers. The later (striated muscles) are continuations of the esophageal musculature.

- Tunica serosa: - As usual.



1-ventricular groove 2-lamina epithelialis 3-prpria-submucosa
4-muscle of the floor 5-outer muscular layer of the stomach
6-thin layer of striated muscle 7-muscles of the lips of the groove

Functions of fore stomach:-

1- Mechanical griding of food through the mucosal irregularities of fore stomach.
2- Bacterial fermentation in the ruminal intercellular space.
3- Microbial digestion and cellulose digestion (by ruminal microflora).
4- Concentration of food and protection through cutaneous m.m.

II. The glandular stomach

(True-stomach or abomasum)

- The glandular stomach represents the following:

1- **Monolocular simple stomach** of **dog, cat and man**

2**- glandular part** of Monolocular compound stomach of **horse and pig**

3- **glandular part** of Multilocular compound stomach of **ruminants (abomasums).**

- According to the type of glands in the lamina propria and the depth of the gastric pits (**foveolae**), It is subdivided into three regions:

  1. Cardiac region. 2. Fundic region. 3. Pyloric region.

- Histologically, the wall of the glandular stomach is composed of:

a. Mucosa: It represents temporary folds in contracted stomach called gastric folds (rugae) subdivide the mucosa and bulge into the lumen. The surface epithelium has many depressions (invaginations) called pits or foveolae.

- ***Lamina epithelialis:*** *simple high columnar mucous secreting cells.*
- ***Lamina propria (lamina glandularis):*** A layer of loose C.T interspersed with smooth muscle and rich in lymphoid cells.

- It contains the gastric glands (simple branched tubular coiled glands):

  1. Cardiac glands. 2- Fundic glands. 3- Pyloric glands.

- ***Lamina muscularis mucosa:*** It consists of irregularly arranged smooth muscle fibers (inner circular and outer longitudinal layers)

- N.B., 1- Strands of muscle fibers from the muscularis mucosae extend in the lamina propria between the glands which facilitate the emptying of the glands.

2- **In carnivores and occasionally horses**, lamina subglandularis intervenes between the muscularis mucosae and the blind ends of the glands. It's composed of **inner cellular stratum granulosum**, is rich in cells (mainly lymphocytes and fibroblasts) and **outer fibrous stratum compactum**, composed of an elastic network and a dense homogenous collagenous substance.

b. Submucosa: a layer of loose C.T with blood vessels and nerve plexus (Meissner's plexus).

c. Muscularis:

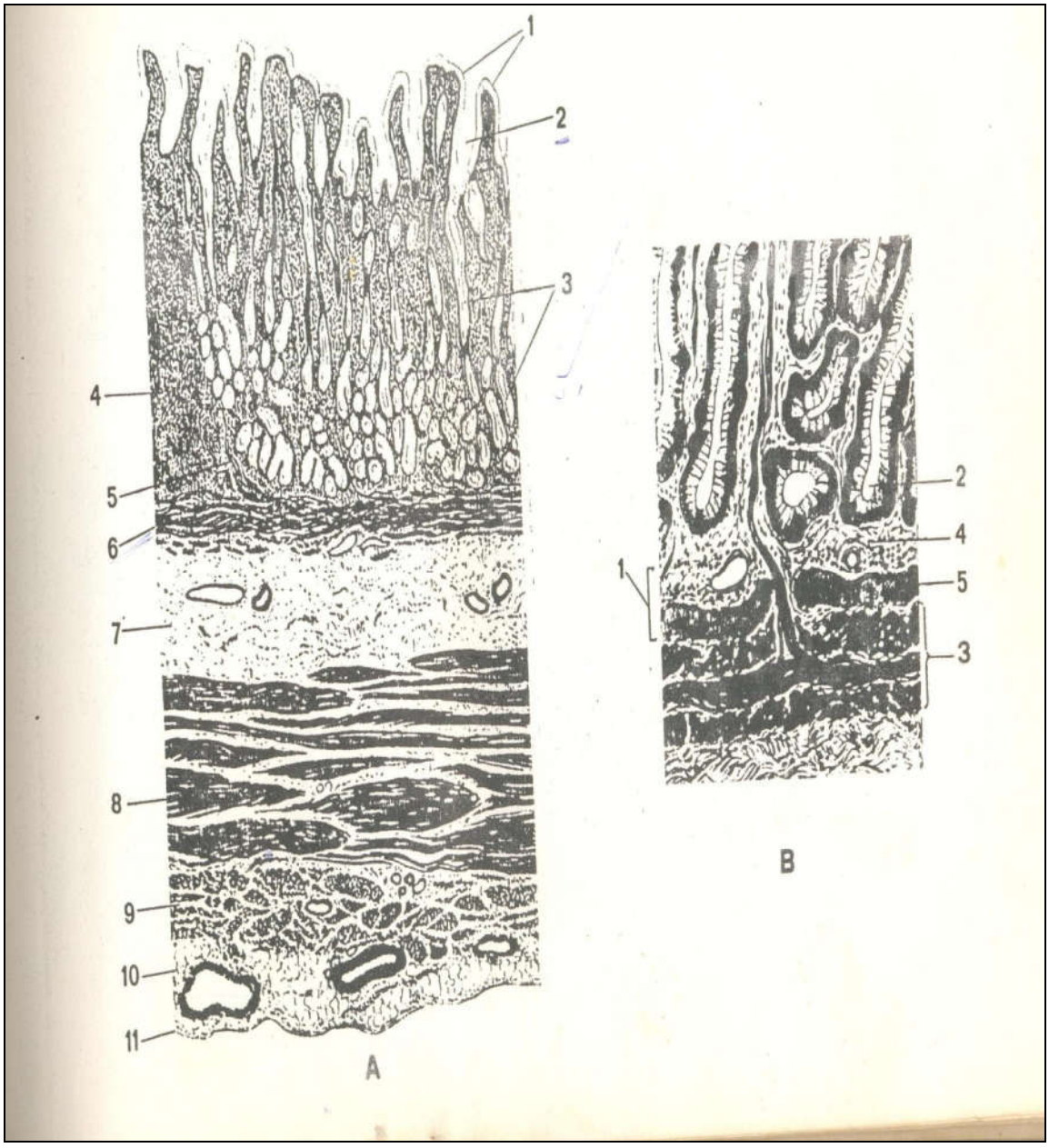
Consists of three layers of smooth muscle fibers, oriented into:

1- Innermost oblique layer. 2- Middle thick circular layer.

3- Outer incomplete longitudinal layer.

d. Serosa: It is composed of:-

- lamina subserosa:- loose connective tissue layer.
- lamina epithelialis serosa:- mesothelial layer.



A- Wall of glandular stomach

1-lamina epithelialis 2-gastric pits 3-gastric glnds 4-lamina propria 5-smooth muscles 6-lamina muscularis mucosa 7-tunica submucosa 8-inner circular smf 9-outer longitudinal SMF 10-lamina subserosa 11-lamina epithelialis serosa

B- lamina subglandularis of dog stomach

1-lamina subglandularis 2-base of gastric glands 3-lamina muscularis mucosa 4-stratum granulosum 5- stratum compactum

- **The difference between a histological section in the fundic and pyloric parts of the stomach.**

Item	**Cardiac glands**	**Fundic glands**	**Pyloric glands**
Gastric pits	Moderate	shallow	deep
Gastric glands			
Length	- moderate in length	- long	- short
Branching	- highly branched	- less branched	- more branched
Coiling	- highly coiled	- less coiled	- more coiled
Lumen	- they have wide lumen	- have wider lumen	- prominent lumen
Lining epitheliu	- they are serous in type	- have four types of secretory cells	- mucous in type

I. <u>Cardiac glands:</u>

- It occupies narrow strips between the glandular and non glandular mucosae in all animals except **pigs** it cover nearly ½ portion of the glandular stomach.
- The cadiac pits moderate in depth.
- **The cardiac glands** are long, highly branched, coiled tubular glands with wide lumen.
- They are serous glands secrete the enzyme lysozyme.
- They are presenting cuboidal cells cells with rounded basal nucleus and acidophilic cytoplasm.
- Some parietal and enteroendocrine cells may occur.

II. Fundic glands: (specific gastric glands):-

- They occupy the largest area of the glandular stomach.
- They are long, less branched and less coiled than the fore mentioned one.
- Gastric pits are relatively short; extend to 1/4 of the thickness of mucosa.

- **Each gland consists of three parts:**
  1. **The neck**: continuous with the gastric pits and lined with **mucous neck cells and parietal cells**.
  2. **The body**: the middle part of the gland contains mainly **chief cells and parietal cells**
  3. **The fundus (the base)**: the deepest part of gland which is made up of **chief cells**.
- **Each gland is lined by five types of cells:**
  1. Isthmus mucous cells. 2- Mucous neck cells.
  3- Parietal (oxyntic) cells. 4- Chief (zymogentic) cells.
  5- Enteroendocrine cells.

<u>The surface epithelial cells</u>:

L/M:

- They are columnar cells with basal pale oval nucleui.
- They have pale staining cytoplasm due to presence of mucus secretory granules.
- Their apical cytoplam contains mucinogen granules, which dissolve during staining with Hx and E, thus, these cells appear vacuolated. These mucinogen granules can be stained by alcian blue.

<u>E/M</u>:

- They have apical short microvilli, covered with glycocalyx.
- They have basal nucleus and the cells organelles are supra-nuclear.

Function: They secrete neutral mucus. This mucus forms a thick layer that adheres to the lining of the stomach and protects it from autodigestion (from HCl).

1) Isthmus mucous cells:

Structure:

- Similar to the surface epithelium, but they have mucous granules (few mucous granules).
- They secrete mucus (neutral) which protects the epithelial surface.

Function:

- They are responsible for the replacement of the lining and glandular epithelium.

2) Mucous neck cells

L/M:

- They are cuboidal (low columnar).
- They have flattened nuclei located at the base of the cells.
- Their cytoplasm is foamy in appearance.
- They are stained pale in H and E sections and red in PAS sections. This is because they contain mucus granules which dissolve in routine stain.

E/M:

- They contain the following: RER (rough endoplasmic reticulum), prominent Golgi complex, mitochondria, open face nucleus.

Function:

- They secrete acidic mucus and lubricate the gastric contents.

3) Parietal cells (oxyntic cells):

Site:

- They are present mainly in the upper half of the gland.
- They are intercalated between mucous neck cells and chief cells.

L/M:

- They are large pyramidal cells with large spherical eccentric nuclei.
- Each cell is triangular in shape and one of its sides is closely applied to the basement membrane of the gland.
- The apex of such cell does not reach the lumen of the gland, thus, the cells are called **parietal cells**.
- They have extensive acidophilic cytoplasm (that is why they are called **oxyntic cells**).

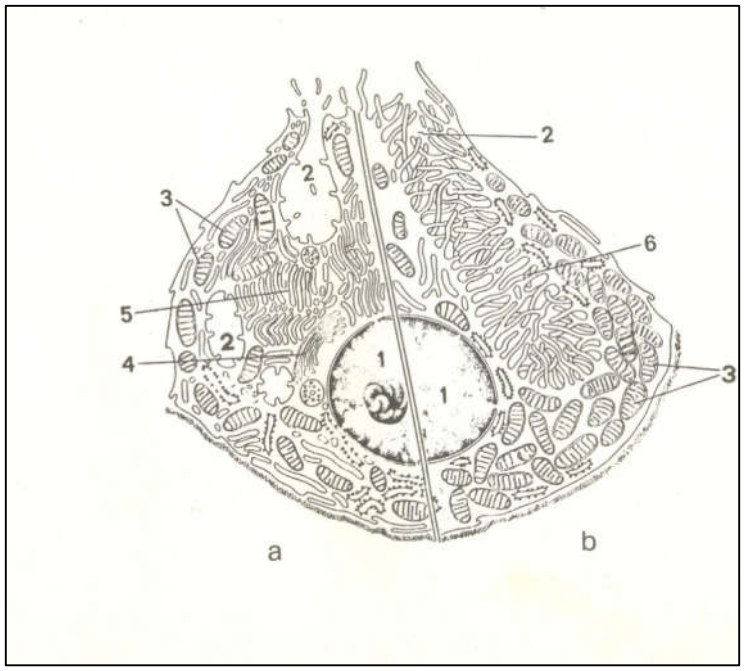
E/M: The most important characters are:

- A deep circular invagination into the luminal surface provided for the presence of intercellular canaliculi with numerous microvilli.
- Their cytoplasm is very rich in intercellular canaliculi.
- They contain very numerous mitochondria which responsible for the acidophilia of the cells.
- They contain numerous S.E.R also rich in active filaments, cytoplasmic tube and vesicles.

Functions:

1- Formation and secretion of HCl (hydrochloric acid):

- Carbonic acid (H_2Co_3) produced from water (H_2O) and carbon dioxide (Co_2) dissociates into hydrogen (H^+) and bicarbonate (Hco_3^-) within the cytoplasm of the parietal cells.
- H^+ is pumped out of the cell into the lumen of the canaliculi.
- Cl^- is pumped out of the cell into the canaliculi.
- Thus, H^+ and Cl^- enter the lumen of the canaliculi separately to combine into the HCl which enters the gastric lumen.



a- parietal cell in resting stage

1-spherical nucleus
2-intracellular canaliculi 3-mitochondria
4-Golgi apparatus
5-tubulovesicular structure

b-parietal cell in active stage: the tubulovesicular structure fuse with the cell membrane to form microvilli

3) Chief cells (zymogenic or peptic cells):

- They are protein secretory cells.

L/M:

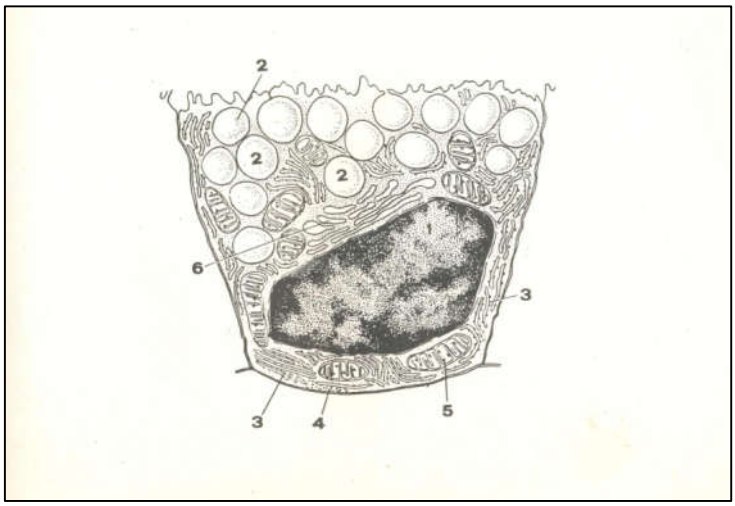
- They are pyramidal or columnar cells with basal and rounded nucleus.
- They have apical acidophilic zymogen granules and basophilic cytoplasm.

E/M:

- They have open face nucleus (vesicular or pale nucleus).
- The nucleus is large and basal with prominent nucleolus.
- The basal part of cytoplasm riches in RER and free ribosomes with many mitochondria.

- Prominent Golgi apparatus is found supranuclear (between nucleus and luminal surface).
- The zymogen secretory granules occupy the apical part.

Function: These cells secrete most of the gastric enzymes as **pepsinogen and rennin**.



1- nucleus basally situated
2- secretory granules
3- rough endoplasmic reticulum
4- free ribosomes
5- mitochondria
6- Golgi apparatus

5) Entero-endocrine cells **(Argentaffin cells or Enterochromaffin cells)**

Site:

- They are present at the base of the glands (distributed between chief cells and basement membrane).

L/M:

- They are flattened or polyhedral cells with eccentric oval nuclei

E/M:

- The cytoplasm contains many basal and scattered small electron dense secretory granules.
- It has many free ribosomes, poorly developed Golgi apparatus and few RER with dilated cisternae.
- Mitochondria are spherical or elongated.

Function:

- These cells synthesize and produce polypeptide hormones with few amino acids or amine hormones.

- In the stomach, they secrete:

1. *Gastrin:* stimulates gastric secretion.
2. *Endorphin:* It is a pain-killer resembling morphine.
3. *Serotonin:* It causes local constriction of smooth muscle of blood vessels.

III. Pyloric region:

- **The gastric pits** in the pyloric region are deeper than the other regions; extend to the ½ of the thickness of the mucosa.
- The pyloric glands are simple, branched tubular coiled glands.
- the gland is short, more coiled, more branched and contains a prominent lumen and is wider.
- They are more widely separated from each other (not crowded as fundic glands).
- The secretory parts of the gland are lined mainly by mucous cells which secrete mucus (the mucous cells contain flat basal nuclei and mucinogen granules in their apical cytoplasm).
- Small number of entero-endocrine cells is also present in the pyloric glands.

The intestinal tract

I. Small intestine

It includes the duodenum, the jejunum and the ileum.

The main functions of the small intestine are:

1. It completes the digestion of food coming to it from the stomach.
2. It absorbs the useful products of digestion which then pass through its blood and lymphatic capillaries.
3. It produces these gastro-intestinal hormones: secretin, somatostatin, cholecystokinin, pancreozymin, serotonin and endorphin.

4. Its cells secrete the intestinal enzymes.

The wall of the small intestine is formed of the following layers from inside to outside.

1) Mucosa:- The mucosa of the small intestine carries finger-like projections that range from 1/2 to 1 mm in length and 0.2 mm in width. These are called the intestinal villi.

The tunica mucosa consists of:

a. Lamina epithelialis: consists of tall simple columnar (absorptive) epithelial cells carry microvilli on their free surface with some goblet cells in between.

b. Lamina propria: It is made principally of lympho-reticular tissue with few elastic and collagen fibers. In between them, are strands of smooth muscle fibers.

- It also contains great numbers of lymphatic nodules (solitary follicles) which are more numerous and larger in the ileum.

c. The muscularis mucosa: It consists of smooth muscles arranged as inner circular and outer longitudinal muscle fibers. Strands from the inner circular layer enter the villus and extend to its tip.

2) Submucosa: It is formed of loose C.T rich in lymphatic and vascular supply and Meissner's nerves plexus in the duodenum, jejunum and ileum.

The submucosa of the duodenum contains glands known as Brunner's glands (duodenal glands).

Brunner's glands are:

1. Branched, compound tubulo-alveolar glands.
2. They open by ducts into the bottom of the crypts of Lieberkubn of the duodenum.
3. The secretory portion is lined by low columnar cells with flattened nuclei at the base.

- It produces alkaline mucus in order to:-

a) Protect the duodenum from the acidic content of chyme (which is introduced into the duodenum from the stomach).
b) Provide an alkaline condition for the intestinal enzymes to be active, thus enabling absorption to take place.
c) Lubricate the intestinal walls.

- The submucosal of the ileum is occupied by large oval lymphoid follicles (intestinal tonsils or Peyer's patches).

3) Muscularis externa:

It is composed of an inner circular layer and an outer longitudinal smooth muscle layers. It is responsible for the peristaltic activity of the small intestine

4) Tunica serosa: Formed of lamina epithelialis serosa and lamina subserosa

The intestinal villi

They are finger-like projections of the mucosa of duodenum, jejunum and ileum extending into their lumina. It Covered by simple columnar absorptive epithelium carrying microvilli with few goblet cells.

Shape:

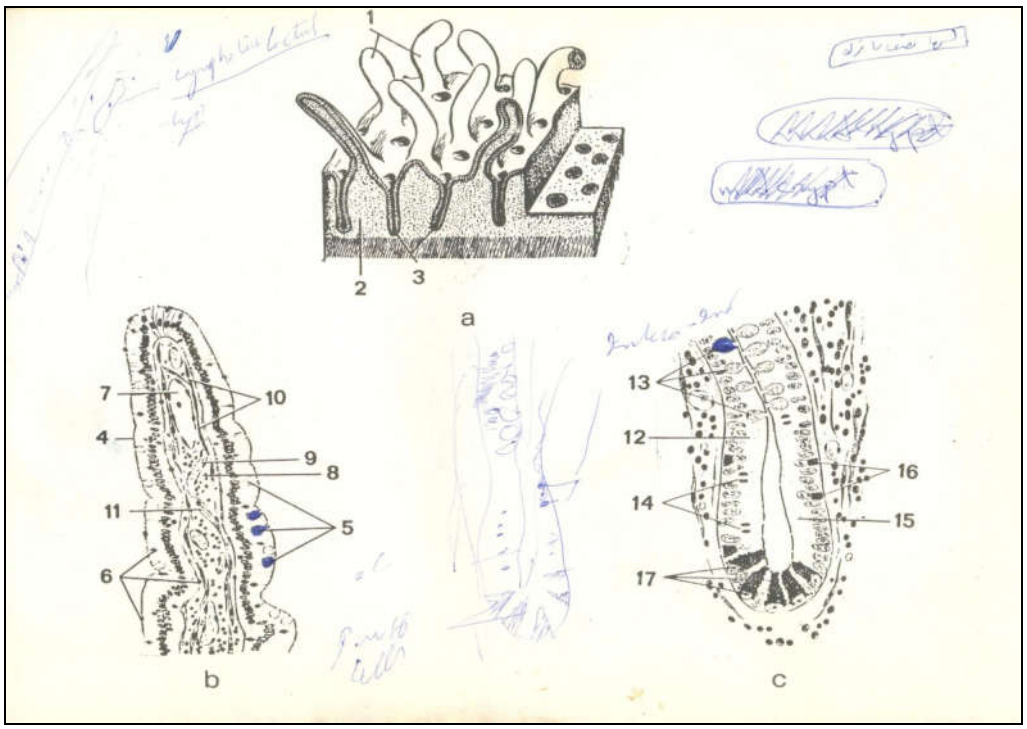
- The villi of the duodenum are broad, long and leaf-like.
- The villi of the jejunum are tongue-shaped and slightly short.
- The villi of the ileum are slender and finger-like.

Structure:

- Each villus is formed of a central core of lymphoreticular T. containing a lymph capillary or lymph space, lined by endothelium and known as the central lacteal (only in thicker villi as in sheep two or more lacteals are present).
- The reticular spongy stroma of the villi contain peripheral and central longitudinal smooth muscle fibers close to lacteal and transverse elastic fibers leucocytes in addition to fat cells, capillaries and nerves

NB: Contraction of the smooth muscle causes shortening of the villi. This widens the lacteals and presses their contents into the efferent lymphatics (aiding in lymphatic drainage and blood pumping).

- The transverse elastic fibers and membranes, which are stretched and relaxation of SMFs in the process, cause the villi to return to their former shape and size.
- The central lacteal (single lymph vessel) responsible for the absorption of fatty acids and blood capillaries (arteriovenous loop) for absorption of amino acids and glucose.



a- intestinal mucosa : 1- intestinal villi 2-lamina propria 3-intestinal glands
b- intestinal villus: 4-columnar cells 5- goblet cells 6- migrating lymphocyte 7-central lacteal 8-lymphoreticular tissue 9- blood capillaries 10-smooth muscle fibers 11-transverse elastic membrane
c- intestinal gland 12-intestinal epithelium 13-goblet cells 14-mitosis in crypt cells 15-oligomucous cells 16- enterochromaffin cells 17-paneth cells

Intestinal glands (the crypts of Lieberkuhn)

- They are invaginations from the surface epithelium between the bases of the villi (tube-like structure).
- They are simple tubular glands that open into the inter-villar spaces.

Structure: The crypts of the small intestine are lined with the glandular epithelium composed of the following cells:

1- Undifferentiated low columnar cells (crypt base columnar cells and mid- crypt columnar cells);- :

- They are also called undifferentiated columnar stem cells or stem cells or regenerative cells.
- **L/M:** They are simple columnar cells with basal oval nuclei and pale cytoplasm.
- **E/M:** Their cytoplasm contains few mitochondria, few RER, small Golgi saccules and few ribosomes Mitotic figures are found.
- **Function:** They are responsible for the replacement of the surface columnar absorptive cells.

2- Paneth cells:

- **Site:** They are found only at the bases of the crypts of small intestine of ruminants and equines between crypt-base columnar cells.
- **Absent in carnivores and swine.**

L/M:

- They are columnar cells or pyramidal in shape.
- They have basal oval nuclei.
- Their cytoplasm has an apical acidophilic (zymogen granules) and basal basophilic cytoplasm.

E/M:

- They show all character of the protein secreting cells.

- Their cytoplasm contains many RER, prominent Golgi body, mitochondria and ribosomes and secretory granules.

Functions:

1. They secrete intestinal enzymes.
2. They also secrete an enzyme called **lysozome** which can kill certain bacteria.
2. These cells phagocytose and transport Ags present in the intestinal lumen.

4- Entero-endocrine cells:

- As in the stomach.

Regional differences in the structure of the intestine

Item	Duodenum	Jejenum	Ileum
Villi	- Its villi are broad, long and leaf-like. - Its villi are numerous.	Its villi are slightly short, narrow, sparse and are tongue-shaped.	- The villi are long, slender and finger-like. - They are the narrowest, shortest
Submucosa	It is thick and contains Brunner's glands which are present deep to the muscularis mucosa.	There are neither Brunner's glands nor Peyer's patches.	Peyer's patches may pierce the muscularis mucosa and extend into the submucosa.
Lamina propria	-	-	It contains Peyer's patches which are antemesentric in position.
Goblet cell	They are **few** and not	They are	They are **more**

	so numerous.	**numerous than** in the duodenum.	**numerous**.

II. Large intestine (colon)

- This includes the caecum, the ascending, transverse, descending and sigmoid colons and the rectum.
- It has the same structure as the small intestine but differs from it in some respects.

1) Mucosa: It is characterized by:

- It has no villi.
- It is much thicker than that of the small intestine as the crypts are deeper.
- The crypts have no paneth cells.
- The crypts have many goblet cells.
- The cypts are absent at the rectoanal junction.
- The muscularis mucosa is formed of inner circular and an outer longitudinal smooth muscles.

2) Submucosa:

- It is formed of C.T containing blood vessels, nerves and lymphatics, but there is no gland.
- In the submucosa of some parts of the large intestine, there are **submucosal glands**, the extension of which differs from lamina propria through the muscularia mucosae in the submucosa. The cells of the submucosal glands are the same as those of the intestinal glands. The glands are usually surrounded by a coat of diffused or follicular lymphoreticular tissue.

3) Musclosa:

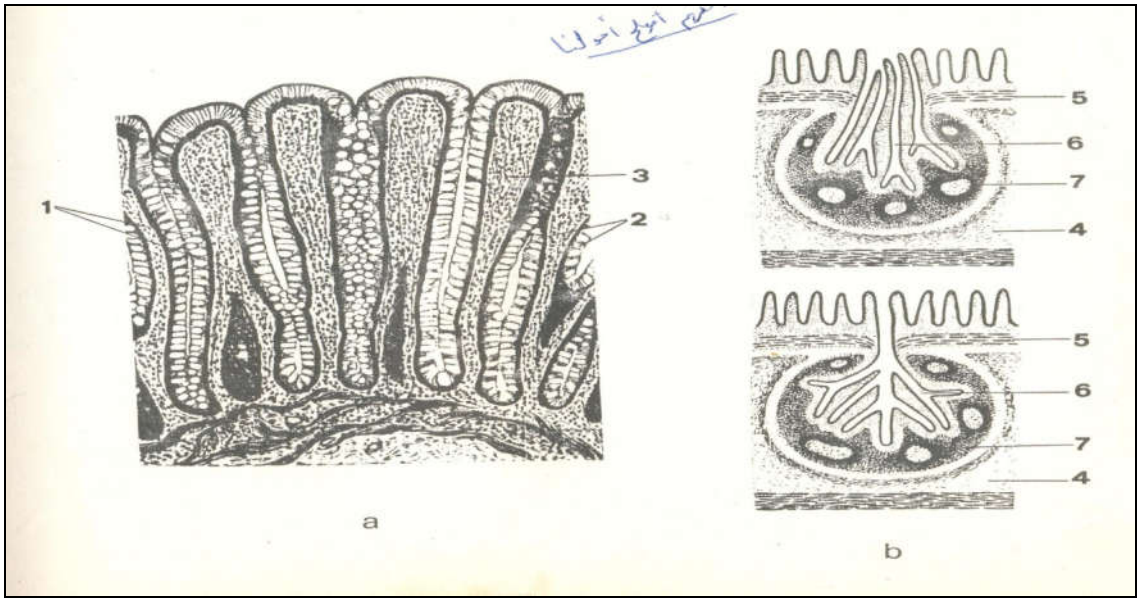
- It is formed of smooth muscles arranged as continuous inner circular muscles.
- The outer longitudinal muscles are present in three bundles only, forming the taenia coli or taenia ceci on the external surface of the colon and caecum.

- In the caecum and large colon of the horse, the taeniae are so rich in elastic fibers and so poor in muscular elements.
- The rectum lacks taeniae.

4) Serosa:

- It is formed of C.T which is rich in fat cells and covered with mesothelium.

- In the terminal portion of the rectum, the serosa is replaced by a loose collagenous adventitia.



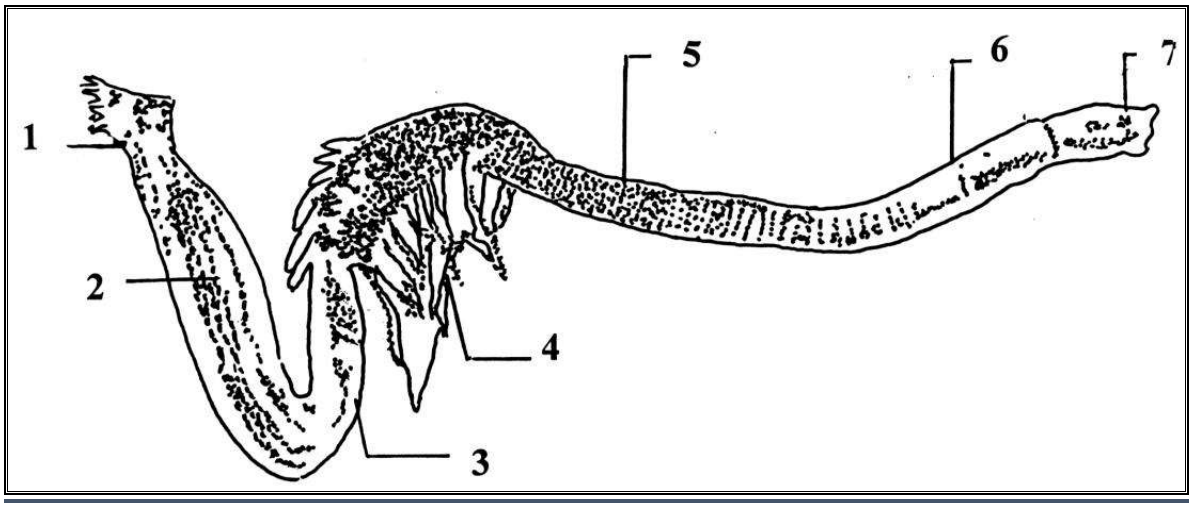
a-large intestine: 1-intestinal glands 2-goblet cells 3- lymphoreticular tissue
b- submucosal gland: 4-tunica submucosa 5-muscularis mucosa 6- submucosal gland 7-lymphoreticular tissue

Differences between small and large intestines

Small intestine	Large intestine
It is about **6 meters** in length.	It is about **180 cm** in length.
It has a **small** diameter.	It is **large** in diameter.
Anatomically, it is formed of duodenum, jejunum and ileum.	**Anatomically**, it is formed of caecum, colon and rectum.

Its **mucosa** is formed of villi and crypts.	Its **mucosa** is formed of longer crypts, but no villi.
The villi are covered with: - Absorptive columnar cells. - Goblet cells. The crypts are lined with: - Columnar stem cells. - Paneth cells. - Entero-endocrine cells. - Caveolate cells.	The crypts are lined with: - Simple columnar absorptive cells. - Many goblet cells. - Columnar stem cells. - No paneth cells. - Entero-endocrine cells. - Caveolate cells may be present.
Globule leucocytes, plasma cells and lymphocytes are present between the crypts.	Solitary lymphatic nodules and diffuse lymphocytes are present between the crypts.
Submucosa of duodenum contains Brunner's glands while Peyer's patches are present in the mucosa of ileum.	**No** true glands and no lymphoid follicles but there is extension of gland of the lamina propria called sub mucosal gland which passing via muscularis mucosa .
The inner circular and outer longitudinal **muscle** layers are continuously surrounding the wall of small intestine.	The inner circular **muscles** are well-developed, while the outer longitudinal form 3 separate bundles
Serosa is formed of C.T and simple squamous mesothelium.	**Serosa** is formed of masses of adipose C.T covered with simple squamous mesothelium

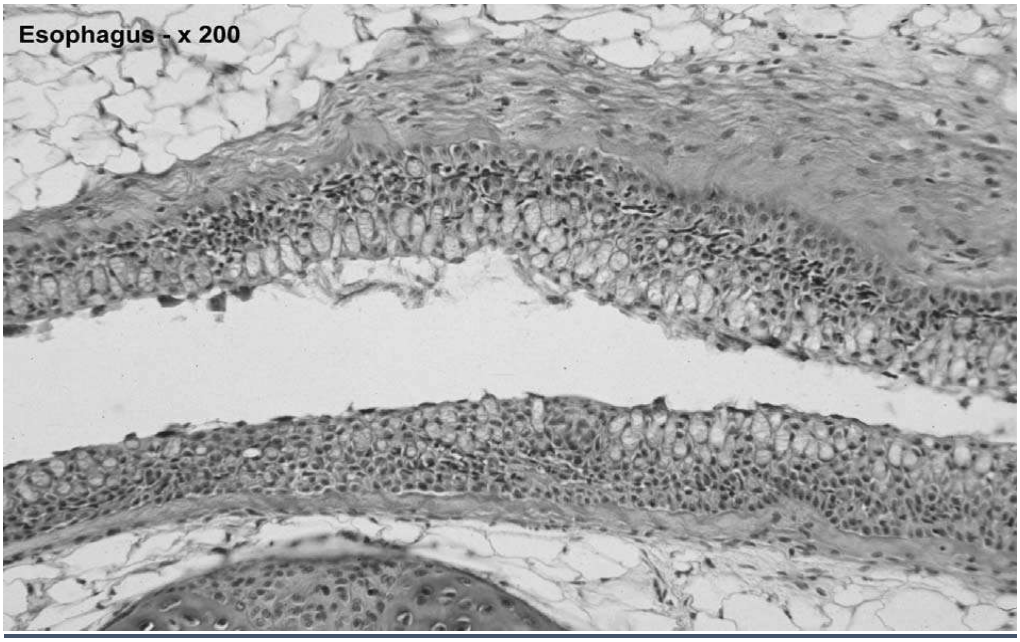
Digestive system of fish

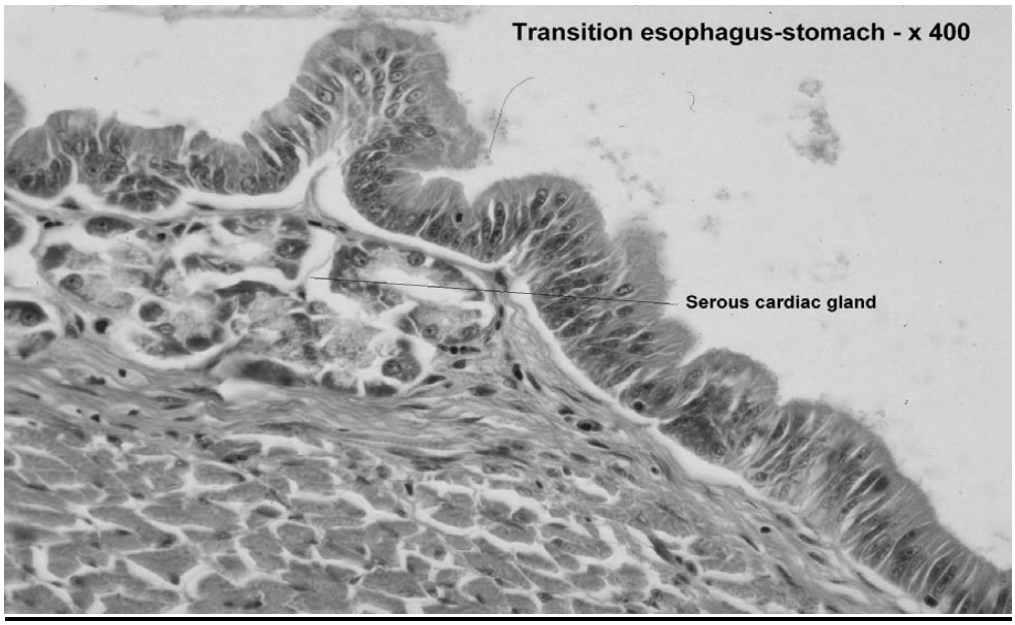


The alimentary tract of teleosts
1-Oesophagus.
2-Stomach (cardiac portion) .
3-Stomach (pyloric portion).
4-Pyloric caeca.
5-Anterior intestine.
6-Posterior intestine.
7-Rectum.

1-Esophagus

- The esophagus is usually a short, straight and very muscular tube passing from the mouth to the cardia of the stomach. Its combination of an epithelial lining containing abundant mucous cells which provide for more lubrication and the extensive longitudinal folds of the inner surface, allows for easy swallowing of awkward food particles.

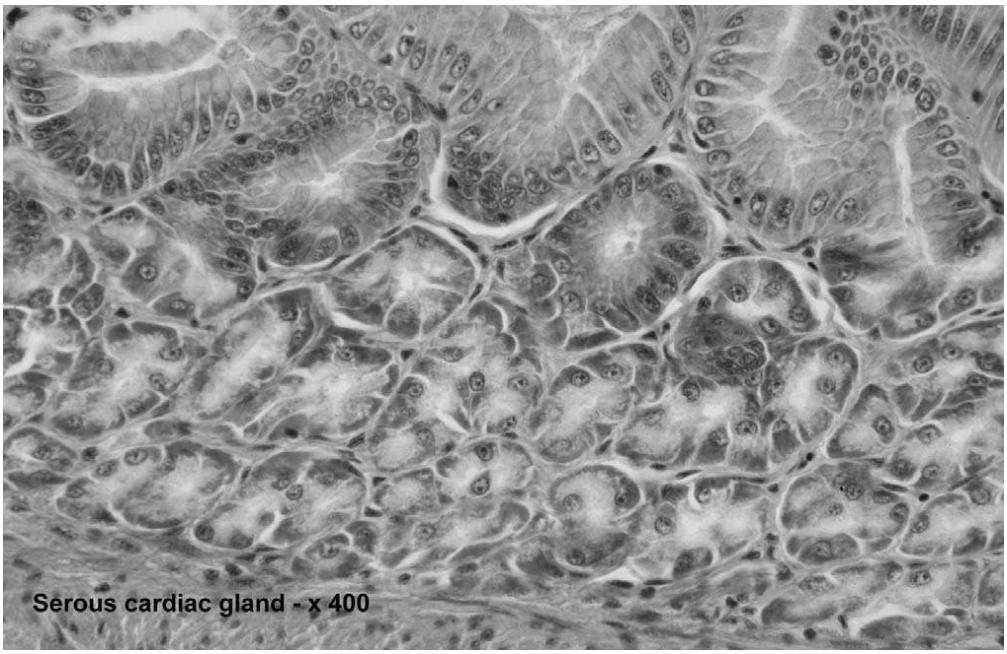




Stomach

The stomach varies in size. It functions to churn contained material, mixing it thoroughly with the digestive juices that it secretes. Some absorption occurs on a limited basis. Typically it is a sigmoid, highly distensible, sac with numerous folds in its lining. The stomach can be divided into 3 sections: cardiac (anterior), transitional (mid), and pyloric (posterior). All sections are highly muscular with the cardia demarcating the change from the striated muscle of the anterior digestive tract to the smooth muscle occurring distally. There are a number of layers of muscle, including a muscularis mucosa with adjacent

layers of connective tissue often containing large numbers of eosinophilic granule cells. The function of these granule cells is uncertain, but they appear to have a role in body defense mechanisms, especially with Infectious Hematopoietic Necrosis Virus (IHNV). The gastric mucosa itself is very mucoid, with numerous glands at the bases of the folds.

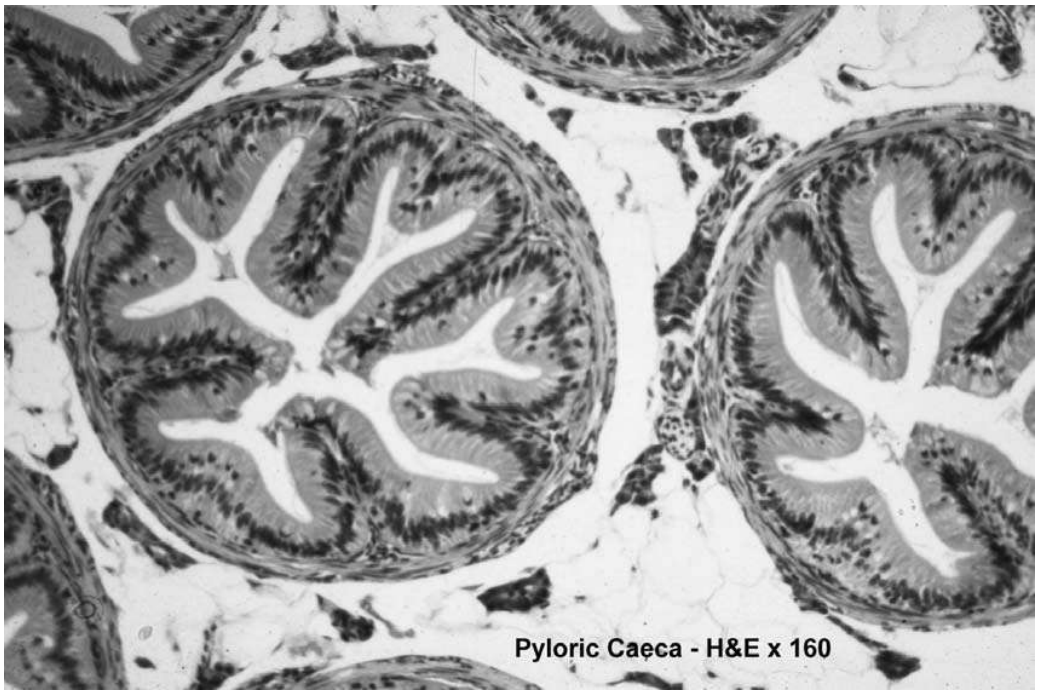


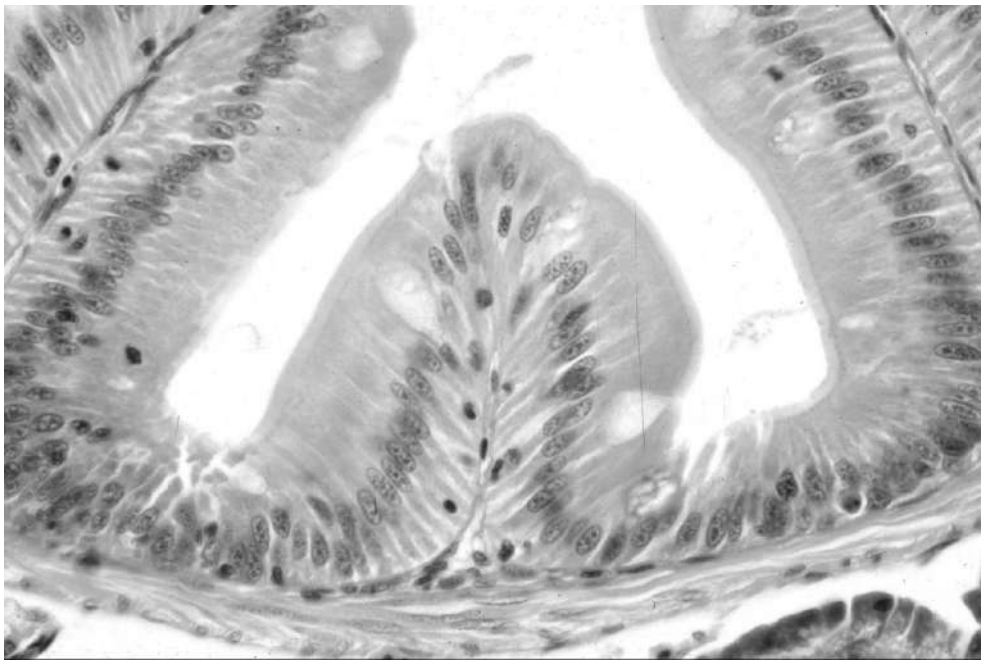
- It is J-shaped (in salmonids) or sigmoid sac (in other fishes).

- Its muvosa is folded, very mucoid with numerous glands at the base of the folds.
- The mucosa is studed by gastric pits.
- The mucosa is demarcated into three regions:-
    1. A longer anterior representing the cardiac region.
    2. A shorter posterior portion which is the pyloric portion.
    3. A mid-area of the stomach, where the cyrvature occur is the transition region (fundic region). It is lined by cells that secret both HCL and the digestive enzymes.

Pyloric caeca

Consists of blind-ending diverticula from the distal pyloric valve region of the stomach and the anterior intestine. Found in many species, but notably in the salmonids where they may number 70 or more. Their histological and histochemical features resemble those of the intestine rather than the stomach. The pyloric caeca has a digestive and absorptive function.

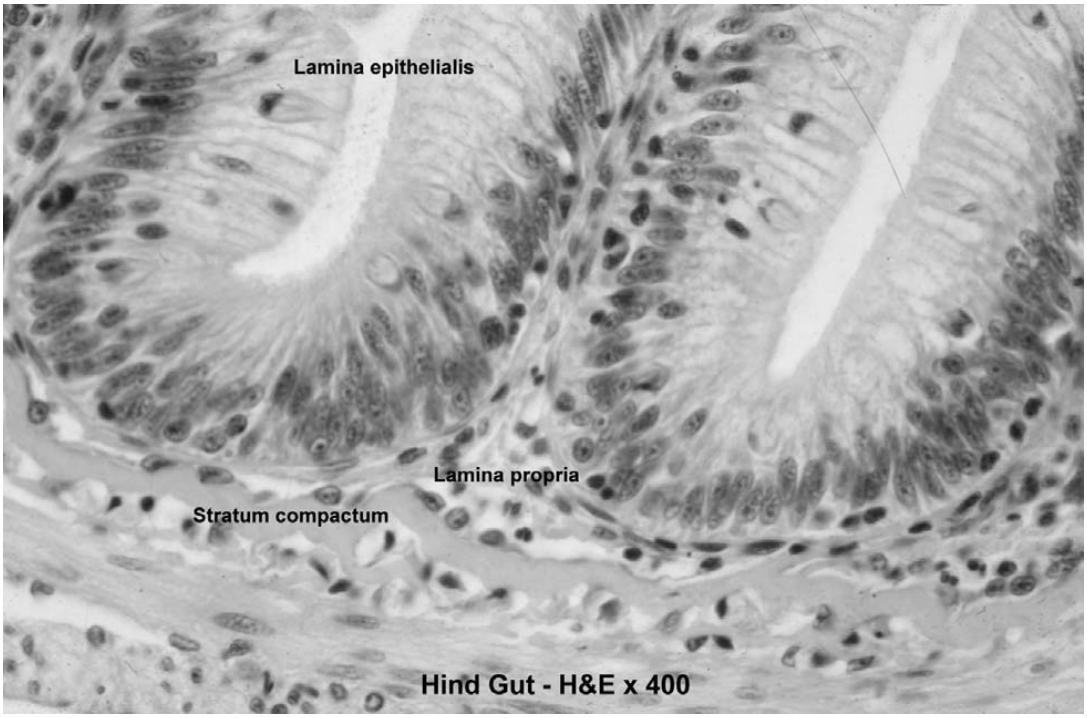




- Appear as a cluster of finger-like blind end diverticula occur at the junction of the distal pyloric valve region of the stomach and the anterior intestine.
- Their wall is generally narrower than the wall of the intestine.
- Their histological structure resembles that of the intestine.

Intestine

Although its relative length may vary according to diet, the intestine of most fish is a simple tube which does not increase in diameter to form a colon posteriorly. It may be straight, sigmoid or coiled, depending on the shape of the abdominal cavity. It has a simple, mucoid, columnar epithelium, overlying a submucosa often with abundant eosinophilic granule cells and limited by a dense muscularis mucosa and fibroelastic layer. The anterior portion of the intestine functions to 1) transport food material from the stomach to the posterior intestine, 2) to complete digestion by the secretion of enzymes from its walls and from accessory glands, 3) to absorb the final products of digestion into blood and lymph vessels in its wall, and 4) to secrete certain hormones (i.e. Secretin, stimulates pancreatic secretion). The posterior intestine functions include fluid absorption, mucous secretion (more goblet cells), and some digestion which is accomplished by enzymes present in food material, and excretion.



- It is a simple tube which forms a short bend at its anterior end, then continuous as a straight tube to the vent or anus.
- The intestine is divided into two portions;
  - Anterior portion or ascending intestine.
  - Posterior portion or descending intestine.
- It does not increase in diameter to form a colon posteriorly.
- The wall of the intestine doesnot includes a submucosa or muscularis mucosa.
- The mucosa has a simple, mucoid columnar epithelium.
- Intercellular mucous cells (goblet cells) and wandering lymphocytes occur in the surface epithelium throughout the intestine.
- Goblet cells are much less apparent in the descending region.
- Both the circular and longitudinal muscles are much thinner than those of the stomach and the oesophegus.

Rectum

The rectum has a thicker muscle wall than that of the intestine and its lining is highly mucigenic. It is capable of considerable distension.

- It has a thicker muscle wall than that of the intestine.
- Its lining is highly mucigenic.
- Spiral valves are common in some species while in others the mucosa carries prominent folds.

Salivary glands

- Most fishes do not have salivary glands but instead certain mucus cells are present.

Liver

- The liver is a large vital organ present in all fish.
- In some species of fish the liver is a separate organ.
- In other species the liver is a compound organ in the form of **hepatopancreas**. Pancreatic tissue can be differentiated from hepatic tissue by **its acinar arrangement**. In addition, **a thin septa** of connective tissue separates the hepatocytes from the exocrine pancreatic cells
-
- The hepatic lobules are not well defined as they are in the liver of higher vertebrate. They are readily identified by the central vein and hepatic triads.
- The hepatic parenchyma in fish is made of two cellular plates surrounded by sinusoids. Between two neighboring sinusoids, the hepatocytes are arranged as cords, generally two cells in thickness. The cords extended between central and portal zones.

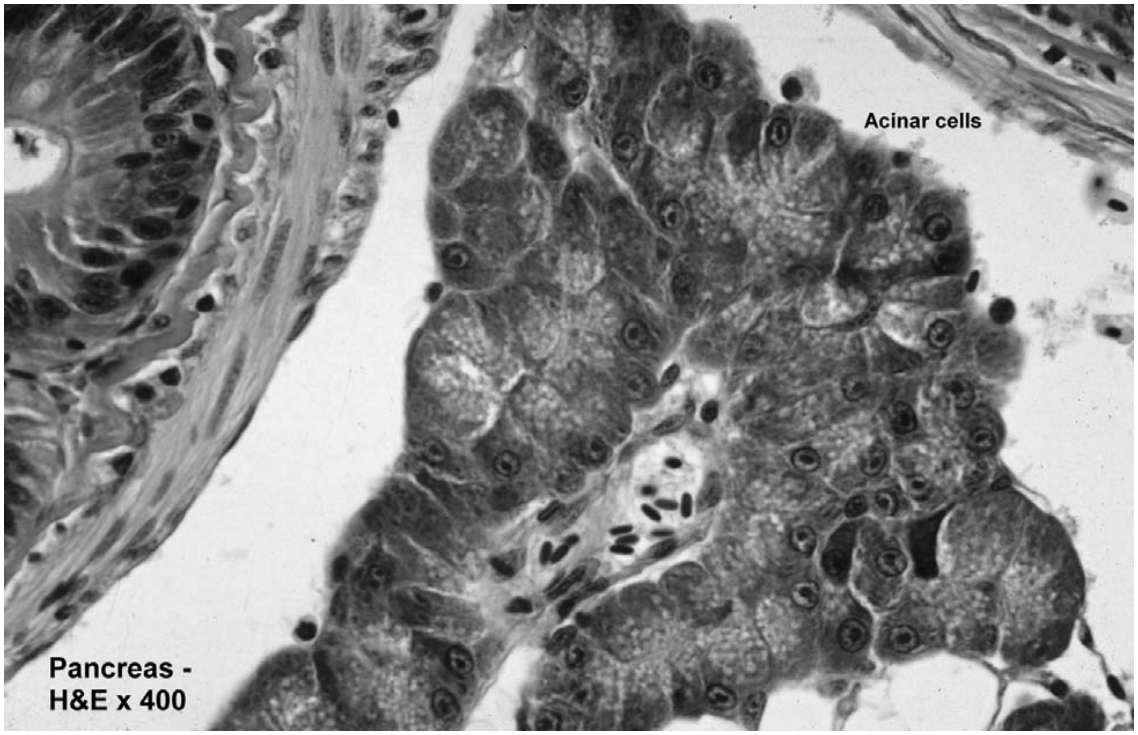
Gall bladder

- It is partially hidden beneath the liver.
- It is connected to the liver by the afferent bile duct and to the pyloric end of the stomach by the efferent bile duct.
- The gall bladder lining is transitional epithelium which often contains rodlets cells.

Pancreas

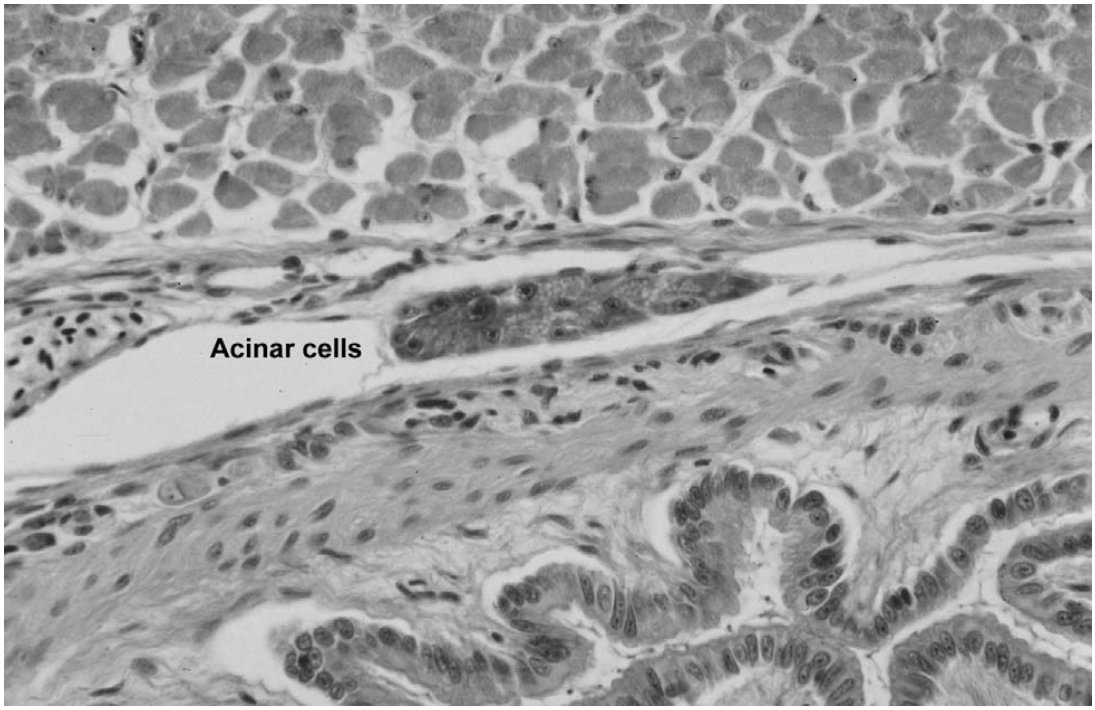
- The pancreas of fish is a lobulated compound acinar gland.
- The pancreatic tissue is more variable in location.
- It occurs as
- **Disseminated type** occurs around gall bladder and in mesentery (Scattered islands of secretory tissue interspersed among the fat cells in the mesentry of the pyloric caeca).
- **The compact pancreas** is located in the splenic mesentery.
- **Intrahepatic pancreas** is located inside the liver (An external layer around the hepatic portal vein).
- The acinar structure of the exocrine pancreatic tissue is very similar to that of mammals.
- It comprises cells with very dark basophilc cytoplasm.
- The endocrine islets of langerhans consist of a number of lightly capsulated poorly stained structures.
- The islets are absent in the hepatopancreas.
- The size of the islets may vary with the season.
- In some species, there are one major islets known as **Brockman body**.

The pancreatic tissue is more variable in location, even within a single species, than the other abdominal viscera. The most common sites for it are as scattered islands of secretory tissue interspersed among the fat cells in the mesentery of the pyloric caeca, as a subcapsular investment, or part, of the spleen and as an external layer around the hepatic portal vein. In salmonids, it is diffuse throughout the tissue (adipose) that surrounds the pyloric caeca. In catfish and bass, it surrounds the portal vessels entering the liver to form a hepatopancreas. The pancreas consists of two types of tissue: exocrine and endocrine.



Exocrine Pancreas

The acinar structure of the exocrine pancreatic tissue is very similar to that of the mammal and is comprised of acinar cells that have a large spherical nucleus with 1-3 nucleoli and a very dark basophillic cytoplasm. In actively feeding fish these contain large numbers of bright, eosinophilic, secretory zymogen granules. Digestive enzymes are secreted from these acinar cells into the anterior intestine to break down proteins, fats, and carbohydrates.



Endocrine Pancreas

The distribution of the pancreatic tissue varies considerably with species, and the endocrine component is also varied. The endocrine components of the pancreas, the islets of Langerhans, consist of a number of lightly capsulated, spherical masses or clusters of pale staining glandular cells. In salmonids, these clusters are founds scattered throughout the pancreas. The size of islet cells may vary with season, and in some species, there is one major islet, known as the Brockmann body. Insulin producing B cells, Beta cells, promote the transfer of glucose across cell membranes which lowers the blood sugar. Glucagon producing A cells, Alpha cells, promote release of stored glycogen which raises the blood sugar. Also, hormone producing D cells and X cells may be present. There is usually considerable change in islet size at spawning, with senility, and with dietary changes. Additionally, there are reported seasonal differences in the proportions of the different cell types.