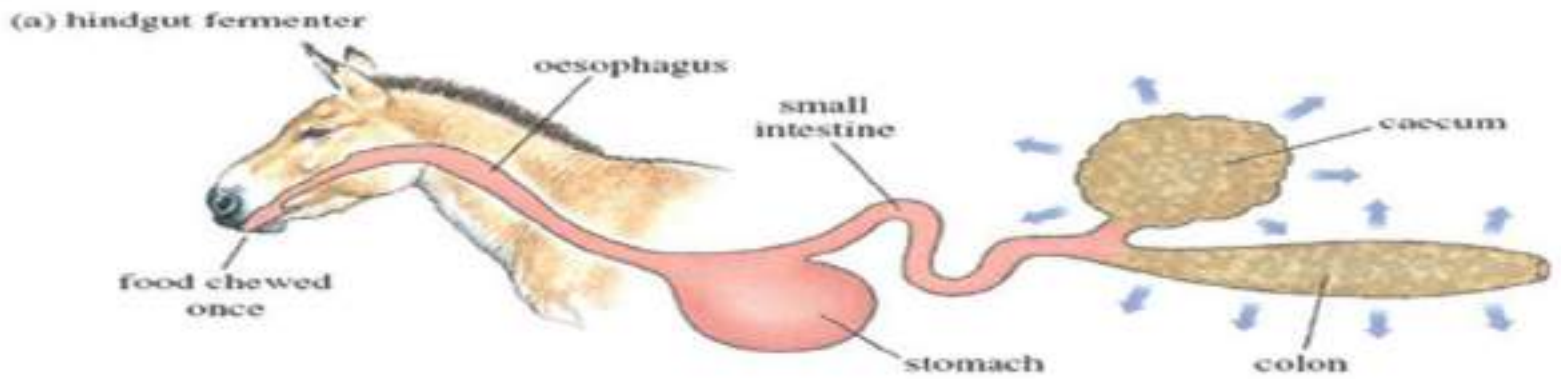
# Department of Veterinary Physiology

MJF College of Veterinary & Animal Sciences,
Jaipur, Rajasthan- 303702
B.V.Sc. & A.H.
1st Year (2023-24)

## Digestive System




**Dr. Brijesh Kumar**
**Assistant Professor**
**Dept. of Veterinary Physiology**

**Dr. Sandeep Bissu**
**Assistant Professor**
**Dept. of Veterinary Physiology**

# Unit- 2

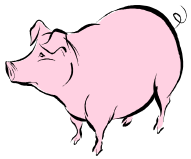
# Digestive System

Table 1: Types of animals

| S.N | Items | Ruminant | Pseudo-ruminant | Non-ruminant or Monogastric |
|---|---|---|---|---|
| 1 | Rumination | Yes | Yes | No |
| 2 | Stomach (No. Of chamber | 4 | 3 (omasum absent) | 1 |
| 3 | Examples | Cattle, Buffalo, Sheep, Goat, Deer, Yak, Mithun, Giraffe, Nilgai(Blue Buck) | Camel, Llama, Alpaca, Vicuna | Horse, Zebra, Donkey,Mule, Pig, Dog, Cat,Rabbit, Elephant |
| | | | | |

## Monogastrics

Chickens



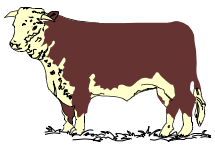
Pigs

Turkeys

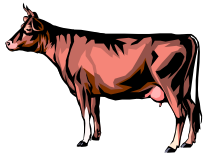
Dogs

Cats

## Ruminants

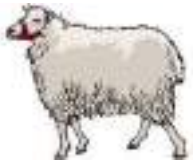


Beef Cattle



Dairy Cattle

Goat

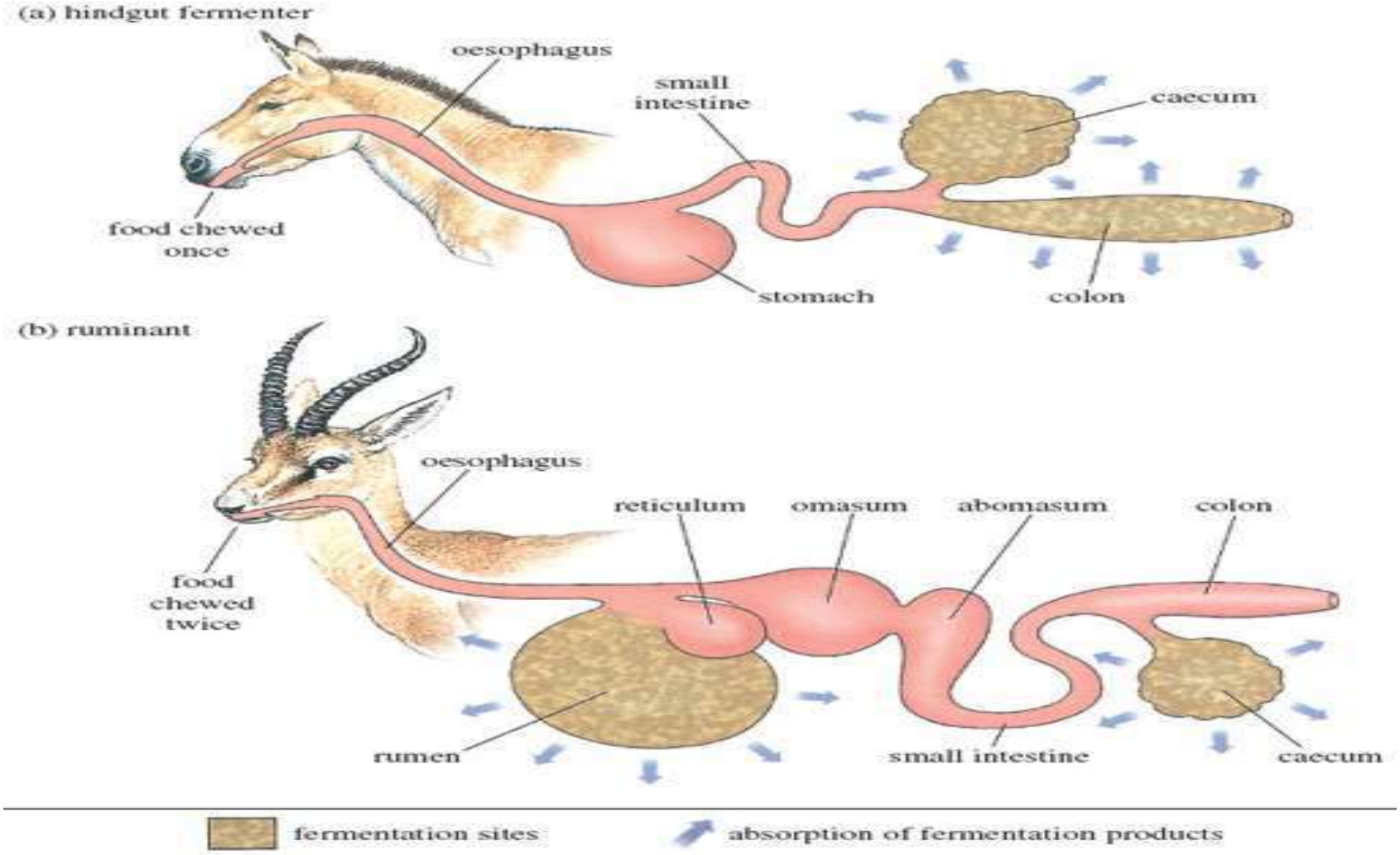


Sheep

Deer

## Table 2: Comparison between normal GIT animal, foregut fermenter & hindgut fermenter

| S.N | Items | Normal GIT animal | Foregut fermenter | Hindgut fermenter |
|---|---|---|---|---|
| 1 | Examples | Pig, Dog, Human | Ruminants, Pseudo-ruminants | Horse, Rabbit |
| 2 | Definition | No fermentation chamber | Fermentation occurs before digestion in the stomach (mainly in rumen) | Fermentation occurs after digestion in the stomach (mainly in caecum & large intestine) |
| 3 | Cellulose digestion | Not adapted | Adapted | adapted |


(a) hindgut fermenter
oesophagus
small intestine
caecum
food chewed once
stomach
colon
(b) ruminant
oesophagus
reticulum
omasum
abomasum
colon
food chewed twice
rumen
small intestine
caecum
fermentation sites
absorption of fermentation products

- **Prehensile organ of different animals:**

  **Horse- sensitive mobile lips**

  **Cow, Dog &Cat- tongue**

  **Sheep- tongue & incisors teeth**

  **Pig- pointed lower lip**

  **Goat, Camel- lips**

**Note:-**

**Common grazing animals - Cattle, Sheep**

**Common browsing animals- Goat, Camel**

- **The gallbladder is absent in horse as well as in all pseudo-ruminants like- camel, llama, alpaca, vicuna**

## Table 3: Normal physiological parameters

| S.N | Animal | Normal temperature | Respiration rate (per min) | Pulse rate (per min) |
|---|---|---|---|---|
| 1 | Camel | 99.5° F | 5-12 | 25-32 |
| 2 | Horse | 100° F | 8-12 | 32-44 |
| 3 | Cattle | 101.5° F | 12-16 | 45-65 |
| 4 | Pig | 102° F | 10-16 | 70-80 |
| 5 | Sheep | 102° F | 12-20 | 70-80 |
| 6 | Goat | 103° F | 12-20 | 70-80 |
| 7 | Dog | 102° F | 15-30 | 100-130 |
| 8 | Fowl | 107° F | 15-30 | 250-300 |

Human - $98.6^0$ F ($37^O$ C)

Temprature Formula $^{O}C = [(^{o}F-32) \times 5]/9$

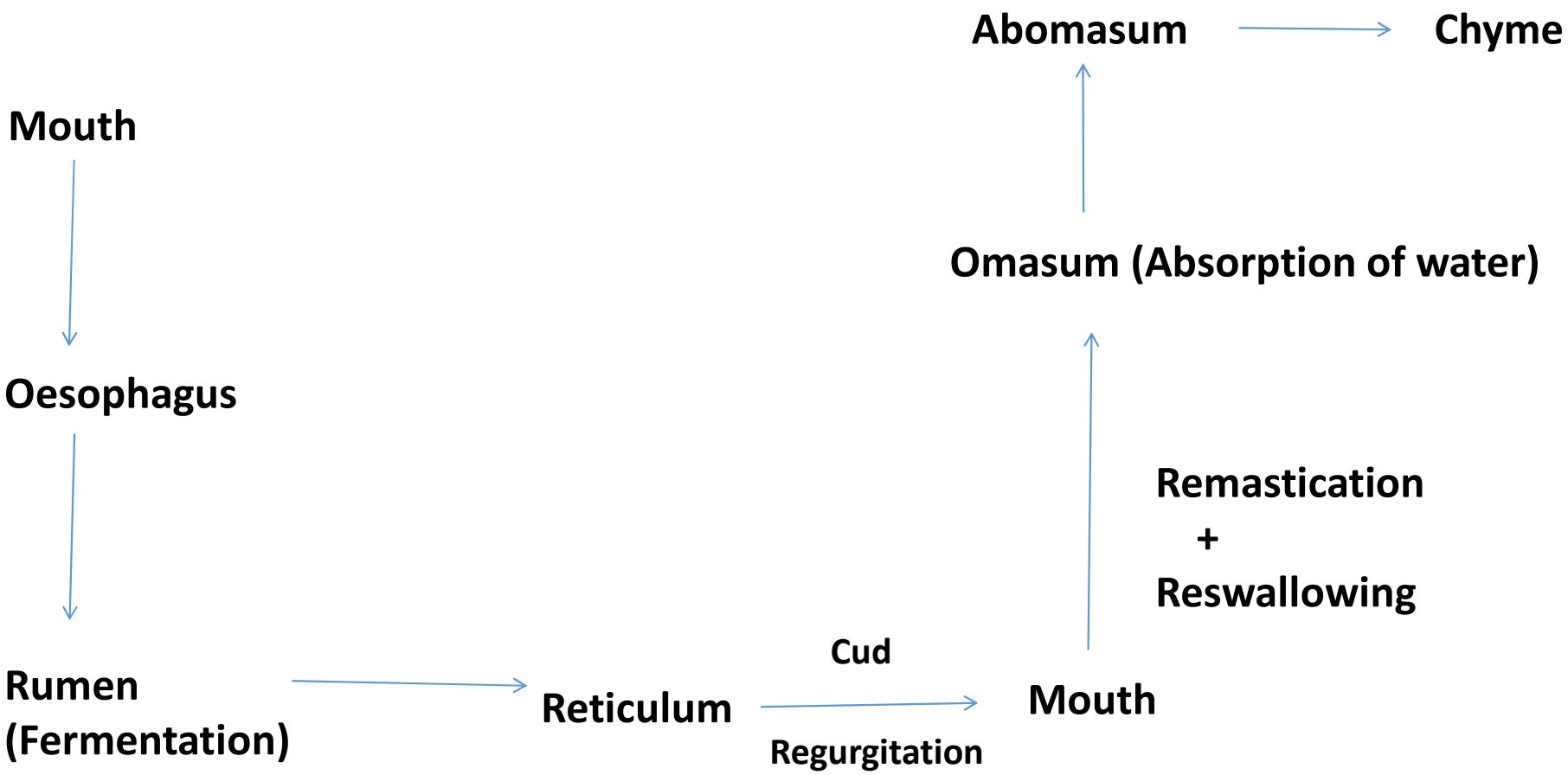
**Note 1:**

- **The greater the bulk of body the lower the pulse, respiration and temperature.**

**Note 2:-**

- **The largest endocrine gland of the body is thyroid while smallest is pineal**
- **Largest endocrine organ of the body is GIT**
- **The largest gland of the body is liver**
- **The largest organ of the body is the skin**
- **Total body water of animal body: 60-70% of body weight**
- **Total blood volume in animal body: 8% of body weight**
- **Plasma volume in animal body: 5% of body weight**
- **Mineral content of animal body: 3% of body weight**
- **The weight of animal heart: 0.6% of body weight**

# Flow of food in ruminant animals



# Digestive system of ruminants

**The digestive system is composed of alimentary canal and its accessory glands. The alimentary canal consists of mouth, pharynx, oesophagus, stomach, small and large intestines. The accessory glands include salivary glands, liver and pancreas.**

**(A) ALIMENTARY CANAL**

**MOUTH :**

**1. It is cylindrical cavity containing tongue and teeth**

**2. It is laterally formed by cheeks**

**3. The roof is formed by hard palate**

**4. The floor is formed by mandible**

**5. It is anteriorly closed by lips**

**6. it is posteriorly separated from naso- pharynx by soft palate**

**Function :**

**1. Prehension : act of taking food into the mouth.**

**2. Mastication : chewing of food**

**3. Insalivation : mixing of food with saliva**

**4. Deglutition : act of swallowing food**

**5. Rumination : process involving regurgitation, remastication, reinsalivation, and redeglutition of food.**

**Regurgitation : Pushing back food into the mouth from the stomach**

**Lips : they serve as a organ of prehension in sheep and goat, horse**

**Cheeks : they help the tongue in postioning food b/w teeth for chewing**

**Teeth : these are hard, dense whitish structures embeded in gum and projects into mouth**

**Teeth function - chewing of food material**

**these are 4 types of teeth -**

**1. Incisors - Front teeth**

**2. Canines - Corner teeth**

**3. Premolars**

**4. Molars** → **Cheek teeth**

**In early age, the teeth are temporary and called as milk teeth or deciduous teeth They are replaced in adult animals by permanent teeth.**

**Methods of age determination of animals:-**

1. By record keeping
2. By physical appearance of animal
3. By counting no. of horn rings (**Age=N+2**; where N is no. of horn ring)
   - ✓ This method is applicable to cattle/buffalo whose calving interval is 1year; in **cattle, first horn ring appears at the age of 3 years.**
4. By dentition: - **most commonly used method for age determination**

**Table 33: Dental formulae of various animals**

| S.N. | Animal | Dental formula (permanent) | Comments |
|---|---|---|---|
| 1. | Ruminants (Cow, Buffalo, Sheep Goat) | $2(I^0/_4C^0/_0PM^3/_3M^3/_3) = 32$ | Incisors are absent from upper jaw in all ruminant& their place is taken up by **"dental pad"** **Canines are absent in all ruminants** |
| 2. | Horse(Stallion) | $2(I^3/_3C^1/_1PM^3/_3M^3/_3) = 40$ | |
| 3. | Mare | $2(I^3/_3C^0/_0PM^3/_3M^3/_3) = 36$ | **Canines are absent in mare** |
| 4. | Pig | $2(I^3/_3C^1/_1PM^4/_4M^3/_3) = 44$ | |
| 5. | Dog | $2(I^3/_3C^1/_1PM^4/_4M^2/_3) = 42$ | |
| 6. | Camel | $2(I^1/_3C^1/_1PM^3/_2M^3/_3) = 34$ | |

**Note:-**

- ✓ Full mouth condition: -Age at which all permanent teeth appear
  [Sheep: 4years (b) Horse: 4.5years (c) Goat, Cattle & Buffalo: 5 years (d) Camel:7 years]
- ✓ Broken mouth condition: -Age at which one or more teeth have disappeared.
- ✓ **Gummer: - an animal that has lost it's all teeth.**
- ✓ Cheek teeth: Premolars& molars together known as cheek teeth
- ✓ Age of the animal is determined by incisors of the lower jaw
- ✓ **Dental Star** (mark on central pulp cavity of incisors) & **Galvayne' s groove** (a groove in upper corner incisor) **are related to incisors of horses.**

**Tongue : It is muscular organ situated on the floor of mouth cavity . it consists of base, body and a tip.**

**Function :**

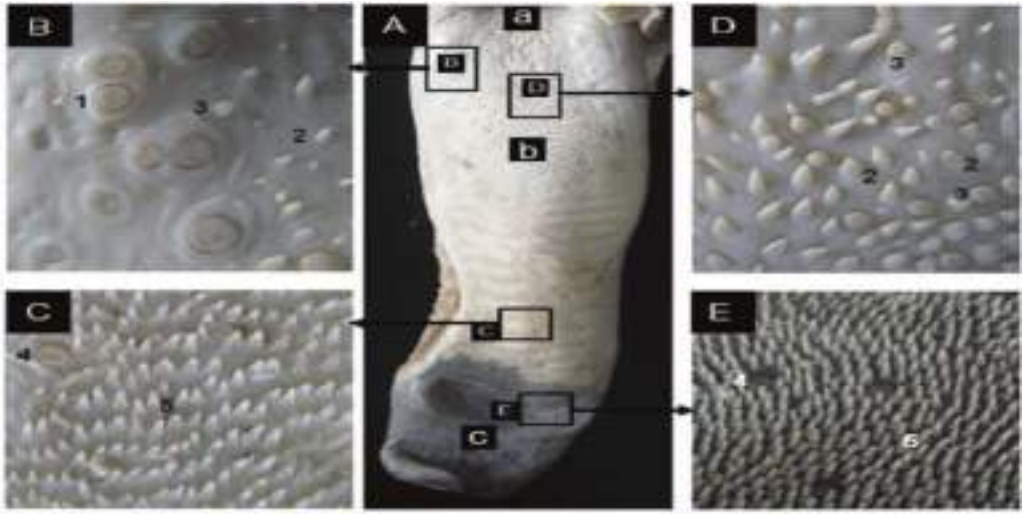
**1. It is the chief organ of prehension in cattle**

**2. It is an organ of taste**

**3. It also helps in mastication and deglutition.**

**Taste perception in tongue :**

| Area of tongue | Type of taste |
|---|---|
| Base | Bitter |
| Lateral side | Sour, Salt |
| Tip | Sweet or salt |




The tongue of cattle: (A) a, lingual root; b, lingual body; c, lingual apex. (B) 1, vallate papillae; 2, conical papillae; 3, lenticular papillae. (C) 4, fungiform papillae; 5, filiform papillae. (D) 2, conical papillae; 3, lenticular papillae; (E) 4, fungiform papillae; 5, filiform papillae

## PHARYNX :

1. It is conical or funnel shaped musulo-membranous sac.
2. it is common for both digestive and respiratory tract
3. It is located just behind mouth cavity
4. There are seven openings in pharynx which are as below

Mouth cavity (Anteriorly) : 1

Posterior nares (Dorsally) : 2

Eustachian tubes (Laterally) : 2

Oesophagus (Posteriorly) : 1

Larynx (Ventrally) : 1

**Function :**

It is a common passage for food, water and air

## Oesophagus :

**1. It is a musculo- membranous tube extending from pharynx to the cardia of the stomach**

**2. it is divided into two parts : cervical and thoracic**

**3. The average length is about 90cm and diameter is about 5 cm**

**Function : Passage for food**

## Ruminant stomach :

**1. It is also called as compound stomach**

**2. It is made up of four compartments viz. rumen, reticulum, omasum and abomasum**

**3. The first 3 compartment are collectively called as fore stomach while the fourth compartment abomasum is called as true stomach**

**4. The average capacity of the stomach in adult cattle ranges from 100-230 liters depending upon the size of animal.**

## A. Rumen (Pouch)

**1. It is the first and the largest compartment of ruminant stomach**

**2. It forms about 70-80 % portion of ruminant stomach**

**3. It is located in the left side of abdominal cavity from diaphragm to pelvis.**

**4. The rumen is subdivided into dorsal and ventral sacs by muscular pillars.**

**5. It is turkish towel like in appearance on its inner side**

**6. It communicates with oesophagus and reticulum by means of cardiac and rumino -reticular openings, respectively**

- **Houses microorganisms.**
  - ✓ **Protozoa – 100000 per gram of rumen fluid.**
  - ✓ **Bacteria/fungi – 100 million per gram of rumen fluid.**

- **Functions of microorganisms.**
  - ✓ **Digest roughages to make Volatile Fatty Acids (VFA's), make microbial protein, and make vitamins K and B-complex.**

**Function :**

1. Storage of food
2. Churning of coarse fibrous food
3. Proper mixing of ingesta
4. Synthesis of vit. B- complex group
5. Microbial digestion of protien, fats and carbohydrates
6. Absorption of VFA (volatile fatty acids)
7. Expulsion of gases like Co2 & methane

**Note :**

Uses of VFA produced during ruminal fermentation :

1. VFA provides 70% of ruminant energy needs
2. Acetate : It is responsible for milk fat synthesis
3. Propionate : It is glucogenic. it is responsible for milk sugar synthesis
4. Butyrate : Ruminal epithelial cells converts it into beta- hydroxy butyrate ( A ketone body )

**Table 20: Ruminal microbiology**

| S.N. | Index | Ruminal ecosystem |
|---|---|---|
| 1 | Normal ruminal PH | **6.5-6.8** |
| 2 | Optimum temperature | **$39^0$C** |
| 3 | Gas production | **$CO_2$: $CH_4$(65: 35)** |
| 4 | $VFA^S$ profile | **Acetate : Propionate : Butyrate (65 : 20 : 10)** |
| 5 | Ruminal microbial population(per ml of rumen liquor) | **Bacteria ($10^{10-11}$), Protozoa($10^6$), Fungi ($10^3$), Bacteriophage($10^9$)** |
| 6 | Ruminal bacteria | **Mostly bacteria are gram (−) ve & obligate anaerobes.** However, lactic acid producing bacteria are facultative anaerobes& they are attached to the ruminal wall because some $O_2$ is present in the periphery. |
| 7 | Ruminal protozoa | The majority are ciliate protozoa.<br>The ruminal microbial population is decided by protozoa because protozoa eat on bacteria |
| 8 | Ruminal fungi | Mostly flagellated fungi<br>Function: Substrate penetration(by breaking lingo-cellulosic bond of fiber diet) |
| 9 | Ruminal bacteriophage | Function: Lysis of bacterial cells so that bacterial protein is easily available to animals as a source of amino acids |

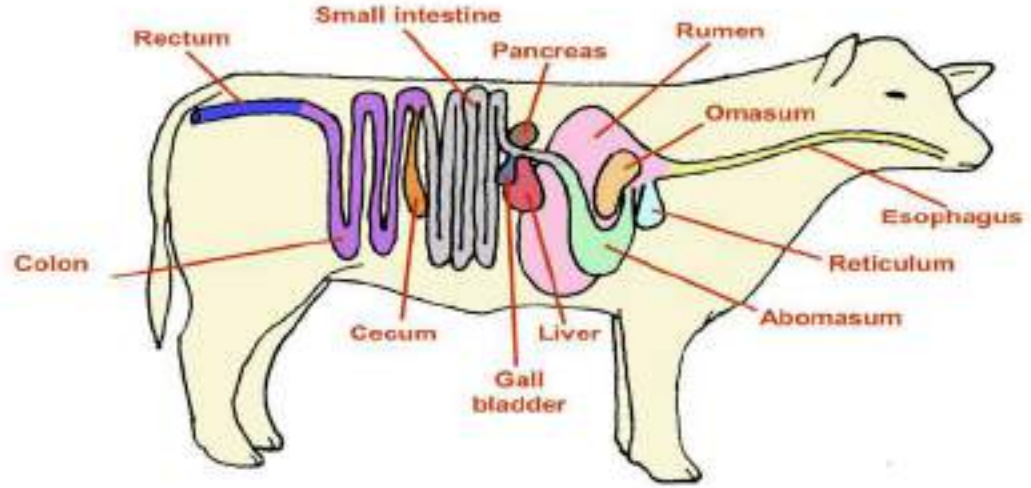
**Note:-**

1. **Defaunation**: Selective removal of protozoa from the ruminal ecosystem
2. **Chemical defaunation**: **Copper sulfate & Sodium lauryl sulfate**

**Table 21: Ruminal bacteria**

| S.N. | Types of ruminal bacteria | **Examples** |
|---|---|---|
| 1 | Cellulose-digesting bacteria | **Fibrobacter (Bacteroides) succinogenes, Ruminococcus albus**, Ruminococcus flavefaciens, Clostridium longisporum |
| 2 | Hemicellulose digesting bacteria | **Butyrivibrio fibrisolvens**, Bacteroids ruminicola |
| 3 | Starch-digesting bacteria | **Streptococcus bovis**, Ruminobacter amylophilus |
| 4 | Methanogenic bacteria | **Methanobacterium ruminantium** |
| 5 | Sugar/dextrin utilizing bacteria | Succinivibrio dextrinosolvens, Succinivibrio amylolytica, Lactobacillus acidophilus |

## Digestive Tract of Cattle



**B. Reticulum (Honey comb)**

**1. It is the second and smallest compartment of ruminant stomach**

**2. It forms approx. 5% portions of stomach**

**3. It has honey comb like structure on its inner side**

**4. It is located behind diaphragm and opposite to heart**

**5. It communicates with rumen and omasum by rumino- reticulo and reticulo-omasal orifices, respectively**

**Function :**

**1. It separates foreign objects like nail, stone, wire from the ingesta food**

**2. It acts as a filter for food materials**

**3. It help in regurgitation**

**C. Omasum (Manyplies) :**

**1. It is third compartment of ruminant stomach**

**2. It is spherical or eliptical in shape**

**3. its forms approx. 7-8 % portion of ruminant stomach**

**4. it is located on right side of the abdominal cavity just behind reticulum**

**5. It content 100 % shaped folds called laminae**

**6. it communicates anteriorly with reticulum and posteriorly with abomasum by means of reticulo- omasal and omasal abomasal orifices, respectively**

**Function:**

**1. its remove about 50% of water from ingesta of food materials**

**2. its absorbed VFA**

**3. its also grinding food particles**

**D. Abomasum (True stomach) :**

**1. It is fourth compartment of ruminant stomach**

**2. It is also called as true stomach of ruminant because it is glandular and resembles to the simple stomach in form and structure**

**3. It is elongated, saccular in shape**

**4. It forms approx. 7-8% portions of ruminant stomach**

**5. It is situated on the floor of abdominal cavity, ventral to the omasum on right side of the rumen**

**6. The anterior part of abomasum is known as "Fundus" while terminal part is known as "pylorus"**

**7. There are about 12 oblique folds within the fundus**

**8. It communicates anteriorly with omasum and posteriorly with dudenum by means of omaso- abomasal and pyloric openings, respectively**

**Function:**

**1. Passes food from omasum to small intestine**

**2. Undertake little digestion of food particles microbial protiens**

**3. Absorption of VFA to some extent**

**4. Secretes gastric juice which contains hydrochloric acid and enzymes like pepsin and rennin**

**SMALL INTESTINE :**

- **I. It extends from pylorus to ileo-caecal junction.**
- **2. Its average length is 50-52 meters in cattle.**
- **3. Its average diameter is 5-6 cm.**
- **4. The innermost lining of small intestine has long finger like projections called villi.**
- **5. The villi increases the surface area for absorption of food nutrients.**
- **6. It is divided into 3 parts viz. duodenum, jejunum, ileum.**

**I) Duodenum :**

- **I. It is the first part of small intestine**
- **2. It forms 'S' shaped**
- **3. It is approximately 1 metre in length.**
- **4. The bile and pancreatic ducts open into duodenum**
- **5. It is located in sublumbar region.**

**2) Jejunum :**

- **I. It is indistinctly separated from duodenum**
- **2. It is approx 48-50 meters in length (longest)**
- **3. It is located on the floor of abdominal cavity on right side.**

**3) Ileum :**

- **I. It is the terminal part of small intestine.**
- **2. It extends upto ileo-caecal junction.**
- **3. It is approximately 1 meter in length.**

**Functions :**

- **I. Receives food from abomasum and passes to large intestine.**
- **2. Secretion of digestive juices.**
- **3. Digestion of carbohydrates, fats and proteins.**
- **4. Absorption of digested food i.e. glucose, amino acids & fatty acids.**

**Note : Mouth, esophagus, stomach, liver, pancreas, gall bladder, and small intestine have similar functions as compared to monogastrics**

**LARGE INTESTINE :**

- **I. It extends from ileo-caecal junction to the anus.**
- **2.It is about 11-12 meters in length**
- **3.its diameter varies from 5-15 cm**
- **4. villi are absent**
- **5. It is divided into 3 parts viz. caecum, colon, rectum**

**1) Caecum**

- **I. It is a blind sac situated between ileum and the large colon.**
- **2. It is located on right side of the abdominal cavity.**
- **3. It is about 0.8 meter long and 5'' in diameter.**

**2) Colon**

- **I. It is the second portion of large intestine.**
- **2. It is located on the right dorsal part of the abdomen.**
- **3. It is arranged in coils**
- **4. It is approximately 10 meters long and 5" in diameter**

**3) Rectum**

- **I. It is the terminal part of large intestine.**
- **2. It is located in the pelvic cavity.**
- **3. It is little less than 30 cm in length.**
- **4. Its wall is more thick and dilated than caecum and colon.**
- **5. It is closed posteriorly by sphincter muscles called anal sphincter.**

**NOTE : Major difference between monogastrics and hind gut fermentors is the large intestine. Large intestine is exceptionally large and complex compared to monogastrics and ruminants.**

**Functions :**

- **l. Microbial digestion of food material to some extent.**
- **2. Absorption of food nutrients to some extent.**
- **3. Absorption of water.**
- **4. Stores food residue temporarily in rectum.**

## B) ACCESSORY GLANDS

**SALIVARY GLANDS :**

**They are - i) Parotid ii) Mandibular and iii) Sublingual**

**1) Parotid glands**

- **1. These are triangular, long & reddish brown glands .**
- **2. These are situated at the base of ear.**
- **3. They open in mouth opposite to fifth upper molar teeth as Stenson 's duct.**

**2) Mandibular or Submaxillary glands :**

- **I. These are elongated, pale yellow, lobulated glands.**
- **2. These are situated along the medial border of the angle of mandible.**
- **3. They open on the floor of mandible as wharton's duct .**

**3) Sublingual glands :**

- **1. These are two glands situated under tongue.**
- **2. They open in the mouth cavity by the side of submaxillary duct.**
- **3. Saliva from these glands is poured into 5 to 15 small ducts called ducts of rivinus/Bartholin's duct.**

**Functions :**

**I. They secrete saliva.**

**2. Saliva acts as lubricant and helps in mastication & deglutition.**

**3. Saliva maintains pH and fluidity of ruminal contents.**

**4. The saliva of domestic animals contains little or no amylase.**

**Saliva- The salivary glands, parotid, sub-mandibular & sublingual secretes the alkaline liquid which helps in mixing & collecting of food material.**

**Composition of saliva :**

- **Colorless, viscid, easily frothing slightly opaque liquid average pH is 6.8 (Human) & slightly alkaline in nature(ruminants and domestic animal)**
- **Specific gravity is 1.005**
- **Contains organic & inorganic constituents in small amounts**
- **Consists of mucin, proteins & ptyalin, desquamated epithelial cells & leucocytes.**
- **Consists Na, K, chloride, bicarbonate & phosphate**

**Electrolytes- saliva is hypotonic & contains K+ & HCO3- in higher concentrations than Na+ & CL**

**Proteins- containing amylase and lingual lipase for digestion of starch & fat. Whereas it contains mucin, a glycoprotein for food lubrication.**

**Contribution by each major salivary gland is:**

- **i. Parotid glands : 25%**
- **ii. Submaxillary glands : 70%**
- **iii. Sublingual glands : 5%**

**NOTE: Normally, glucose is absent in saliva, But, it is found in saliva during diabetes mellitus**

TABLE 37.2: Digestive enzymes of saliva

| Enzyme | Source of secretion | Activator | Action |
|---|---|---|---|
| Salivary amylase | All salivary glands | Acid medium | Converts starch into maltose |
| Maltase | Major salivary glands | Acid medium | Converts maltose into glucose |
| Lingual lipase | Lingual glands | Acid medium | Converts triglycerides of milk fat into fatty acids and diacylglycerol |

## REGULATION OF SALIVARY SECRETION

- Salivary secretion is regulated only by nervous mechanism. Autonomic nervous system is involved in the regulation of salivary secretion.

## NERVE SUPPLY TO SALIVARY GLANDS

- Salivary glands are supplied by both parasympathetic and sympathetic divisions of autonomic nervous system.

### PARASYMPATHETIC FIBERS

#### *Parasympathetic Fibers to Submandibular and Sublingual Glands*

Parasympathetic preganglionic fibers to submandibular and sublingual glands arise from the superior salivatory nucleus, situated in pons. After taking origin from this nucleus, the preganglionic fibers run through nervus intermedius of Wrisberg, geniculate ganglion, the motor fibers of facial nerve(VII), chorda tympani branch of facial nerve and lingual branch of trigeminal nerve and finally reach the submaxillary ganglion. Postganglionic fibers arising from this ganglion supply the submaxillary and sublingual glands.

### *Parasympathetic Fibers to Parotid Gland*

Parasympathetic preganglionic fibers to parotid gland arise from inferior salivatory nucleus situated in the upper part of medulla oblongata. From here, the fibers pass through the tympanic branch of glossopharyngeal nerve, tympanic plexus and lesser petrosal nerve and end in otic ganglion. Postganglionic fibers arise from this ganglion and supply the parotid gland by passing through auriculotemporal branch in mandibular division of trigeminal nerve.

### *Function of Parasympathetic Fibers*

Stimulation of parasympathetic fibers of salivary glands causes secretion of saliva with large quantity of water. It is because the parasympathetic fibers activate the acinar cells and dilate the blood vessels of salivary glands. However, the amount of organic constituents in saliva is less. The neurotransmitter is acetylcholine.

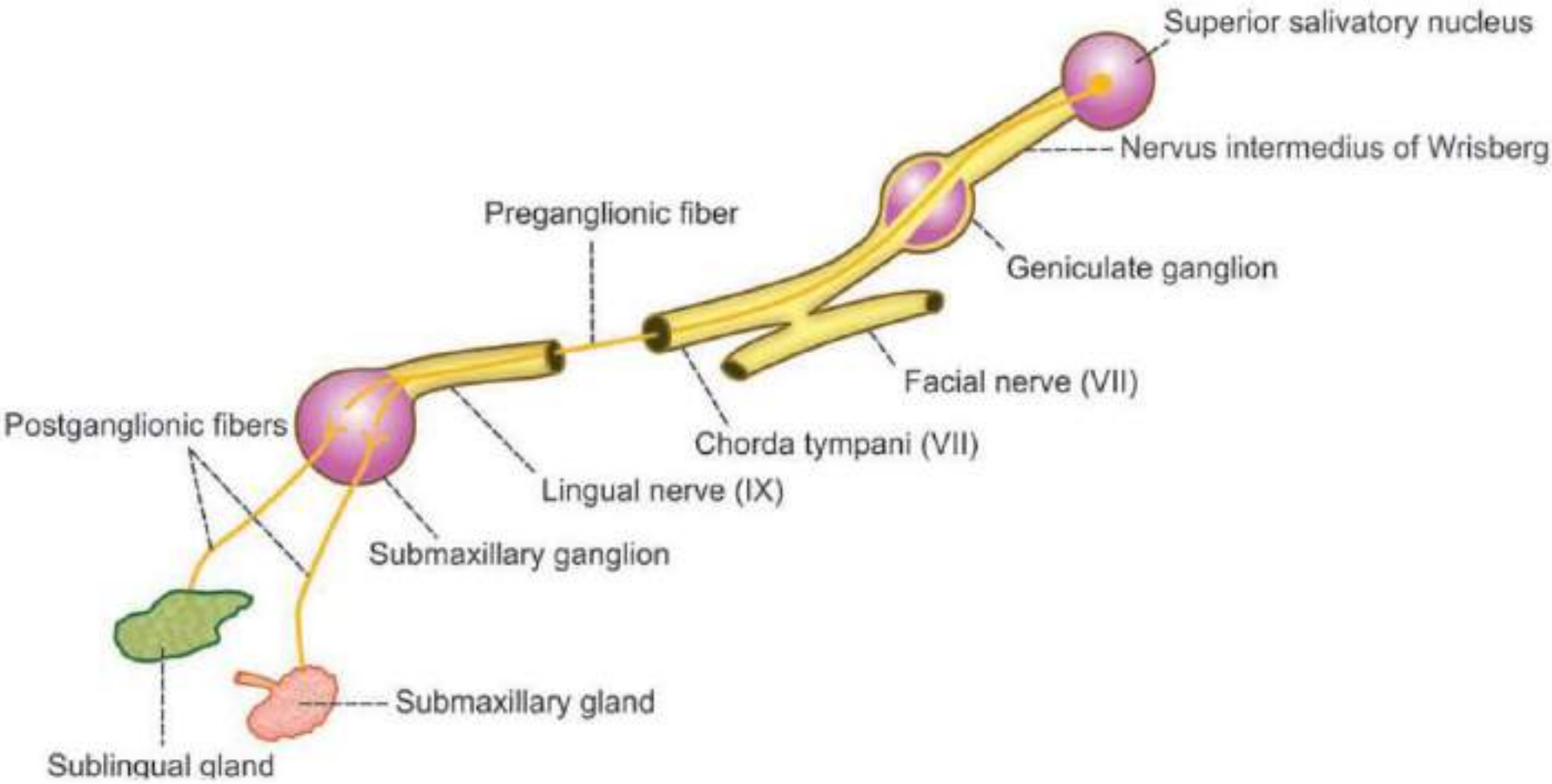



**FIGURE** : Parasympathetic nerve supply to submaxillary and sublingual glands

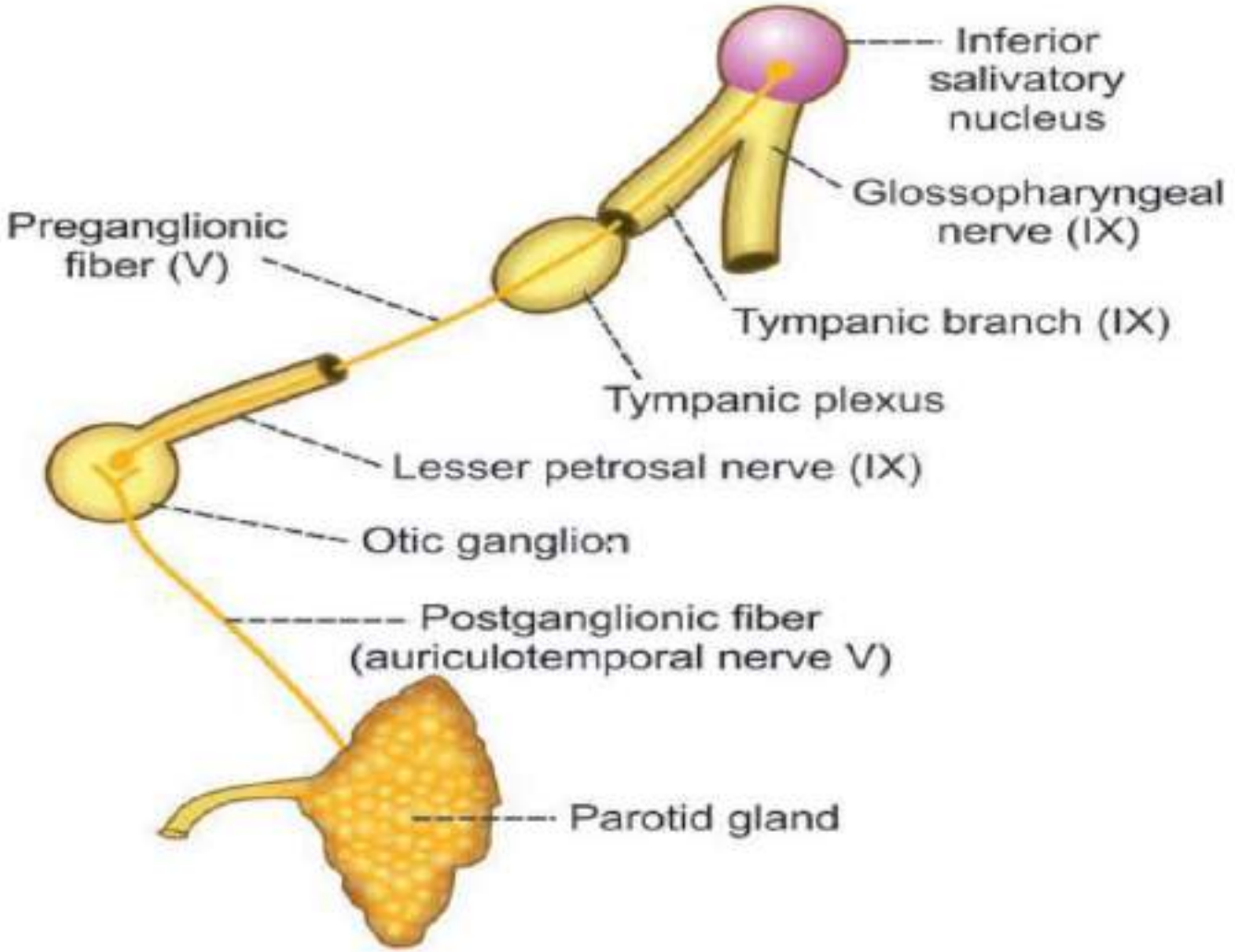



**FIGURE** : Parasympathetic nerve supply to parotid gland

Preganglionic neurons are a set of nerve fibers of the autonomic nervous system that connect the central nervous system to the ganglia

Postganglionic neurons are a set of nerve fibers that present in the autonomic nervous system which connects the ganglion to the effector organ

**SYMPATHETIC FIBERS: Sympathetic preganglionic fibers to salivary glands arise from the lateral horns of first and second thoracic segments of spinal cord. The fibers leave the cord through the anterior nerve roots and end in superior cervical ganglion of the sympathetic chain. Postganglionic fibers arise from this ganglion and are distributed to the salivary glands along the nerve plexus, around the arteries supplying the glands.**

***Function of Sympathetic Fibers:*** **Stimulation of sympathetic fibers causes secretion of saliva, which is thick and rich in organic constituents such as mucus. It is because, these fibers activate the acinar cells and cause vasoconstriction. The neurotransmitter is noradrenaline/norepinephrine(is made from dopamine by nerve cells in the brainstem area of brain).**

**REFLEX: This is a sudden, involuntry unplanned action or response to a stimulus. It may or may not involve the brain. It helps in the survival of an individual by protecting it from dangerous stimuli like pain or heat. Reflex are of two types-**

**1. Unconditioned reflex 2. Conditioned reflex**

**REFLEX REGULATION OF SALIVARY SECRETION:**

**Salivary secretion is regulated by nervous mechanism through reflex action. Salivary reflexes are of two types:**

**1. Unconditioned reflex 2. Conditioned reflex**

**1. *Unconditioned Reflex:* Unconditioned reflex is the inborn reflex that is present since birth. This reflex induces salivary secretion when any substance is placed in the mouth. It is due to the stimulation of nerve endings in the mucus membrane of the oral cavity.**

**2. *Conditioned Reflex:* Presence of food in the mouth is not necessary to elicit this reflex. The stimuli for this reflex are the sight, smell, hearing or thought of food.**

# Difference b/w unconditioned reflex and condition reflex

| **Unconditioned reflex** | **Condition reflex** |
|---|---|
| Inborn and inherited; present for all life | Acquired during lifetime; temporary |
| Constant response | Response based on individual preference |
| Lower nerve centers activated | Cortical centers activated |
| Involves reflex arcs | Involves neural connection |
| Eg- Withdrawal of the hand on touching a hot Pan | Eg- Standing up when the teacher enters the class |

## EFFECT OF DRUGS AND CHEMICALS ON SALIVARY SECRETION

***Substances which increase salivary secretion***

**1. Sympathomimetic drugs like adrenaline and ephedrine.**

**2. Parasympathomimetic drugs like acetylcholine, pilocarpine, muscarine and physostigmine.**

**3. Histamine.**

***Substances which decrease salivary secretion***

**1. Sympathetic depressants like ergotamine and dibenamine.**

**2. Parasympathetic depressants like atropine and scopolamine.**

**3. Anesthetics such as chloroform and ether stimulate the secretion of saliva. However, deep anesthesia decreases the secretion due to central inhibition.**

**Secretion of saliva: controlled by ANS reflexes**

- **Parasympathetic nerve secrete a large volume of watery fluid i.e. high in electrolytes but low in proteins**
- **Sympathetic nerve stimulation causes secretion of small volume of fluid containing a high content of mucus**
- **Salivary reflexes are elicited by thought, aroma or by taste or presence of the food in alimentary canal**

**Functions of saliva:**

**Cleansing and Protection- i. Due to the constant secretion of saliva, the mouth and teeth are rinsed and kept free off food debris, shed epithelial cells and foreign particles. In this way, saliva prevents bacterial growth by removing materials, which may serve as culture media for the bacterial growth.**

**ii. Enzyme lysozyme of saliva kills some bacteria such as staphylococcus, streptococcus and brucella.**

**iii. Proline-rich proteins present in saliva posses antimicrobial property and neutralize the toxic substances such as tannins. Tannins are present in many food substances including fruits.**

**Digestive function- α amylase (Ptyalin) break down the starch into disaccharides. α amylase is inactivated by low pH of the stomach. Lingual lipase breakdown ingested fat. *Salivary Amylase:* Salivary amylase is a carbohydrate-digesting (amylolytic) enzyme. It acts on cooked or boiled starch and converts it into dextrin and maltose. Though starch digestion starts in the mouth, major part of it occurs in stomach because, food stays only for a short time in the mouth. Optimum pH necessary for the activation of salivary amylase is 6. Salivary amylase cannot act on cellulose. *Maltase:* Maltase is present only in traces in human saliva and it converts maltose into glucose. *Lingual Lipase:* Lingual lipase is a lipid-digesting (lipolytic) enzyme. It is secreted from serous glands situated on the posterior aspect of tongue. It digests milk fats (pre-emulsified fats). It hydrolyzes triglycerides into fatty acids and diacylglycerol**

**Lubrication- Lubricates the food for easy swallowing & moisten the mouth**

**Role in speech- by moistening and lubricating soft parts of mouth and lips, saliva helps in speech**

**Excretory function:** many substances, both organic and inorganic are excreted in saliva It excretes substances like 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. Example is 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 BODY TEMPERATURE:** In dogs and cattle, excessive dripping of saliva during panting helps in the loss of heat and regulation of body temperature. However, in human beings, sweat glands play a major role in temperature regulation and saliva does not play any role in this function.

**REGULATION OF WATER BALANCE:** When the body water content decreases, salivary secretion also decreases. This causes dryness of the mouth and induces thirst. When water is taken, it quenches the thirst and restores the body water content.

**Amount of Saliva** - Enormous quantities of saliva are produced in herbivores. Amount of salivary secretion is inversely related to the amount of moisture in the food. Quantity of saliva secreted:

a) Horse – 50mL/min during mastication

b) Cow – 100 to 200 L/day

c) Man – 1500 mL/day

d) Single parotid gland of sheep – 930 to 1840 ml/24 h.

e) Dog – 0.5 L/day in 20 kg dog.

## APPLIED PHYSIOLOGY

### HYPOSALIVATION

**Reduction in the secretion of saliva is called hyposalivation. It is of two types, namely temporary hyposalivation and permanent hyposalivation.**

**1. Temporary hyposalivation occurs in:**

**i. Emotional conditions like fear.**

**ii. Fever.**

**iii. Dehydration.**

**2. Permanent hyposalivation occurs in:**

**i. Sialolithiasis (obstruction of salivary duct).**

**ii. Congenital absence or hypoplasia of salivary glands.**

**iii. Bell palsy (paralysis of facial nerve).**

### HYPERSALIVATION

**Excess secretion of saliva is known as hypersalivation. Physiological condition when hypersalivation occurs is pregnancy. Hypersalivation in pathological conditions is called ptyalism, sialorrhea, sialism or sialosis.**

**Hypersalivation occurs in the following pathological conditions:**

**1. Decay of tooth or neoplasm (abnormal new growth or tumor) in mouth or tongue due to continuous irritation of nerve endings in the mouth.**

**2. Disease of esophagus, stomach and intestine.**

**3. Neurological disorders such as cerebral palsy(motor disability) , mental retardation , cerebral stroke and parkinsonism (CNS disorder include tremors dopamine levels low).**

**4. Some psychological and psychiatric conditions.**

**5. Nausea and vomiting.**

## OTHER DISORDERS

**In addition to hyposalivation and hypersalivation, salivary secretion is affected by other disorders also, which include:**

**1. Xerostomia 2. Drooling 3. Chorda tympani syndrome 4. Paralytic secretion of saliva 5. Augmented secretion of saliva 6. Mumps 7. Sjögren syndrome.**

### 1. *Xerostomia*

**Xerostomia means dry mouth. It is also called pasties or cotton mouth. It is due to hyposalivation or absence of salivary secretion (aptyalism).**

***Causes:***

**i. Dehydration or renal failure.**

**ii. Sjögren syndrome (see below).**

**iii. Radiotherapy.**

**iv. Trauma to salivary gland or their ducts.**

**v. Side effect of some drugs like antihistamines, antidepressants, monoamine oxidase inhibitors, antiparkinsonian drugs and antimuscarinic drugs.**

**vi. Shock.**

**vii. After smoking marijuana (psychoactive compound from the plant *Cannabis*).**

**Xerostomia causes difficulties in mastication, swallowing and speech. It also causes halitosis (bad breath; exhalation of unpleasant odors).**

**2. *Drooling:* Uncontrolled flow of saliva outside the mouth is called drooling. It is often called ptyalism.**

***Causes:***

**Drooling occurs because of excess production of saliva, in association with inability to retain saliva within the mouth. Drooling occurs in the following conditions: i.During teeth eruption in children ii.Upper respiratory tract infection or nasal allergies in children iii.Difficulty in swallowing iv. Tonsillitis v. Peritonsillar abscess.**

### 3. *Chorda Tympani Syndrome*

**Chorda tympani syndrome is the condition characterized by sweating while eating. During trauma or surgical procedure, some of the parasympathetic nerve fibers to salivary glands may be severed. During the regeneration, some of these nerve fibers, which run along with chorda tympani branch of facial nerve may deviate and join with the nerve fibers supplying sweat glands. When the food is placed in the mouth, salivary secretion is associated with sweat secretion.**

### 4. *Paralytic Secretion of Saliva*

**When the parasympathetic nerve to salivary gland is cut in experimental animals, salivary secretion increases for first three weeks and later diminishes; finally it stops at about sixth week. The increased secretion of saliva after cutting the parasympathetic nerve fibers is called paralytic secretion. It is because of hyperactivity of sympathetic nerve fibers to salivary glands after cutting the parasympathetic fibers. These hyperactive sympathetic fibers release large amount of catecholamines, which induce paralytic secretion. Moreover, the acinar cells of the salivary glands become hypersensitive to catecholamines after denervation. The paralytic secretion does not occur after the sympathetic nerve fibers to salivary glands are cut.**

### 5. *Augmented Secretion of Saliva*

**If the nerves supplying salivary glands are stimulated twice, the amount of saliva secreted by the second stimulus is more than the amount secreted by the first stimulus. It is because, the first stimulus increases excitability of acinar cells, so that when the second stimulus is applied, the salivary secretion is augmented.**

### 6. *Mumps*

**Mumps is the acute viral infection affecting the parotid glands. The virus causing this disease is paramyxovirus. It is common in children who are not immunized. It occurs in adults also. Features of mumps are puffiness of cheeks (due to swelling of parotid glands), fever, sore throat and weakness. Mumps affects meninges, gonads and pancreas also.**

### 7. *Sjögren Syndrome*

**Sjögren syndrome is an autoimmune disorder in which the immune cells destroy exocrine glands such as lacrimal glands and salivary glands. It is named after Henrik Sjögren who discovered it. Common symptoms of this syndrome are dryness of the mouth due to lack of saliva (xerostomia), persistent cough and dryness of eyes. In some cases, it causes dryness of skin, nose and vagina. In severe conditions, the organs like kidneys, lungs, liver, pancreas, thyroid, blood vessels and brain are affected.**

**LIVER :**

1. It is the largest gland in the body.
2. It is situated on right side of the abdominal cavity near diaphragm.
3. It is irregularly rectangular with rounded corners.
4. It is reddish brown in colour.
5. It is soft and pliable.
6. It weights about 3 - 5 kg in adult animals.
7. It consists of a body and two small lobes.
8. A pear shaped sac present near visceral surface of liver is called as gall bladder.
9. A gall bladder acts as a reservoir or store house of bile.
10. Bile duct carries bile from gall bladder to duodenum.

Functions : 1.It secretes bile which contains bile pigments and bile salts. 2. The bile salts help in emulsification and absorption of fats. 3. It plays important role in synthesis of plasma proteins like albumin, globulin, fibrinogen and prothrombin. 4. It helps in synthesis of tissue proteins. 5. It converts highly toxic ammonium salts into less toxic urea. 6. It helps in the synthesis and storage of glycogen. 7. It helps in the synthesis of fats from fatty acids and glycerols. 8. It stores minerals like Fe, Cu and Co. 9. It detoxifies toxins which have entered in blood circulation from digestive tract. 10. It helps in storage of fat soluble vitamins like Vit. A. D. E & K.

**Bile: required for digestion & absorption of fats & for the excretion of water insoluble substances (cholesterol and bilirubin**

**Regulation- It is formed by liver epithelial cells (hepatocytes) & epithelial cells lining the bile ducts.**

- **stored in the gallbladder during inter digestive period**
- **consists of electrolytes & water and controlled by secretin secreted by ductal cells having HCO3-**
- **Secretion is directly related to amount of bile**
- **reabsorbed by the hepatocytes.**
- **It is not under any direct hormonal or nervous control**

**Bile Composition:**

- **Synthesized from cholesterol & converted into bile salts by hepatocytes & at ileum they are absorbed actively**
- **Bilirubin & biliverdin are two principal bile pigments which are metabolites of hemoglobin formed in liver**
- **conjugated as glucoronides for excretion.**
- **Phospholipids are abundantly found in bile with Na & K, CL, Zn etc in small amounts & HCO3-.**

**Secretion and Regulation of Bile**

- Bile secretion involves two components
  1. *Bile salt dependent flow*
  2. *Bile salt independent flow*

***Bile Salt Dependent Flow***

- The formation and secretion of bile by liver is an active process, carried out by hepatocytes. Bile salts are secreted into canaliculi; presence of bile salts and $Na^+$ in canaliculi draws water by osmosis from the cell into bile.
- Substances that stimulate bile secretion are known as *cholerectics* and the most important cholerectic is bile salts themselves. The bile salts act directly on liver to increase secretion.
- Bile salts are synthesised by liver and secreted in bile. After entering the absorptive region of small intestine, they are reabsorbed into the portal blood and passed back to liver; the absorption of bile salts is active and occurs in ileum only. This recycling of bile salts is known as *entero-hepatic circulation* of bile salts. The reabsorbed bile salts reaches liver and they are the most potent stimulant to bile secretion.
- About 90% of bile salts are reabsorbed in ileum.

***Bile Salt Independent Flow***

- This phase involves ductular epithelium. $Na^+$ ions are actively transported from ductular cells into the lumen accompanied by $HCO_3^-$, $Cl^-$ and water. $HCO_3$ concentration in bile is higher than that blood.
- This phase is under the control of secretin and it results in $HCO_3^-$ rich secretion. Vagal stimulation also provokes bile secretion.

***Hormones Regulating Bile secretion***

- Secretin stimulates bile secretion. It increases $HCO_3^-$ secretion from the biliary duct cells. Acidic duodenal contents releases secretin and $HCO_3$ helps to neutralize the acidic content
- The CCK causes relaxation of sphincter of Oddi and contraction of gall bladder and also increases flow of bile.

**Functions of Bile Salts** (Functions of Bile)

- Due to the presence of bile salts, bile is useful in the digestion and absorption of nutrients in the following ways.
    1) It activates pancreatic lipase
    2) Assists in fat emulsification
    3) Increases solubility of higher fatty acids which are insoluble in water and aids in their absorption.
    4) Bile assists in absorption of fat-soluble vitamins

*Other functions of bile in the intestine*

5) It is a reservoir of alkali and thus assists in maintaining optimal reactions in intestine
6) Mucin and mucin-like substances of bile act as stabilisers of fat emulsion in intestine.
7) Bile has antiseptic properties and regulates bacterial growth in bowel. When bile does not enter the intestine, fat absorption is diminished and other constituents of food become coated with fat. Hence, their digestion is limited and proteins putrefy. Therefore, the faeces develop an offensive odour.
8) Bile has a mild laxative effect.

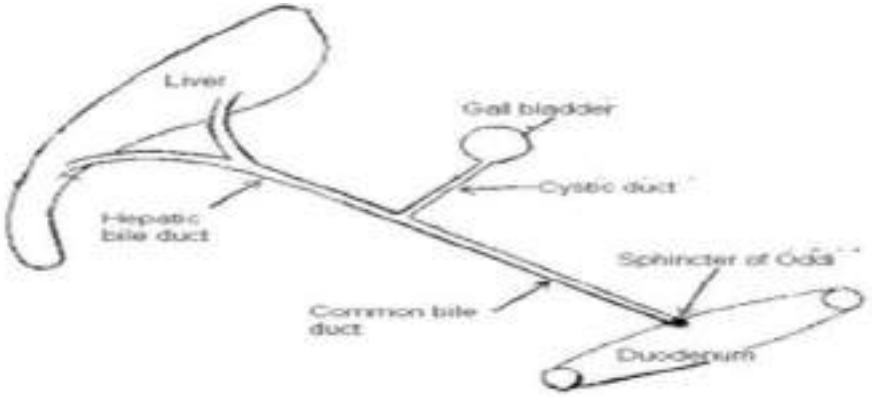
*Reactions in Intestine*

- Gastric juice is acidic in reaction. Duodenal juice, pancreatic juice, bile and intestinal juice are alkaline.
- pH at different regions of digestive tract

| Stomach | Duodenum | Jejunum | Ileum | Caecum | Large colon | Rectum |
|---|---|---|---|---|---|---|
| 2– 2.5 | 7– 7.4 | 7.5 | 7.55 | 7.24 | 7.09 | 6.24 |

## Gall Bladder

- Formation of bile is continuous but they are stored in gall bladder between periods of digestive activity and emptied from gall bladder during digestion.
- The concentrated bile is discharged into the duodenum by gall bladder contraction during digestion.
- Horse, rat, deer, mouse, giraffe, camel, elephant, pigeon and dove do not posses a gall bladder and flow of bile in these species is continuous.
- Gall bladder contraction is under the control of nerves and hormones.
- CCK secreted from the upper part of small intestine produces gall bladder contraction. When food enters duodenum, it causes release of CCK and bile enters duodenum.
- Once gall bladder is empty, bile flows directly into the duodenum and its secretion is maintained by enterohepatic circulation of bile salts.



## Anatomy of gall bladder

**Shape: pear shaped organ**

**Size: 8-12 cm length, lumen is 1-3 mm diameter**

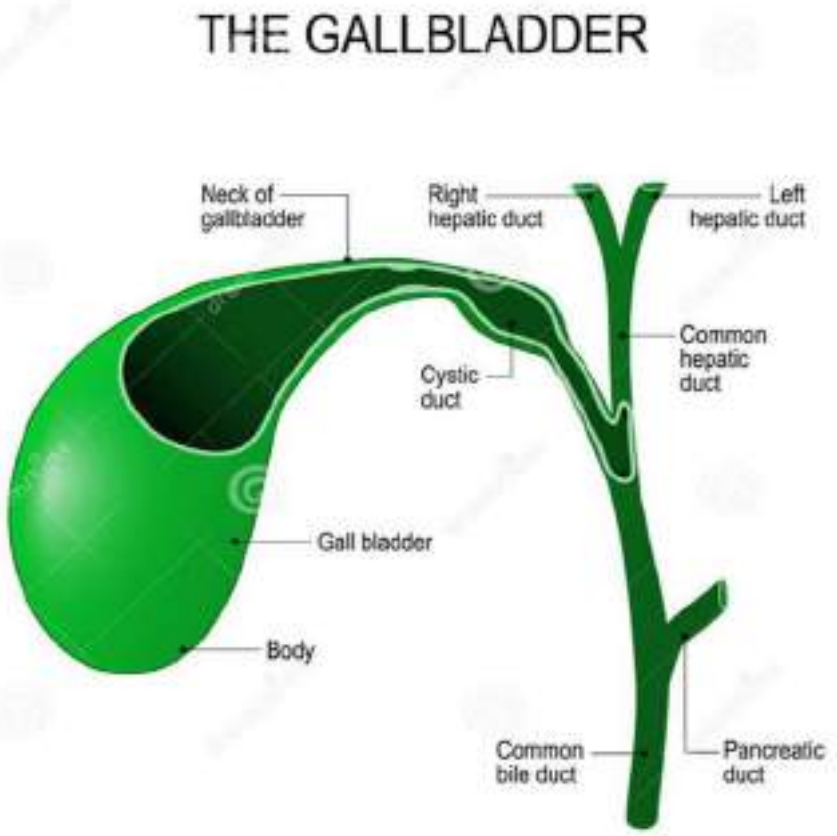
**Location: at the junction of the right and left lobes of the liver**

**Anatomical structure:**

**1) Fundus: dilated portion of GB attached to under surface of liver**

**2) Neck: the narrow, anugulated and distal portion of neck called as Hartmann ‘s Pouch.**

**3) Ducts: GB drains into common bile duct (CBD) through Cystic duct**



# Ducts of Gall Bladder

**1) Right and left hepatic ducts:**

**These are originating from the liver**

**2) Common heptic duct:**

- **The right and left hepatic duct**

**union to forms CHD**

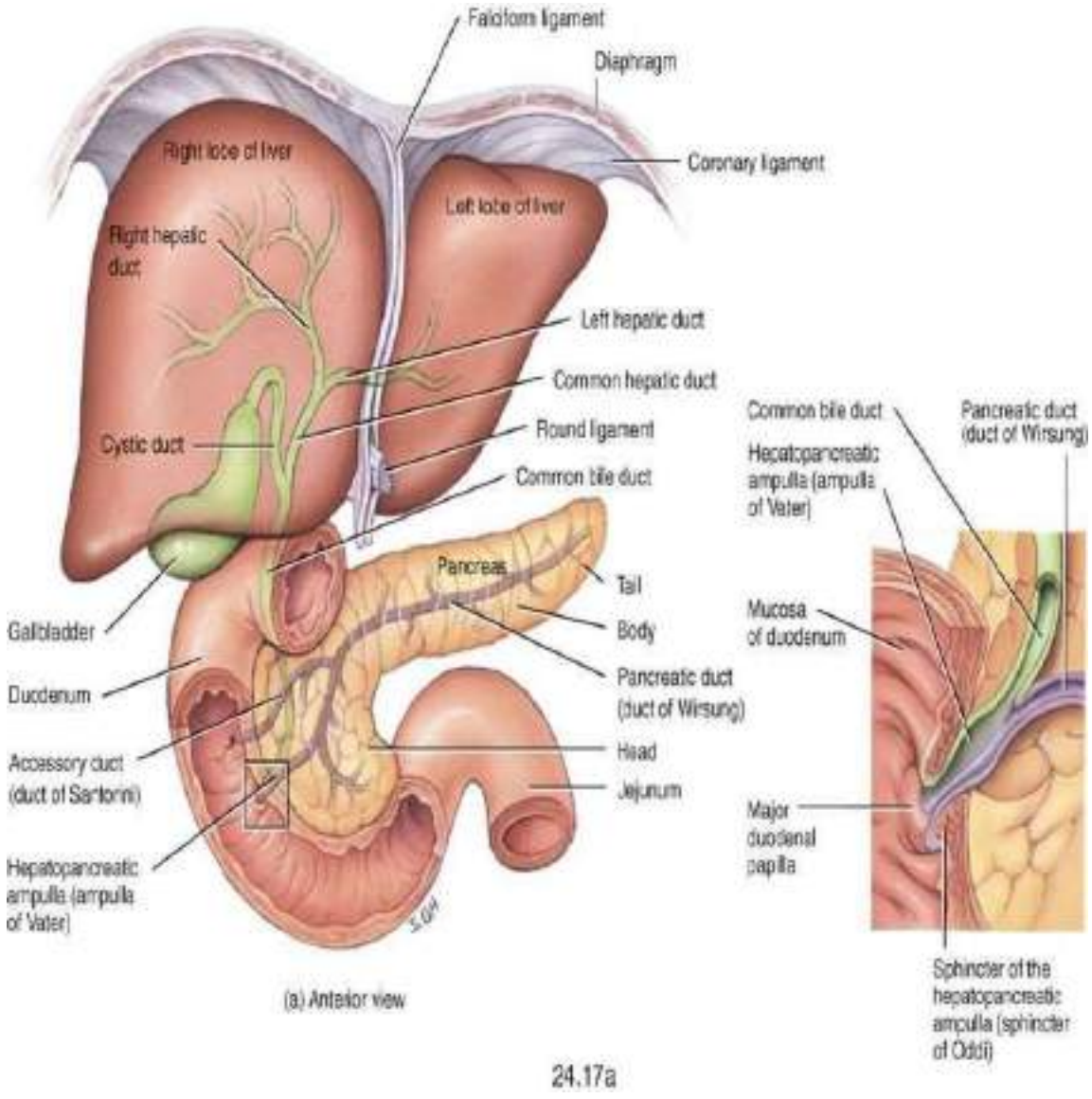
- **About 3 cm, recieves cystic duct and forms CBD**

**3) Common bile duct:**

**About 8cm length, has 4 parts**

- ❖ **Supraduodenal**
- ❖ **Retroduodenal**
- ❖ **Infraduodenal**
- ❖ **Intraduodenal**

- **Combines with pancreatic duct to from Hepatopancreatic ampulla (sphincter of Oddi)**



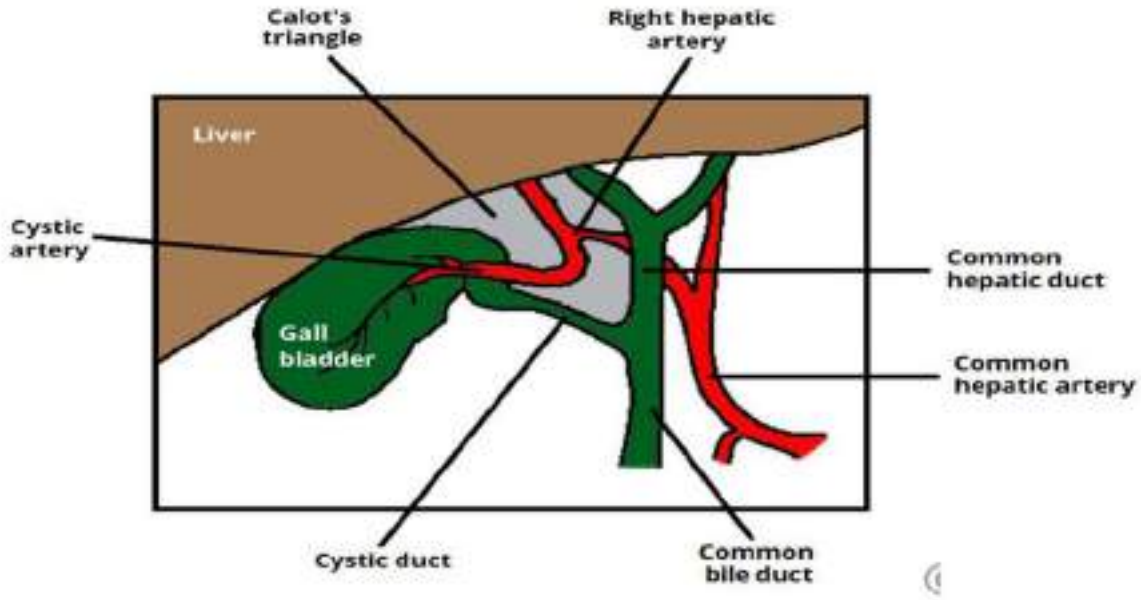
# Calot`s Triangle:

**It is important landmark to identify cystic duct and cystic artery during cholecystectomy.**

**Laterally : Cystic Duct and Gall Bladder**

**Medially : Common Heptic Duct**

**Above : Inferior surface of right lobe of Liver**



# Physiological functions of gall bladder

❖ **Functions of Gall Bladder:**

**1) Storage of bile:**

- **Bile is a mixture of mainly cholestrol,bilirubin and bile salts.**
- **Bile helps digestive system break down fats**
- **Bile: Secreted from hepatocytes of liver**

**Normal pH> 7.0**

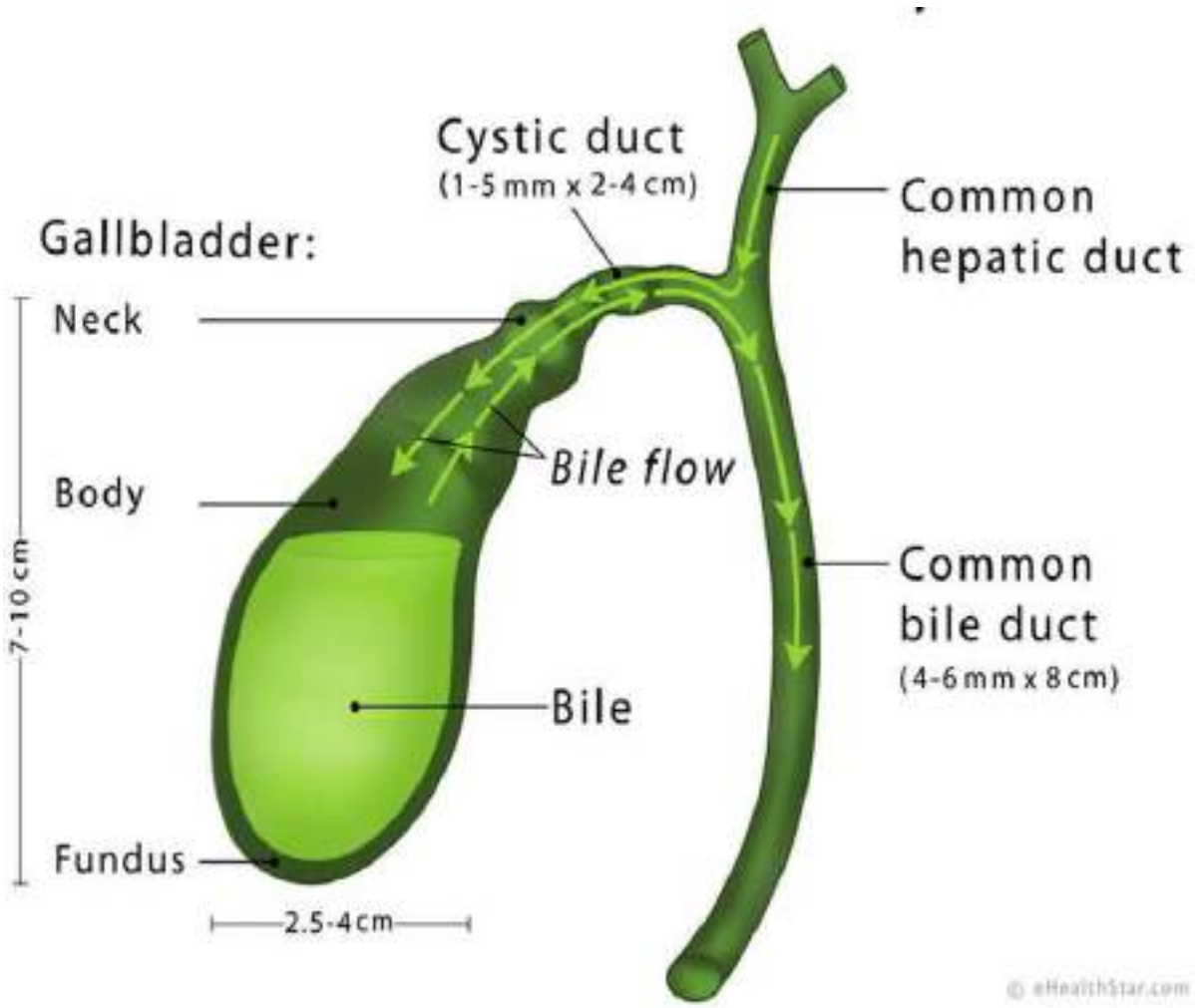
**Secretion-1/2 to 1 litre/day**

**2) Concentration of bile:**

- **Concentration form by active absorption of water, sodium chloride and bicarbonate with the help mucous membrane of the gall bladder**

**3) Mucus Secretion:**

- **approx 20mL per day**



***Jaundice*** is a condition in which there is excessive accumulation of bilirubin in tissues especially in fatty tissues and in visible mucous membrane imparting a yellowish colouration.

**Types of jaundice :**

**I.Obstructive Jaundice it is caused by blockage to flow of bile. E.g. due to gallstones, bile ducts are obstructed and conjugated bilirubin accumulates in blood.**

**II.Hepatic Jaundice is due to liver damage caused by disease or poison. In this condition, bilirubin is not conjugated and accumulates in tissues and blood as free bilirubin. In new-born animals, mild jaundice occurs during the first few days of life because liver is immature to excrete bilirubin (neonatal jaundice)**

**III.Haemolytic Jaundice occurs due to excessive production of bilirubin by RBC breakdown. Since excess haemoglobin is broken down, it exceeds liver's capacity to conjugate available bilirubin and so both free and conjugated bilirubin level increases in plasma. Occurs in hereditary diseases (sickle-cell anaemia), parasitic infections (babesiosis) incompatible antigen-antibody reaction (mismatched blood transfusion)**

- **Van den Bergh Test can be used to differentiate free and conjugated bilirubin and it is helpful to find out the type of jaundice.**

**PANCREAS :**

**I. It is flat and irregularly quadrilateral in shape.**

**2. It is located in the duodenal loop**

**3. It is reddish yellow in colour.**

**4. It weights about 300-500 gms.**

**5. It is endocrine as well as exocrine gland.**

**6. It is communicated with duodenum by pancreatic duct.**

**Functions :**

**1. The endocrine portion contains "Islets of Langerhans" 'Which produces hormones like insulin and glucagon.**

**2. The exocrine portion which secretes contains pancreatic juice which contains three digestive enzymes namely:**

**a) Trypsin : helps in digestion of protiens**

**b) Lipase : helps in digestion of fats / lipids**

**c) Amylase : helps in digestion of carbohydrates/ starch**

**Pancreatic secretions: Regulation- Pancreas secretion is divided into three phases**

- **Cephalic phase:- Thought, sight, smell or taste of food produces cephalic phase of pancreatic secretion. Enzyme secreted by acinar cells are stimulated by enteric neurons releases from ACh (vagal stimulation) $HCO_3^-$ secreted by ductal cells and stimulated by vagus nerves releases a noncholinergic & non-adrenergic transmitter**
- **Gastric phase:- enhanced during the distension & food breakdown products. Distension leads to secretion of $HCO_3$ & enzymes through ACh (Antrum & corpus). When food breakdown occurs G-cells of the antrum releases gastrin, produces a low volume & high enzyme pancreatic secretion**
- **Intestinal phase:- Major stimulants for pancreatic secretion are CCk & secretin. They are released from endocrine cells in the duodenum & jejunum. Both CCk & secretin along with potentiate secretion of $HCO_3^-$ & produce in significant amount**

**Pancreatic Composition-** secretion consists of electrolytes & enzymes

**Electrolytes:** $Na^{+}$ & $K^{+}$, $HCO_3^{-}$ & $H^{+}$ from the dissociation of $H_2CO_3$. It also contains small amounts of $Ca^{2+}$, $Mg^{2+}$, $Zn^{2+}$, $HPO_4^{2-}$ (mono-hydrogen phosphate) & $SO_4^{2-}$ (sulfate)

**Enzymes:** consists of α-amylase which hydrolyzes glycogen, starch to disaccharides except cellulose in carbohydrate.

- Water soluble esters can be hydrolyzed through pancreatic lipases. Trypsinogen & chymo-trypsinogen is converted to trypsin by enterokinase.

## DUODENAL SECRETION

- In the duodenum, a number of mucous glands known as *Brunner's glands* lie in the submucosa. Their ducts open into crypts. The Brunner's glands occupy only a short distance in carnivores and they extend over most of the duodenum in herbivores.
- The secretion of Brunner's glands is thick, clear mucous fluid with a pH between 7 and 8 has a high $HCO_3$ content and possesses enzymic activities.
- Secretion of duodenal glands is known as *duodenal juice*.
- It contains enzymes amylase, lipase, sucrase and lactase.
- Secretin and vagal stimulation increases secretion.

The duodenal juice helps to neutralise the acidic gastric contents as they enter duodenum and thus protects the duodenal mucosa from acid contents.

## INTESTINAL SECRETION

- The small intestine is composed of four layers – outer serosal, muscular, submucosa and the innermost mucosal layer.
- Mucosa is the functional layer where digestion and absorption occurs.
- The mucosa of the small intestine is thrown into many circular folds called *plica circulares*
- The surface epithelium of the mucosa projects from the *surface* into the lumen of intestine and these are called as *villi*;
- The luminal surface of the intestinal epithalial cells exhibits numerous microvilli called *brush border*
- Located over the entire surface of the small intestine between the villi are small pits called *crypts of Lieberkuhn* and they are the proper intestinal glands.
- The intestinal glands contain *goblet cells* (secrete mucus and $HCO_3$), *enteroendocrine cells* (produce many types of chemical messengers) and large *paneth cells* (produce enzymes including enterokinase).
- The cells of the crypts secrete fluid and enzymes which form the intestinal juice or *succus entericus*.
- The surface of the villi is lined by tall columnar epithelial cells called *enterocytes* which are the absorptive cells.

### Regulation of Intestinal Secretion

- Mechanical stimulation of intestinal mucous membrane by the digesta causes secretion of intestinal juice and it is the most important stimulus for intestinal secretion.
- Nervous regulation is limited and not clear. Vagal stimulation increases duodenal secretion and sympathetic stimulation inhibits secretion.

| Digestive enzymes | | | |
|---|---|---|---|
| *Enzyme* | *Source* | *Substrate* | *Products* |
| Saliva | | | |
| Salivary amylase | Salivary glands | Starch and glycogen | Maltose (disaccharide), maltotriose (trisaccharide), and a-dextrins |
| Lingual lipase | Gland in the tongue | Triglycerides and other lipids | Fatty acids and diglycerides |
| Gastric secretions | | | |
| Pepsin | Chief cells | Proteins | Peptides |
| Gastric lipase | Chief cells | Short-chain triglycerides | Fatty acids and monoglycerides |
| Renin | Chief cells | Milk casein | Coagulation of milk casein |
| Pancreatic Secretions | | | |
| Trypsin | Pancreatic acinar cells | Proteins, chymotrypsinogen, procarboxypeptidase | Peptides |
| Chymotrypsin | Pancreatic acinar cells | Proteins | Peptides |
| Elastase | Pancreatic acinar cells | Proteins | Peptides |
| Carboxypeptidase | Pancreatic acinar cells | Terminal amino acid at carboxyl end of peptides | Peptides and amino acids |
| Pancreatic lipase | Pancreatic acinar cells | Triglycerides | Fatty acids and monoglycerides |
| Ribonuclease | Pancreatic acinar cells | Ribonucleic acid | Nucleotides |
| Deoxyribonuclease | Pancreatic acinar cells | Deoxyribonucleic acid | Nucleotides |
| Brush Border Enzymes | | | |
| a-dextrinase | Plasma membrane of microvilli | a-dextrins | Glucose |
| Maltase | Plasma membrane of microvilli | Maltose | Glucose |
| Sucrase | Plasma membrane of microvilli | Sucrose | Glucose and fructose |
| Lactase | Plasma membrane of microvilli | Lactose | Glucose and galactose |
| Enterokinase | Plasma membrane of microvilli | Trypsinogen | Trypsin |
| Aminopeptidase | Plasma membrane of microvilli | Terminal amino acid at amino end of proteins | Peptides and amino acids |
| Dipeptidase | Plasma membrane of microvilli | Dipeptides | Amino acids |
| Nucleosidase | Plasma membrane of microvilli | Nucleotides | Nitogenous bases, pentoses, and phosphates |
| Phosphatase | Plasma membrane of microvilli | Nucleotides | Phosphate ions |

## ii. DIGESTIVE SYSTEM OF NON-RUMINANTS

**The digestive system of non-ruminants is very simple and it differs from ruminants mainly in the structure of stomach and to some extent in the large intestine.**

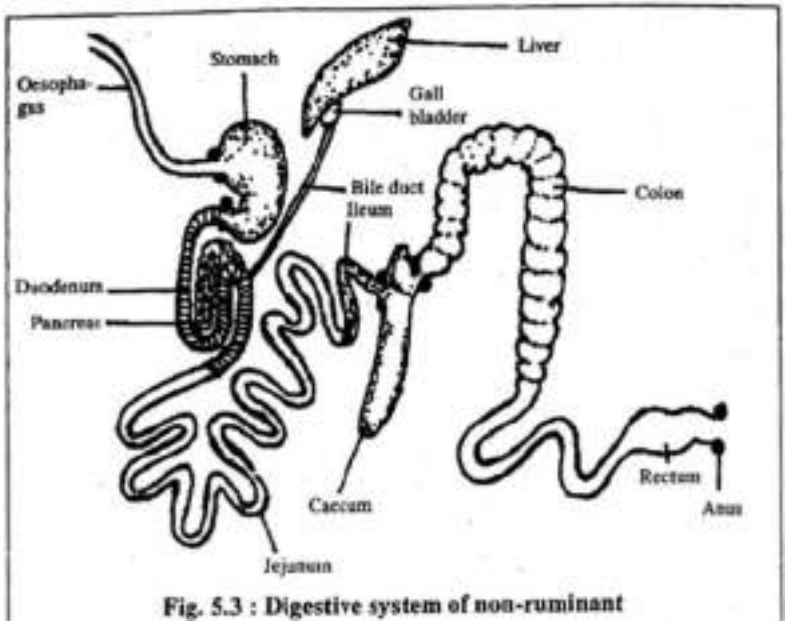


Fig. 5.3 : Digestive system of non-ruminant

### SIMPLE STOMACH

1. **It is located just behind the left side of the diaphragm.**
2. **It is divided into three regions i.e. cardiac, fundic and pyloric.**
3. **The cardic region is close to the oesophageal region.**
4. **The body of the stomach is called as "fundic region"**
5. **The caudal part of the stomach is called as "pyloric region"**
6. **The cardiac and pyloric sphincters separate the stomach from oesophagus and duodenum respectively.**

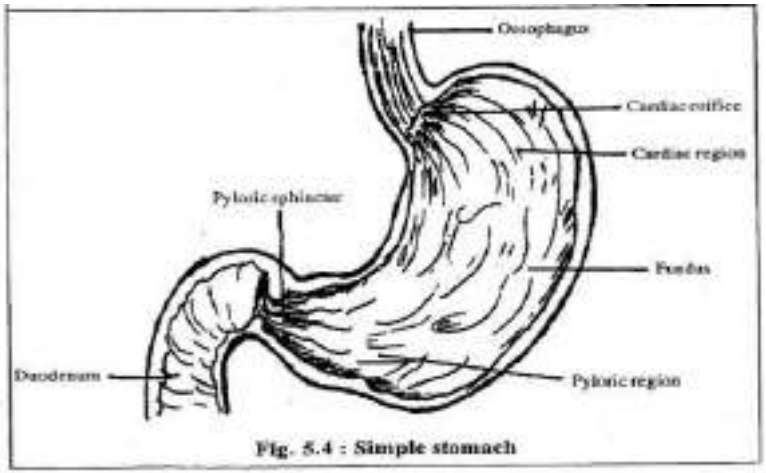


Fig. 5.4 : Simple stomach

**Function :**

**It secretes gastric juice which contains hydrochloric acid, and renin.**

...which contains hydrochloric acid, pepsin and renin.

**Table 5.1 : Difference between Ruminants and Non - Ruminants**

| Ruminants | Non-Ruminants |
|---|---|
| 1. They possess ruminant or compound stomach. | 1. They possess simple stomach |
| 2. Stomach is four chambered | 2. Stomach is single chambered |
| 3. Capacity of stomach is high | 3. Capacity of stomach is less |
| 4. Rumination takes place | 4. No rumination |
| 5. They ingest large quantity of food | 5. They ingest small quantity of food |
| 6. Microbial digestion is major | 6. Microbial digestion is minor |
| 7. Enzymatic digestion is minor | 7. Enzymatic digestion is major |
| 8. Maximum digestion & absorption of food takes place in rumen. | 8. Maximum digestion and absorption of food takes place in intestine. |
| 9. They can synthesize high quality proteins with the help of rumen microbes. | 9. They can not |
| 10. They can utilise non-protein nitrogenous (NPN) substances for protein synthesis. | 10. They can not |
| 11. They can digest cellulose. | 11. They can not |
| 12. End product of carbohydrate digestion is volatile fatty acids (VFA) | 12. End product is glucose |
| 13. Major carbohydrate digestion in rumen | 13. Carbohydrate digestion takes place in intestine. |
| 14. Major lipid digestion takes place in rumen | 14. Lipid digestion takes place in intestine. |
| 15. *e.g.*, Cattle, Buffalo, Sheep, Goat. | 15. *e.g.*, Dog, Pig, Man, Horse. |

**PARTS OF STOMACH:** In monogastric, stomach has four parts: 1. Cardiac region 2. Fundus 3. Body or corpus 4. Pyloric region. **1. *Cardiac Region:*** Cardiac region is the upper part of the stomach where esophagus opens. The opening is guarded by a sphincter called **cardiac sphincter,** which opens only towards stomach. This portion is also known as **cardiac end.** **2. *Fundus:*** Fundus is a small dome shaped structure. It is elevated above the level of esophageal opening. **3. *Body or Corpus:*** Body is the largest part of stomach forming about 75% to 80% of the whole stomach. It extends from just below the fundus up to the pyloric region. **4. *Pyloric Region:*** Pyloric region has two parts, antrum and pyloric canal.The body of stomach ends in **antrum.** Junction between body and antrum is marked by an angular notch called **incisura angularis.** Antrum is continued as the narrow canal, which is called **pyloric canal** or pyloric end. Pyloric canal opens into first part of small intestine called duodenum.The opening of pyloric canal is guarded by a sphincter called pyloric sphincter. It opens towards duodenum. Stomach has two curvatures. One on the right side is **lesser curvature** and the other on left side is **greater curvature.**

- **STRUCTURE OF STOMACH WALL:** Stomach wall is formed by four layers of structures: 1. *Outer serous layer:* Formed by **peritoneum** 2. *Muscular layer:* Made up of three layers of smooth muscle fibers, namely inner oblique, middle circular and outer longitudinal layers 3. *Submucus layer:* Formed by areolar tissue, blood vessels, lymph vessels and **Meissner nerve plexus.** 4. *Inner mucus layer:* Lined by mucus secreting columnar epithelial cells. The gastric glands are situated in this layer. Under resting conditions, the mucosa of the stomach is thrown into many folds. These folds are called rugae. The rugae disappear when the stomach is distended after meals. Throughout the inner mucus layer, small depressions called **gastric pits** are present. Glands of the stomach open into these pits. Inner surface of mucus layer is covered by 2 mm thick mucus.

## GLANDS OF STOMACH –

**GASTRIC GLANDS-** Glands of the stomach or gastric glands are tubular structures made up of different types of cells. These glands open into the stomach cavity via **gastric pits.**

**CLASSIFICATION OF GLANDS OF THE STOMACH:** Gastric glands are classified into three types, on the basis of their location in the stomach: 1.*Fundic glands or main gastric glands or oxyntic glands:* Situated in body and fundus of stomach 2. *Pyloric glands:* Present in the pyloric part of the stomach 3. *Cardiac glands:* Located in the cardiac region of the stomach.

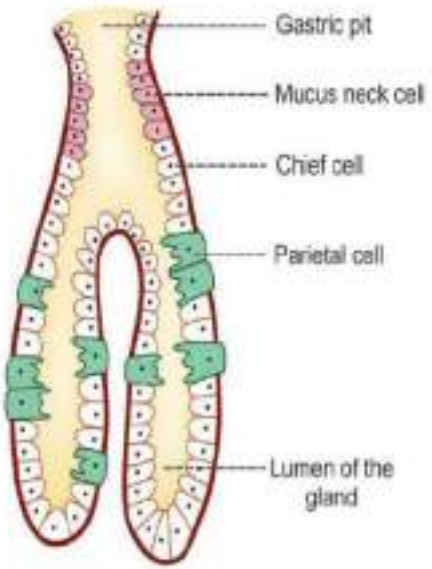


FIGURE 38.2: Gastric glands

## STRUCTURE OF GASTRIC GLANDS

**1. *Fundic Glands:*** Fundic glands are considered as the typical gastric glands (Fig. 38.2). These glands are long and tubular. Each gland has three parts, viz. body, neck and isthmus. *Cells of fundic glands* 1.Chief cells or pepsinogen cells 2. Parietal cells or oxyntic cells 3.Mucus neck cells 4.Enterochromaffin (EC) cells or Kulchitsky cells 5.Enterochromaffinlike (ECL) cells. Parietal cells are different from other cells of the gland because of the presence of **canaliculi** (singular = canaliculus). Parietal cells empty their secretions into the lumen of the gland through the canaliculi. But, other cells empty their secretions directly into lumen of the gland.

**2. *Pyloric Glands:*** **Pyloric glands are short and tortuous in nature. These glands are formed by G cells, mucus cells, EC cells and ECL cells.**

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

***Enteroendocrine Cells:*** **Enteroendocrine cells are the hormonesecreting cells present in the glands or mucosa of gastrointestinal tract, particularly stomach and intestine. The enteroendocrine cells present in gastric glands are G cells, EC cells and ECL cells (Table 38.1).**

**FUNCTIONS OF GASTRIC GLANDS: Function of the gastric gland is to secrete gastric juice. Secretory activities of different cells of gastric glands and enteroendocrine cells**

## FUNCTIONS OF STOMACH :

### 1.MECHANICAL FUNCTION

#### i. *Storage Function*

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

#### ii. *Formation of Chyme*

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

**2. DIGESTIVE FUNCTION:** Refer functions of gastric juice.

**3. PROTECTIVE FUNCTION:** Refer functions of gastric juice.

**4. HEMOPOIETIC FUNCTION:** Refer functions of gastric juice.

**5. EXCRETORY FUNCTION:** Many substances like toxins, alkaloids and metals are excreted through gastric juice.

**TABLE 38.1: Secretory function of cells in gastric glands**

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

## PROPERTIES AND COMPOSITION OF GASTRIC JUICE

Gastric juice is a mixture of secretions from different gastric glands.

**PROPERTIES OF GASTRIC JUICE:** Volume : 1200 mL/day to 1500 mL/day.

Reaction : Gastric juice is highly acidic with a pH of 0.9 to 1.2. Acidity of gastric juice is due to the presence of hydrochloric acid.

Specific gravity : 1.002 to 1.004

**COMPOSITION OF GASTRIC JUICE:** Gastric juice contains 99.5% of water and 0.5% solids. Solids are organic and inorganic substances.

## FUNCTIONS OF GASTRIC JUICE

### 1. DIGESTIVE FUNCTION

Gastric juice acts mainly on proteins. Proteolytic enzymes of the gastric juice are pepsin and rennin (Table 38.2). Gastric juice also contains some other enzymes like gastric lipase, gelatinase, urase and gastric amylase.

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

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

***Gastric Lipase:*** **Gastric lipase is a weak lipolytic enzyme when compared to pancreatic lipase. It is active only when the pH is between 4 and 5 and becomes inactive at a pH below 2.5. Gastric lipase is a tributyrase and it hydrolyzes tributyrin (butter fat) into fatty acids and glycerols.**

***Actions of Other Enzymes of Gastric Juice:*** **i.Gelatinase: Degrades type I and type V gela tin and type IV and V collagen (which are proteoglycans in meat) into peptides. ii. Urase: Acts on urea and produces ammonia iii. Gastric amylase: Degrades starch (but its action is insignificant) iv. Rennin: Curdles milk (present in animals only)**

**2.HEMOPOIETIC FUNCTION : Intrinsic factor of Castle, secreted by parietal cells of gastric glands plays an important role in erythropoiesis. It is necessary for the absorption of vitamin B12 (which is called extrinsic factor) from GI tract into the blood. Vitamin B12 is an important maturation factor during erythropoiesis. Absence of intrinsic factor in gastric juice causes deficiency of vitamin B12, leading to pernicious anemia (Chapter 14).**

**3.PROTECTIVE FUNCTION –FUNCTION OF MUCUS: Mucus is a mucoprotein, secreted by mucus neck cells of the gastric glands and surface mucus cells in fundus, body and other parts of stomach. It protects the gastric wall by the following ways:**

***Mucus:*** **i.Protects the stomach wall from irritation or mechanical injury, by virtue of its high viscosity.**

**ii. Prevents the digestive action of pepsin on the wall of the stomach, particularly gastric mucosa.**

**iii. Protects the gastric mucosa from hydrochloric acid of gastric juice because of its alkaline nature and its acidcombining power.**

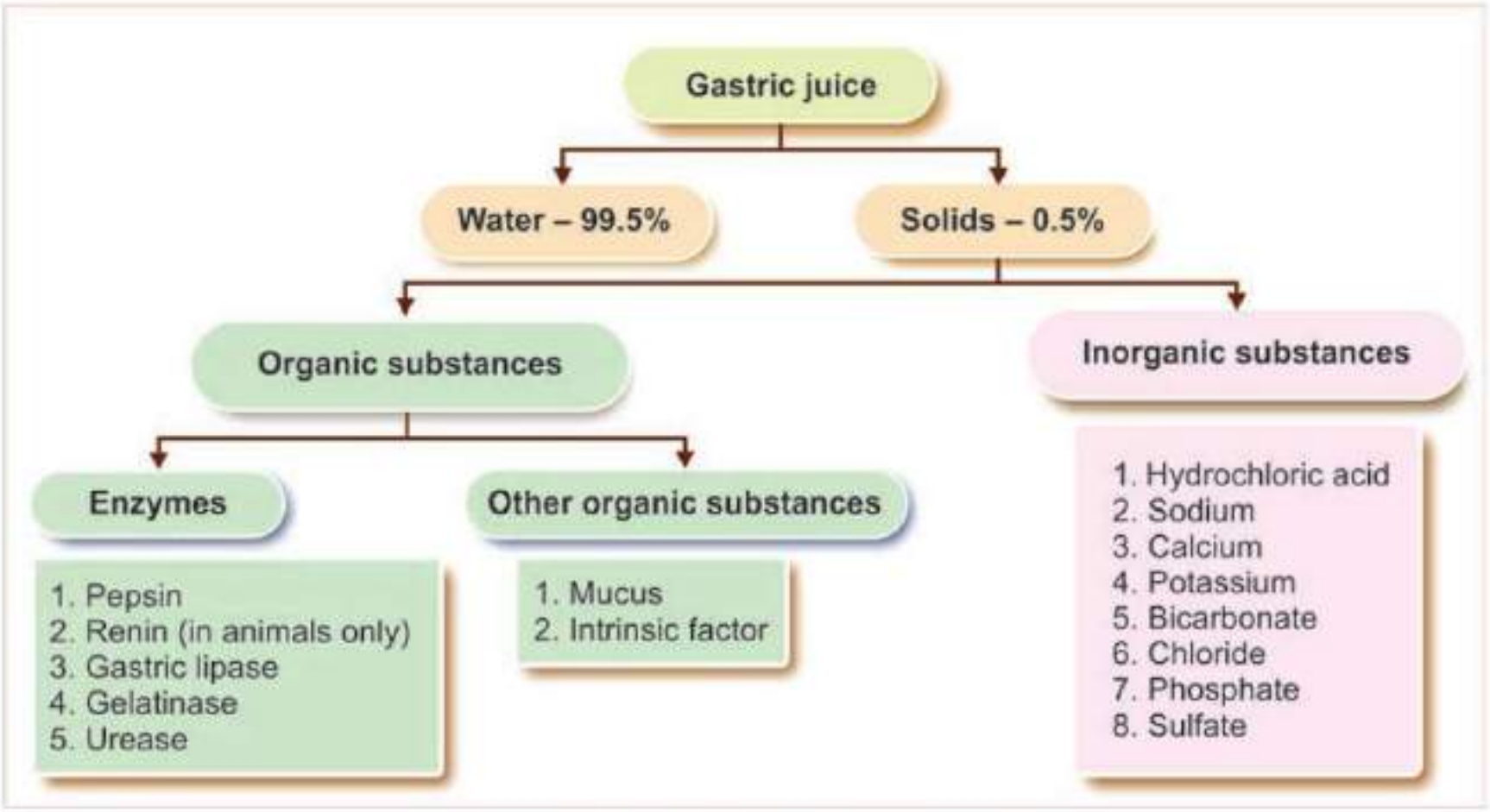



**FIGURE 38.3:** Composition of gastric juice

**4. FUNCTIONS OF HYDROCHLORIC ACID:** Hydrochloric acid is present in the gastric juice: i. Activates pepsinogen into pepsin ii. Kills some of the bacteria entering the stomach along with food substances. This action is called bacteriolytic action iii. Provides acid medium, which is necessary for the action of hormones.

## SECRETION OF GASTRIC JUICE

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

## SECRETION OF HYDROCHLORIC ACID

According to **Davenport theory,** hydrochloric acid secretion is an active process that takes place in the canaliculi of parietal cells in gastric glands. The energy for this process is derived from oxidation of glucose. Carbon dioxide is derived from metabolic activities of parietal cell. Some amount of carbon dioxide is obtained from blood also. It combines with water to form **carbonic acid** in the presence of **carbonic anhydrase.** This enzyme is present in high concentration in parietal cells. Carbonic acid is the most unstable compound and immediately splits into hydrogen ion and bicarbonate ion. The hydrogen ion is actively pumped into the canaliculus of parietal cell. Simultaneously, the chloride ion is also pumped into canaliculus actively. The chloride is derived from sodium chloride in the blood. Now, the hydrogen ion combines with chloride ion to form hydrochloric acid. To compensate the loss of chloride ion, the bicarbonate ion from parietal cell enters the blood and combines with sodium to form sodium bicarbonate. Thus, the entire process is summarized as (Fig. 38.4):

$CO_2 + H_2O + NaCl \rightarrow HCl + NaHCO_3$

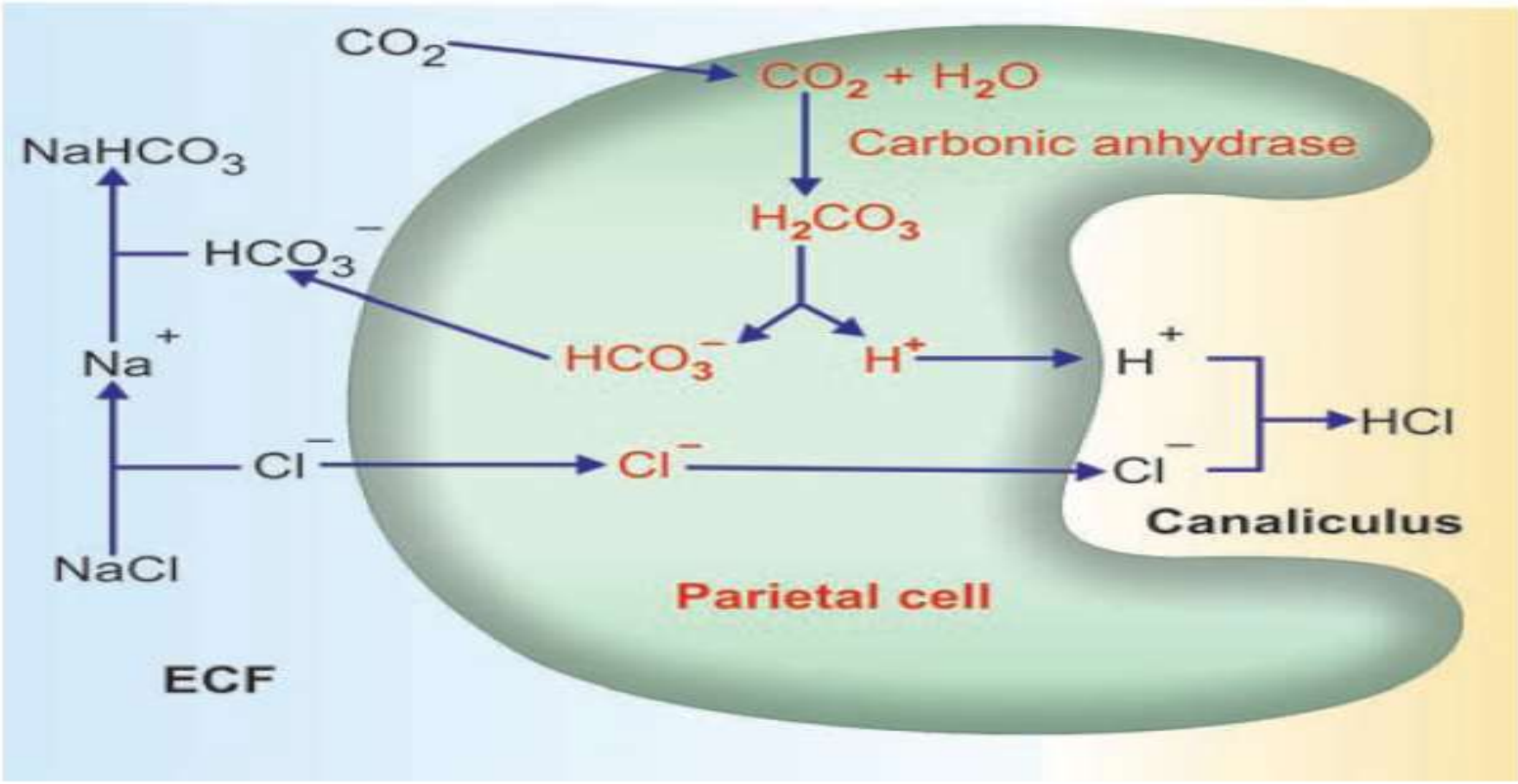



**FIGURE 38.4:** Secretion of hydrochloric acid in the parietal cell of gastric gland

***Factors Stimulating the Secretion of Hydrochloric Acid*** 1. Gastrin 2. Histamine 3. Vagal stimulation.

***Factors Inhibiting the Secretion of Hydrochloric Acid*** 1. Secretin 2. Gastric inhibitory polypeptide 3. Peptide YY.

## REGULATION OF GASTRIC SECRETION

Regulation of gastric secretion and intestinal secretion is studied by some experimental procedures.

## METHODS OF STUDY

**1. *Pavlov Pouch:*** Pavlov pouch is a small part of the stomach that is incompletely separated from the main portion and made into a small baglike pouch (Fig. 38.5). Pavlov pouch was designed by the Russian scientist Pavlov, in a dog during his studies on conditioned reflexes.

*Procedure:* To prepare a Pavlov pouch, stomach of an anesthetized dog is divided into a larger part and a smaller part by making an incomplete incision. The mucus membrane is completely divided. A small part of muscular coat called **isthmus** is retained. Isthmus connects the two parts.

The cut edges of major portions are stitched. Smaller part is also stitched, leaving a small outlet. This outlet is brought out through the abdominal wall and used to drain the pouch.

*Nerve supply of Pavlov pouch :* Pavlov pouch receives parasympathetic (vagus) nerve fibers through isthmus and sympathetic fibers through blood vessels.

*Use of Pavlov pouch:* Pavlov pouch is used to demonstrate the different phases of gastric secretion, particularly the cephalic phase and used to demonstrate the role of vagus in cephalic phase.

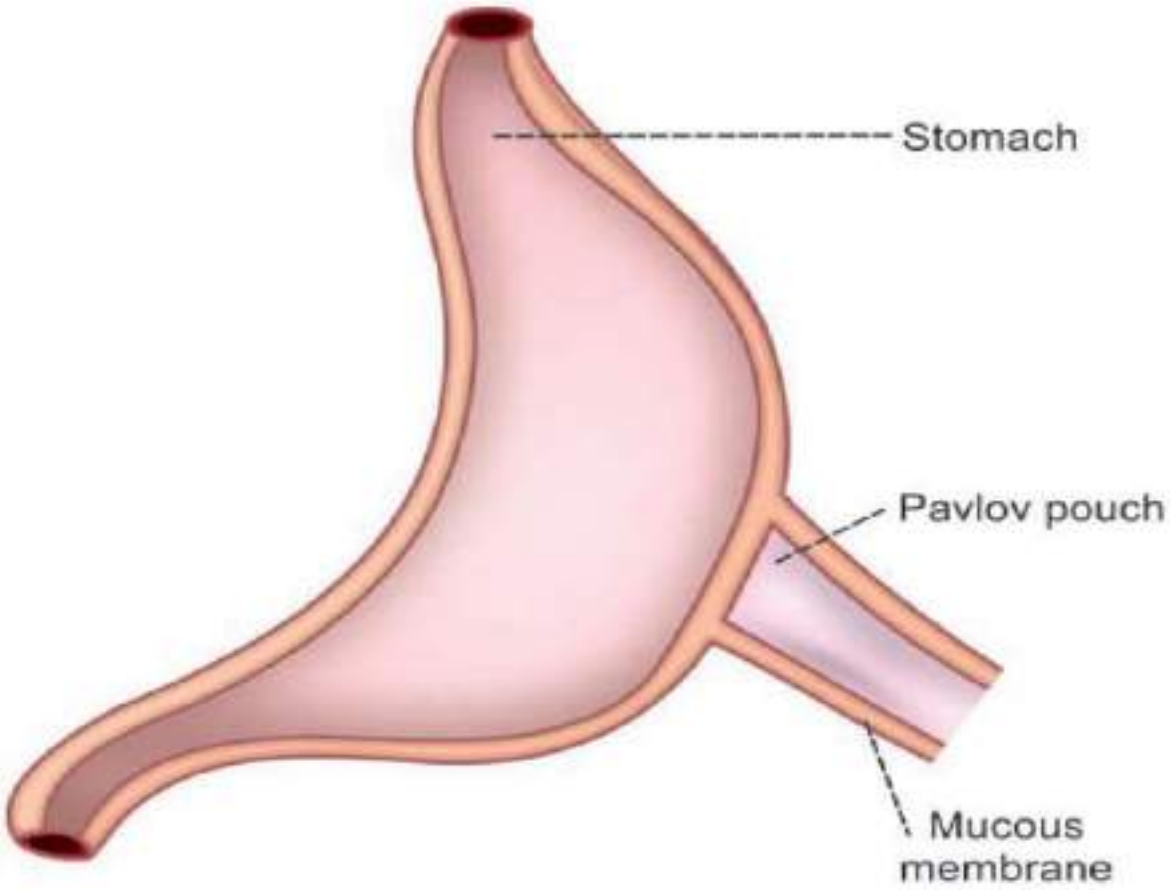



**FIGURE 38.5:** Pavlov pouch

**2. *Heidenhain Pouch:*** Heidenhain pouch is the modified Pavlov pouch. It is completely separated from main portion of stomach by cutting the isthmus without damaging blood vessels. So, the blood vessels are intact. Thus, Heidenhain pouch does not have parasympathetic supply, but the sympathetic fibers remain intact through the blood vessels.

*Uses of Heidenhain pouch:* Heidenhain pouch is useful to demonstrate the role of sympathetic nerve and the hormonal regulation of gastric secretion after vagotomy (cutting the vagus nerve).

**3. *Bickel Pouch:*** In this, even the sympathetic nerve fibers are cut by removing the blood vessels. So, Bickel pouch is a totally denervated pouch.

*Uses of Bickel pouch*

- Bickel pouch is used to demonstrate the role of hormones in gastric secretion.

**4. *Farrel and Ivy Pouch:*** Farrel and Ivy pouch is prepared by completely removing the Bickel pouch from the stomach and transplanting it in the subcutaneous tissue of abdominal wall or thoracic wall in the same animal. New blood vessels develop after some days. It is used for experimental purpose, when the new blood vessels are developed.

*Uses of Farrel and Ivy pouch*

- This pouch is useful to study the role of hormones during gastric and intestinal phases of gastric secretion.

***5. Sham Feeding:*** Sham feeding means the false feeding. It is another experimental procedure devised by Pavlov to demonstrate the regulation of gastric secretion.

*Procedure:*

i. A hole is made in the neck of an anesthetized dog

ii. Esophagus is transversely cut and the cut ends are drawn out through the hole in the neck

iii. When the dog eats food, it comes out through the cut end of the esophagus

iv. But the dog has the satisfaction of eating the food. Hence it is called sham feeding.

This experimental procedure is supported by the preparation of Pavlov pouch with a **fistula** from the stomach. The fistula opens to exterior and it is used to observe the gastric secretion. The animal is used for experimental purpose after a week, when healing is completed.

*Advantage of sham feeding*

- Sham feeding is useful to demonstrate the secretion of gastric juice during cephalic phase. In the same animal after **vagotomy,** sham feeding does not induce gastric secretion. It proves the role of vagus nerve during cephalic phase.

## INTERDIGESTIVE PHASE

- Secretion of small amount of gastric juice in between meals (or during period of fasting) is called interdigestive phase. Gastric secretion during this phase is mainly due to the hormones like gastrin. This phase of gastric secretion is demonstrated by Farrel and Ivy pouch.

## FACTORS INFLUENCING GASTRIC SECRETION

- Gastric secretion is also influenced by some factors which increase the gastric secretion by stimulating gastric mucosa such as: 1. Alcohol 2. Caffeine.

**GASTRIC ANALYSIS:** For analysis, the gastric juice is collected from patient only in the morning. Analysis of the gastric juice is done for the diagnosis of ulcer and other disorders of stomach.

Gastric juice is analyzed for the following:

1. Measurement of peptic activity

2. Measurement of gastric acidity: Total acid, free acid (hydrochloric acid) and combined acid.

## PHASES OF GASTRIC SECRETION

Secretion of gastric juice is a continuous process. But the quantity varies, depending upon time and stimulus. Accordingly, gastric secretion occurs in three different phases: I. Cephalic phase II. Gastric phase III. Intestinal phase. In human beings, a fourth phase called **interdigestive phase** exists. Each phase is regulated by neural mechanism or hormonal mechanism or both.

**Cephalic Phase**

- Stimulation of sensory nerve endings in mouth and pharynx or anticipation of eating can evoke this phase of secretion. Presence of food in the stomach is not necessary for initiation of secretion.

**Gastric Phase**

- When food enters the stomach, there is more copious secretion of gastric juice; this constitutes the gastric phase of secretary response.
- Gastric phase is caused by at least two kinds of stimuli.

(1) Mechanical stimuli

(2) Humoral or hormonal stimuli

***Mechanical Stimulation***

- When food or even inert substances come in contact with the stomach mucous membrane, flow of gastric juice is set up.
- Distension of the stomach stimulates the intrinsic nerves which releases Ach; the Ach stimulate the G cells and parietal cells. The G cells by producing gastrin further stimulate the parietal cells to release HCl.

***Hormonal Stimulation***

- *Gastrin*, a protein hormone produced by the 'G' cells of the pyloric glands stimulates the gastric acid secretion.
- *Gastrin* is also released in small amounts from the fundus, duodenum and small intestine.
- Peptides released by proteolysis stimulate the G cells to release gastrin.
- Gastrin is also released by vagal stimulation that occurs during anticipation of eating and distension of stomach
- Gastrin increase HCl secretion.
- *Histamine* is another powerful stimulator of gastric acid secretion,
- Histamine acts through $H_2$ receptors and it is present in the gastric mucosa.
- Acetylcholine produced by parasympathetic nerve endings also stimulates the parietal cells
- Vagus nerve can potentiate gastrin release and condition the parietal cells for the action of gastrin.

**Intestinal Phase**

- Addition of food to the intestine through a fistula will excite gastric secretion and this is due to a humoral mechanism involved in the intestinal phase of secretion. This may be due to entry of intestinal gastrin and pancreatic peptide (PP) from duodenum during digestion of food into the blood stream and stimulating the gastric glands to activity.
- *Relative importance of the three phases*: Cephalic phase accounts for 45% of total daily secretion, gastric phase -another 45% and intestinal phase for 10% or less.

**Gastric Mucosal barrier**

- The gastric juice is highly acidic and can cause tissue damage. But this damage does not happen in the stomach because of mucosal barrier contributed by mucus and $HCO_3$.
- The gastric mucus is continuously produced from cardiac and pyloric glands and neck chief cells of fundic glands and surface epithelium of stomach.
- Gastric ulcers are produced by a special type of bacteria – *Helicobacter pylori,* alcohol, certain anti-inflammatory substances like NSAIDS (aspirin)
- Ulcers can occur in many domestic animals and very common in dogs
- Ulcers occur both in stomach and duodenum.
- Anti histamine drugs (H2 blockers) greatly reduce H production and helps in healing of ulcers

**HUNGER:**

- The adult animal and man maintain their body weight within relatively narrow limits, despite variations in energy expenditure. So food intake is adapted to calorie expenditure. Even a small increase in food intake greatly increases body weight.
- Animals can adapt to variable environmental conditions by adjusting their food intake.
- Two centres in the hypothalamus are involved in regulating feed intake
- Stimulation of *appetite centre* (*hunger centre*) located on the ventro-lateral part of hypothalamus causes an animal to search for food and eat it voraciously. This centre tells an animal when to eat.
- Stimulation of *satiety centre* in the ventro-medial hypothalamus makes an animal to stop eating. This centre makes an animal when to stop eating; in other words how much to eat and it prevents overeating
- Fullness of stomach and duodenum after a meal stimulates stretch-sensitive neurons which transmit impulses through vagi to the satiety centre which in turn stops eating. Some hormones released during eating and when the stomach is full are also involved in stimulating the satiety centre
- There are many theories that try to explain the regulation of food intake. Three important ones are
    - *Glucostatic theory* – availability of glucose at hypothalamus determines food intake – increase in blood glucose reaching hypothalamus after a meal stimulates satiety centre
    - *CCK theory* – CCK released in response to increased concentration of peptides and fatty acids in the small intestine stimulates satiety centre
    - *Lipostatic theory* – increase in adipose tissue of the body releases a hormone *leptin* from adipose cells which in turn stimulates the satiety centre; this is involved in long-term regulation of feed intake
- The feeling of hunger pangs in man is accompanied by marked rhythmic contractions of the stomach and is termed as *hunger contractions*.
- Hunger contractions are observed in fasted dogs.

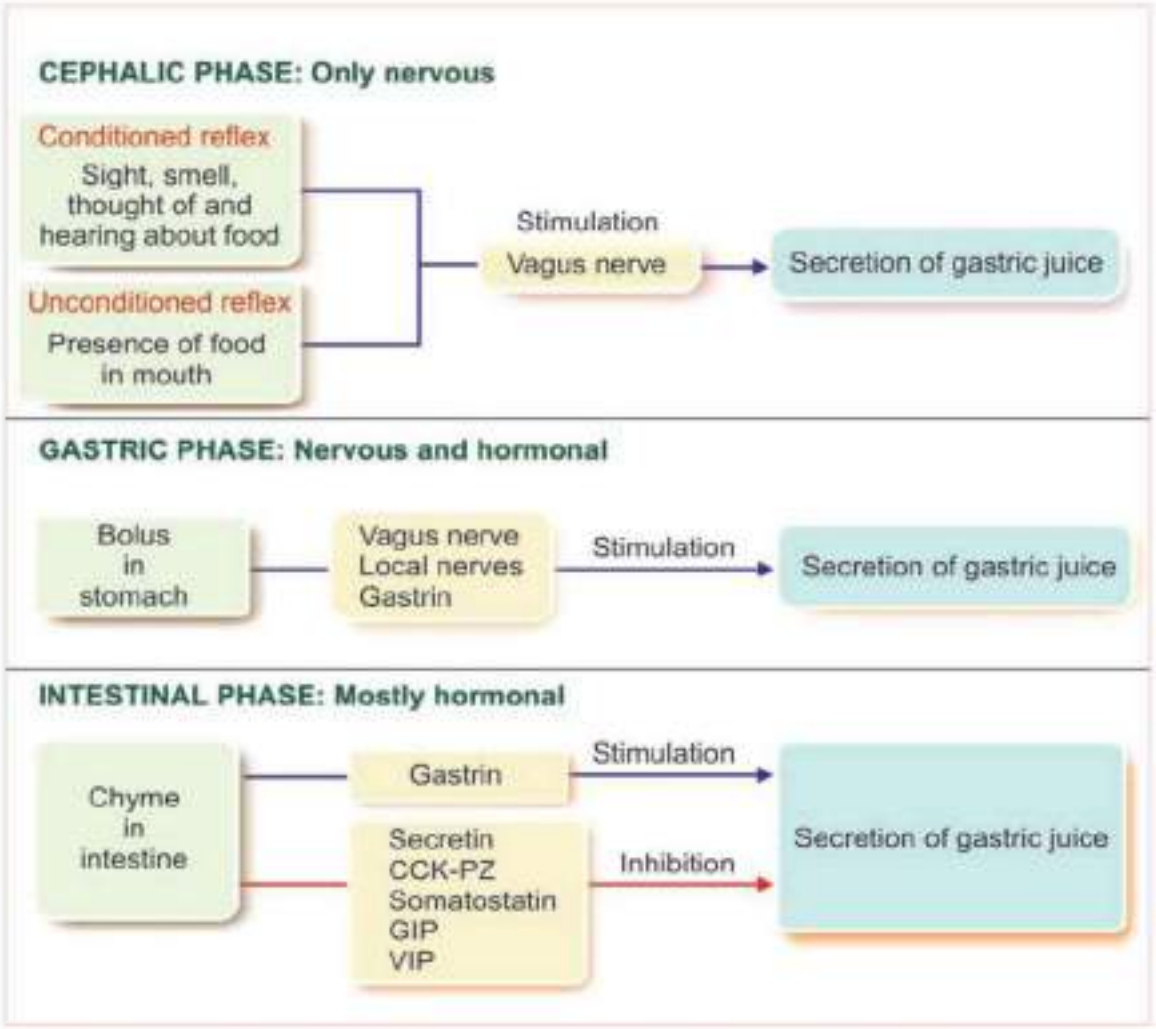



**FIGURE 38.6**: Schematic diagram showing the regulation of gastric secretion
CCK-PZ = Cholecystokinin-pancreozymin, GIP = Gastric inhibitory peptide, VIP = Vasoactive intestinal peptide.

## APPLIED PHYSIOLOGY

**Gastric secretion is affected by the following disorders:**

**1. GASTRITIS: Inflammation of gastric mucosa is called gastritis. It may be acute or chronic. Acute gastritis is characterized by inflammation of superficial layers of mucus membrane and infiltration with leukocytes, mostly neutrophils. Chronic gastritis involves inflammation of even the deeper layers and infiltration with more lymphocytes. It results in the atrophy of the gastric mucosa, with loss of chief cells and parietal cells of glands. Therefore, the secretion of gastric juice decreases.**

***Causes of Acute Gastritis:*** ***i.*** **Infection with bacterium *Helicobacter pylori***

**ii. Excess consumption of alcohol**

**iii. Excess administration of Aspirin and other nonsteroidal antiinflammatory drugs (NSAIDs)**

**iv. Trauma by nasogastric tubes**

**v. Repeated exposure to radiation (rare).**

***Causes of Chronic Gastritis:*** **i. Chronic infection with *Helicobacter pylori***

**ii. Longterm intake of excess alcohol**

**iii. Longterm use of NSAIDs**

**iv. Autoimmune disease.**

### *Features*

**Features of gastritis are nonspecific. Common feature is abdominal upset or pain felt as a diffused burning sensation. It is often referred to epigastric pain. Other features are:**

**i. Nausea**

**ii. Vomiting**

**iii. Anorexia (loss of appetite)**

**iv. Indigestion**

**v. Discomfort or feeling of fullness in the epigastric region**

**vi. Belching (process to relieve swallowed air that is accumulated in stomach)**

**2. GASTRIC ATROPHY:** Gastric atrophy is the condition in which the muscles of the stomach shrink and become weak. Gastric glands also shrink, resulting in the deficiency of gastric juice.

### *Cause*

- Gastric atrophy is caused by chronic gastritis called chronic atrophic gastritis. There is atrophy of gastric mucosa including loss of gastric glands. **Autoimmune atrophic gastritis** also causes gastric atrophy.

### *Features*

- Generally, gastric atrophy does not cause any noticeable symptom. However, it may lead to **achlorhydria** (absence of hydrochloric acid in gastric juice) and pernicious anemia. Some patients develop gastric cancer.

## 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.**

### *Causes*

i. Increased peptic activity due to excessive secretion of pepsin in gastric juice

ii. Hyperacidity of gastric juice

iii. Reduced alkalinity of duodenal content

iv. Decreased mucin content in gastric juice or decreased protective activity in stomach or duodenum

v. Constant physical or emotional stress

vi. Food with excess spices or smoking (classical causes of ulcers)

vii. Longterm use of NSAIDs (see above) such as Aspirin, Ibuprofen and Naproxen

viii. Chronic inflammation due to *Helicobacter pylori*.

### *Features*

- Most common feature of peptic ulcer is severe burning pain in epigastric region. In gastric ulcer, pain occurs while eating or drinking. In duodenal ulcer, pain is felt 1 or 2 hours after food intake and during night.

Other symptoms accompanying pain are:

i. Nausea

ii. Vomiting

iii. **Hematemesis** (vomiting blood)

iv. **Heartburn** (burning pain in chest due to regurgitation of acid from stomach into esophagus)

v. Anorexia (loss of appetite)

vi. Loss of weight.

## ZOLLINGER-ELLISON SYNDROME

- Zollinger Ellison syndrome is characterized by secretion of excess hydrochloric acid in the stomach.

### *Cause*

- This disorder is caused by tumor of pancreas. Pancreatic tumor produces a large quantity of gastrin. Gastrin increases the hydrochloric acid secretion in stomach by stimulating the parietal cells of gastric glands.

### *Features*

- i. Abdominal pain
- ii. Diarrhea (frequent and watery, loose bowel movements)
- iii. Difficulty in eating
- iv. Occasional hematemesis (see above).

**Mechanism of absorptions of carbohydrate, protein & fat:**

- Ruminal microbes consists of yeast, fungi & mixed but independent population of bacteria
- CH2O in diet consists of starch, sucrose, lactose & fiber
- In lumen, pancreatic α-amylase combines disaccharides & tri-glysaccharides & α-limit dextrins
- Intra-luminal products of CH2O digestion with the dietary disaccharides can`t be absorbed by mucosa
- further breakdown into mono-saccharides being transported into the epithelial cells by Na-dependent cotransport & facilitated diffusion process & enters into the blood stream
- Protein hydrolysis begins in stomach but digestion occurs in proximal small intestine
- **Amino acids, di-peptides & tri-peptides are the remaining products after pancreatic digestion**
- **Peptides are further hydrolsed by brush border hydrolases (junction between intestinal lumen & cytoplasm)**
- **10% of peptides escape hydrolysis & diffuse to baso-lateral membrane having neuro-active properties contains non nutritional value**
- **Amino acids are absorbed by Na-dependent co-transport & diffuse across the baso-lateral membrane into portal vein**
- **Dietary fat consists of water insoluble triglycerides, emulsified in the stomach**
- **In duodenum, pancreatic lipase acts at oil-water interface of the emulsion particles releasing β-monoglycerides & 2 free fatty acids (amphipaths)**
- **Bile salts act as detergent & bring the water insoluble into micelle & get dissolved into micelle core in jejunum**

**Amphipaths-** **part polar-water insoluble & non polar-lipid soluble**

**Micelle** **(-vely charged aggregates)- to form micelles, need bile acids, 2mM**

**Micelles diffuse from the emulsion particle to the brushn border where fat releases for diffusion across the lipid membrane into cell**

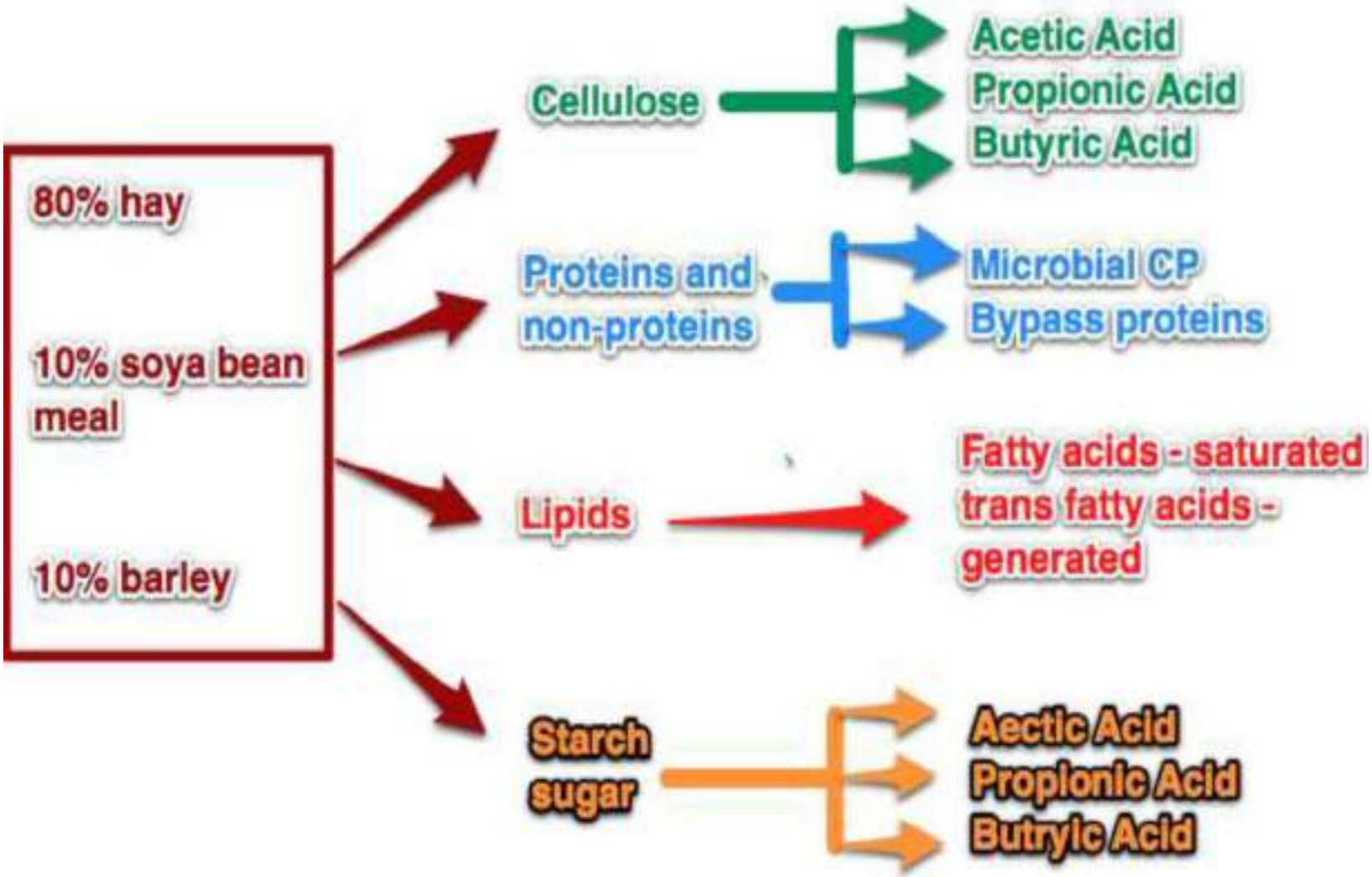
- **Fat soluble vitamins absorbed when incorporated into micelle**
- **Chylomicrons facilitate transport of water insoluble triglycerides & without protein coat, fat is unable to leave the cell**

**Cellular fermentative digestion-**

- **Due to low metabolic rate, fermentation of cellulolytic bacteria occurs slow**
- **optimum pH is 6.2 to 6.8 of cellulolytic bacteria (methanogenic bacteria)**
- **requires $CO_2$ & 2H supply to produce methane & amino acids supply to get their protein requirements**
- **These mixed microbes leads to produce VFA, $CO_2$ & $CH_4$**

**Fermentative digestion of Starch-**

- Starch & simple sugar degradation is performed by various primary amylolytic bacteria
- Bacteria`s have faster fermentative rates & low pH 5.5 to 6.6
- require NH3 & amino acid for synthesis of protein


80% hay
10% soya bean meal
10% barley
Cellulose
Acetic Acid
Propionic Acid
Butyric Acid
Proteins and non-proteins
Microbial CP
Bypass proteins
Lipids
Fatty acids - saturated
trans fatty acids - generated
Starch sugar
Aectic Acid
Propionic Acid
Butryic Acid

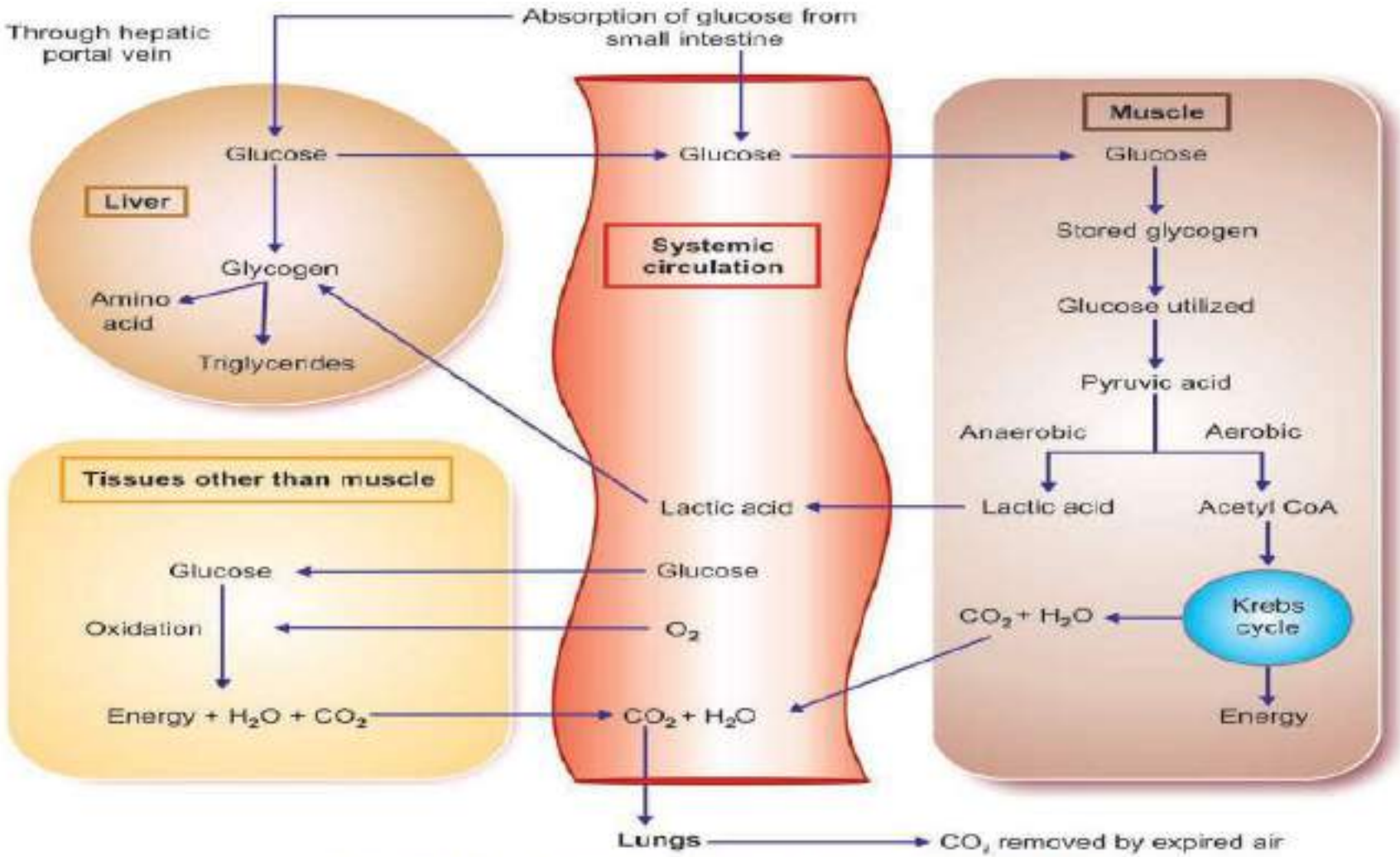



**FIGURE 45.1:** Schematic diagram of carbohydrate metabolism

**Fermentative digestion of Protein:**

- Proteolytic bacteria degrades 15 to 35% of dietary protein in the rumen
- Bacterial proteolysis produce peptides which are absorbed & further hydrolyze within the cell of bacteria
- End products are amino acids taken up by some other microbes & rest are used to produce ammonia & certain metabolic acids
- end products are further fermented to VFA`s required as nutrition for cellulolytic bacteria
- After conversion of dietary & NPN compounds & deamination, results in production of ammonia
- Ammonia is an important substrate for microbial protein synthesis to provide energy needed for synthetic reaction
- During fermentation of dietary protein, recycling of dead microbes protein continues

**Fermentative digestion of Lipids:**

❖ Ruminal microbes hydrolyze dietary lipids, using the unsaturated fatty acids as hydrogen acceptors which converts mostly into stearic acid

❖ From VFA`s ruminal microbes synthesize microbial lipids

❖ Protozoa absorb PUFA in their own structure to protect them from hydrogenation

❖ During intestinal digestion, protozoa`s comes from rumen, release their content of PUFA as main source for ruminants

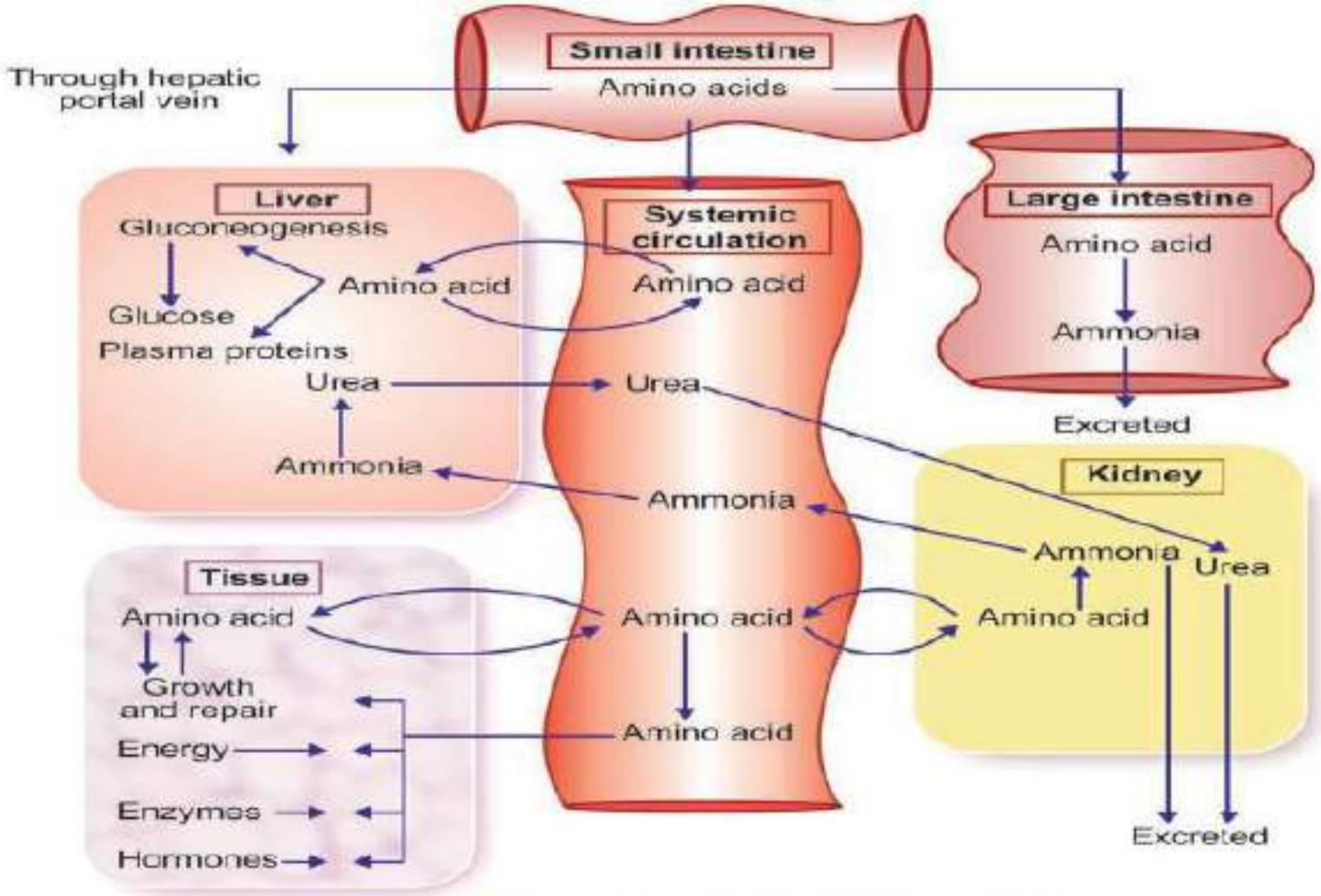



**FIGURE 46.1:** Schematic diagram of protein metabolism

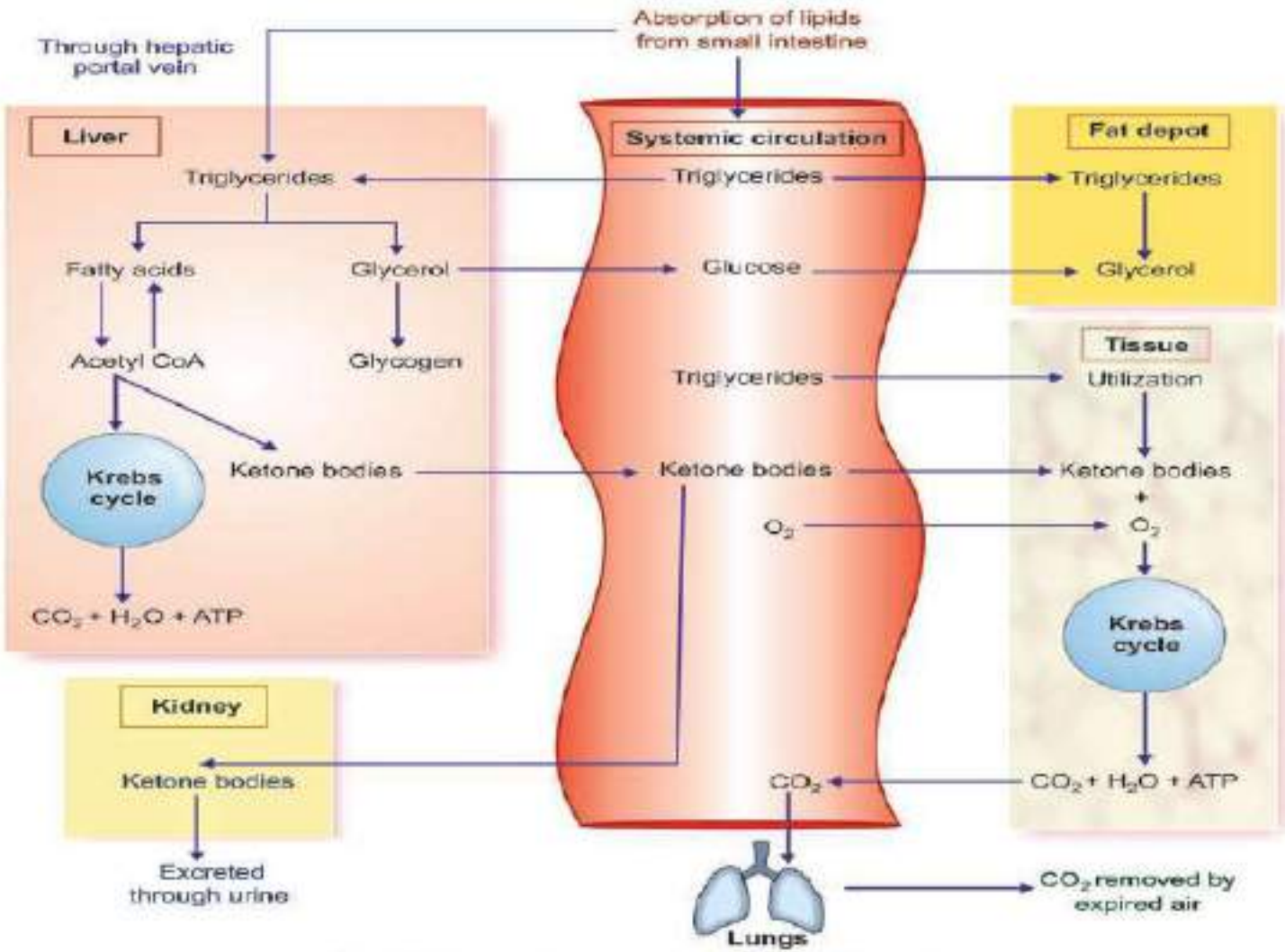



**FIGURE 47.1:** Schematic diagram of lipid metabolism

**Absorption of food stuffs:**

**VFA`s-** absorbed by passive diffusion through the granulosum cells of the fore-stomach epithelium

**Lactic acid-** absorbed by fore-stomach epithelium

## DIGESTION IN SIMPLE STOMACH OR NON-RUMINANT ANIMALS

**Mouth** : Starch —Salivary Amylase / Ptyalin→ Disaccharides

**Stomach** Secretion - Gastric juice

| Pepsin | Hydrochloric acid | Rennin |
|---|---|---|
| ↓ | ↓ | ↓ |
| Protein → Polypeptides & Peptone | Maintains optimum pH for digestion | Coagulates milk protein |

**Small Intestine**

Secretions - a) Pancreatic juice with trypsin, lipase & amylase
b) Bile - bile salts
c) Intestinal juice - dipeptidase & invertase consisting of lactase, maltase & sucrase

Proteins, Polypeptides & Peptones —Trypsin→ Dipeptides.
↓ Dipeptidase
Amino acids
↓
Absorbed through small intestine

Fats/Triglycerides —Bile salts→ Fat emulsion
↓ Lipase
Monoglycerides
↓
Absrobed through small intestine

Starch/Glycogen —Amylase→ Disaccharides like

Maltose —Maltase→ Glucose

Sucrose —Sucrase→ Glucose

Lactose —Lactase→ Glucose + Galactose

Absorbed through small intestine

**Large intestine** : Absorption of remaining digested nutrients. Undigested material is expelled as faeces through anus via rectum.

## RUMINANT DIGESTION

***Digestion :*** It is the process of conversion of complex food material into its simpler form.

***Enzymes :*** These are soluble organic catalysts manufactured by living cells.

**Mouth :**

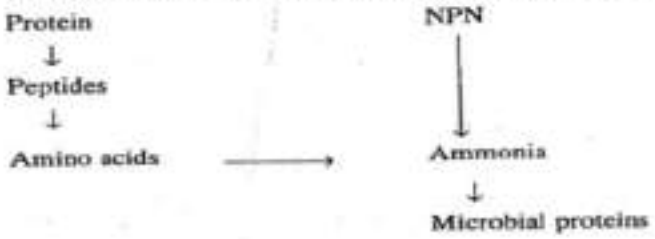
The offerred feed is taken up by the animal with the help of tongue and is partially chewed and swallowed. The swallowed food reaches rumen. Animal during rest brings back the food into mouth by regurgitation, where it is remasticated, reinsalivated and again swallowed. This act is called as ***rumination*** which is the typical feature of ruminant animals. After rumination, food reaches the rumen where major digestion takes place.

**Rumintant Stomach :**

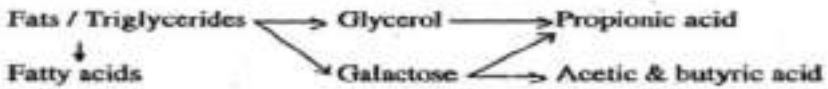
In rumen, the carbohydrate components of the diet like cellulose, hemicellulose, starches, sugars are converted to volatile fatty acids i.e. ***Acetic acid, Propionic acid and Butyric acid*** along with production of gases viz. methane & carbon dioxide. These volatile fatty acids are absorbed through ruminal wall and the gases are eructed through mouth during rumination.

Cellulose
Hemicellulose
Pectin
Starch
} Carbohydrates —Microbial enzymes→ Volatile fatty acids like acetic acid, propionic acid & butyric acid + Gases like methane & $CO_2$

The feed proteins are hydrolysed to amino acids and peptides by the proteolytic enzymes produced by ruminal microbes , while small portion of dietary proteins escape ruminal action which are called as ***bypass proteins***. Some amount of amino acids formed are used by microbes for their body protein synthesis. The remaining amino acids are then deaminated to produce ammonia, $CO_2$ and short chain fatty acids. Further the NPN substances from the diet are also converted to ammonia in rumen. The ammonia thus formed in the rumen is mostly utilized by rumen micro-organisms to synthesize their body proteins. The ammonia reaching the liver is converted to urea. Some part of this urea recycles back in the rumen through saliva or ruminal wall, however major portion is excreted in the urine.



**Fats / Triglycerides are converted to glycerol and galactose which in turn are converted to volatile fatty acids (VFA) by microbial enzymes.**




**The heavier food components settles down in the reticulum, thus reticulum acts as a filter for food material. The food then reaches the omasum where about 50% of water from food material is removed. The omasum also helps in fine grinding of food material.**

**The food after reaching abomasum is acted upon by the gastric juice which contains hydrochloric acid, mucin and enzymes like pepsin, rennin and lipase.**

***a) Hydrochloric acid* -**

i) It activates pepsinogen to form pepsin.
ii) It provides suitable pH for enzymatic action of pepsin.
iii) It also protects body by killing most foreign bacteria ingested with food.

Pepsinogen $\xrightarrow{HCL}$ Pepsin

***b) Rennin*** - It is present only in calves and which coagulates milk proteins.

Cascin + $Ca^{++}$ $\xrightarrow{Rennin}$ Calcium Paracaseinate (Coagulum)

***c) Pepsin*** - It hydrolyses small amount of microbial body proteins & bypass dietary proteins into peptones / polypeptides.

Microbial / Dietary bypass proteins $\xrightarrow{Pepsin}$ Peptones and Polypeptides

***d) Gastric lipase*** - It hydrolyses fats into fatty acids and glycerols.

Fats $\xrightarrow{Lipase}$ Fatty acids + Glycerols

**Small Intestine :**

The partially digested food then reaches to small intestine where the action of bile, pancreatic juice and intestinal juice completes the remaining digestion.

The ***bile*** secreted by liver reaches to duodenum through bile duct. The bile contains ***bile salts*** (sodium and potassium salts of taurocholic and glycocholic acids ) and ***bile pigments*** (bilirubin and biliverdin). The bile activates the secretion of pancreatic lipase. Further bile salts help in the emulsification of the fats.

Fats $\xrightarrow{Bile}$ Fat emulsion

The pancreas secretes pancreatic juice which is carried to duodenum by pancreatic duct. Pancreatic juice contains three enzymes namely ***trypsin, lipase or steapsin and amylase or amylopsin.***

***a) Trypsin*** converts food and microbial proteins to short chain peptides.

***b) Lipase*** hydrolyses fats into fatty acids and glycerols

***c) Amylase*** converts disaccharides to monosaccharides.

The intestinal juice contains enzymes like ***enterokinase, peptidase & invertase***

***a) Enterokinase*** - activates trypsinogen to form trypsin.

***b) Peptidase*** converts peptides to amino acids.

***c) Invertase*** is composed of 3 enzymes i.e. maltase, sucrase & lactase. They convert diasaccharides into monosaccharides.

The end products of nutrient digestion are then absorbed through villi of small intestine and reaches blood and lymph circulation.

**Large intestine :**

The digested but unabsorbed food components and water are absorbed through large intestine. While the undigested and unabsorbed portion mixes with the mucous secreted by large intestine and also with the glycerols and soluble soaps to form ***faeces.*** The peristaltic movement of large intestine expels out the faeces through anus via rectum.

- **Prehension: Process of feed & water intake by domestic animals are aided by muzzle, lips, cheek, tongue & teeth is called prehension.**
- **Mastication: Feed intake is crushed & divided into small pieces for further smooth digestion & absorption by chewing & mastication.**
- **Deglutition: Deglutition or swallowing is conveying of food from mouth through the pharynx & esophagus to stomach. This is under control of a centre in the medulla**
- **Rumination: In polygastric animals, food once swallowed is taken back to the oral cavity for re-mastication & reinsalivation.**
- **Defecation: Complex reflex act where the feces are excrete or expelled through the anus.**
- **Hunger contraction: These are peristaltic waves travelling from cardia to pylorus. They appear before the stomach has completely or partially emptied.**
- Eructation (belching): **Fermentation of foodstuffs in the rumen. generates enormous quantities of gas.**

✓ **30-50 liters per hour in adult cattle.**

✓ **5-7 liters per hour in adult sheep or goats.**

- Belching **is how ruminants get rid of fermentation gases**

✓ **Anything that causes a hindrance to belching can be life threatening.**

✓ **Bloating can result in death from asphyxiation.**

**Thirst**- a sensation referred to the mucous membrane of mouth & pharynx

**Vomition**- the spasmodic ejection of contents of the stomach through esophagus & mouth.

**Act of vomition**: It comprises following actions

- Relaxation of stomach muscles & esophageal sphincter & closing of pylorus.
- Contraction of abdominal muscles leading to ↑ in intra abdominal pressure
- Expansion of chest cavity with closed glottis
- Opening of upper esophageal sphincter

## Wall of gastointestinal tract:

**In general, wall of GI tract is formed by Four layers which are formed insideout :**

**1.Mucus layer**

**2.Submucus layer**

**3.Muscular layer**

**4.Serous layer or fibrous layer**

### 1. MUCUS LAYER

- **Mucus layer is the innermost layer of the wall of GI tract. It is also called gastrointestinal mucosa or mucus membrane. It faces the cavity of GI tract.**

**Mucosa has three layer of structures:**

- **i. Epithelial lining**
- **ii. Lamina propria**
- **iii. Muscularis mucosa.**

**i. Epithelial Lining : Epithelial lining is in contact with the contents of GI tract. The type of cells in this layer varies in different parts of GI tract. The inner surface of mouth, surface of tongue, inner surface of pharynx and esophagus have stratified squamous epithelial cells. However, mucus membrane lining the other parts such as stomach, small intestine and large intestine has columnar epithelial cells.**

### *ii. Lamina Propria*

- **Lamina propria is formed by connective tissues, which contain fibro blasts, macrophages, lymphocytes and eosinophils.**

### *iii. Muscularis Mucosa*

- **Muscularis mucosa layer consists of a thin layer of smooth muscle fibers. It is absent in mouth and pharynx. It is present from esophagus onwards.**

## 2. SUBMUCUS LAYER

- **Submucus layer is also present in all parts of GI tract, except the mouth and pharynx. It contains loose collagen fibers, elastic fibers, reticular fibers and few cells of connective tissue. Blood vessels, lymphatic vessels and nerve plexus are present in this layer.**

## 3. MUSCULAR LAYER

- **Muscular layer in lips, cheeks and wall of pharynx contains skeletal muscle fibers. The esophagus has both skeletal and smooth muscle fibers. Wall of the stomach and intestine is formed by smooth muscle fibers. Smooth muscle fibers in stomach are arranged in three layers:**

**i. Inner oblique layer**

**ii. Middle circular layer**

**iii. Outer longitudinal layer.**

- **Smooth muscle fibers in the intestine are arranged in two layers:**

**i. Inner circular layer**

**ii. Outer longitudinal layer.**

**Auerbach nerve plexus is present in between the circular and longitudinal muscle fibers. The smooth muscle fibers present in inner circular layer of anal canal constitute internal anal sphincter. The external anal sphincter is formed by skeletal muscle fibers.**

**4. SEROUS OR FIBROUS LAYER**

**Outermost layer of the wall of GI tract is either serous or fibrous in nature. The serous layer is also called serosa or serous membrane and it is formed by connective tissue and mesoepithelial cells. It covers stomach, small intestine and large intestine. The fibrous layer is otherwise called fibrosa and it is formed by connective tissue. It covers pharynx and esophagus.**

## NERVE SUPPLY TO GASTROINTESTINAL TRACT

**GI tract has two types of nerve supply:**

**I. Intrinsic nerve supply**

**II. Extrinsic nerve supply.**

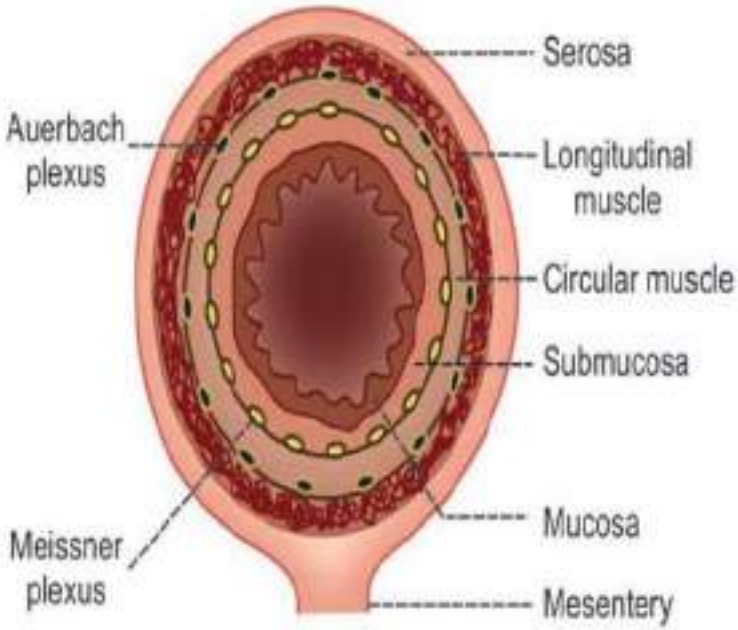



**FIGURE 36.2**: Structure of intestinal wall with intrinsic nerve plexus

## INTRINSIC NERVE SUPPLY :

**ENTERIC NERVOUS SYSTEM**

- **Intrinsic nerves to GI tract form the enteric nervous system that controls all the secretions and movements of GI tract. Enteric nervous system is present within the wall of GI tract from esophagus to anus. Nerve fibers of this system are interconnected and form two major networks called**

**1. Auerbach plexus**

**2. Meissner plexus.**

- **These nerve plexus contain nerve cell bodies, processes of nerve cells and the receptors. The receptors in the GI tract are stretch receptors and chemoreceptors. Enteric nervous system is controlled by extrinsic nerves.**
- **1. Auerbach Plexus or myenetric nerve plexus**
- **Auerbach plexus is also known as myenteric nerve plexus. It is present in between the inner circular muscle layer and the outer longitudinal muscle layer**

**Functions of Auerbach plexus :**

- **Major function of this plexus is to regulate the movements of GI tract. Some nerve fibers of this plexus accelerate the movements by secreting the excitatory neurotransmitter substances like acetylcholine, serotonin and substance P. Other fibers of this plexus inhibit the GI motility by secreting the inhibitory neurotransmitters such as vasoactive intestinal polypeptide (VIP), neurotensin and enkephalin.**

**2. Meissner Nerve Plexus or meissner nerve plexus**

- **Meissner plexus is otherwise called submucus nerve plexus. It is situated in between the muscular layer and submucosal layer of GI tract.**
- **Functions of Meissner plexus**

**Function of Meissner plexus is the regulation of secretory functions of GI tract. These nerve fibers cause constriction of blood vessels of GI tract.**

**EXTRINSIC NERVE SUPPLY**

**Extrinsic nerves that control the enteric nervous system are from autonomic nervous system. Both sympathetic and parasympathetic divisions of autonomic nervous system innervate the GI tract .**

**Sympathetic Nerve Fibers**

**Preganglionic sympathetic nerve fibers to GI tract arise from lateral horns of spinal cord between fifth thoracic and second lumbar segments (T5 to L2). From here, the fibers leave the spinal cord, pass through the ganglia of sympathetic chain without having any synapse and then terminate in the celiac and mesenteric ganglia. The postganglionic fibers from these ganglia are distributed throughout the GI tract.**

**Functions of sympathetic nerve fibers**

- **Sympathetic nerve fibers inhibit the movements and decrease the secretions of GI tract by secreting the neurotransmitter noradrenaline. It also causes constriction of sphincters.**

**Parasympathetic Nerve Fibers :**

- **Parasympathetic nerve fibers to GI tract pass through some of the cranial nerves and sacral nerves. The preganglionic and postganglionic parasympathetic nerve fibers to mouth and salivary glands pass through facial and glossopharyngeal nerves. Preganglionic parasympathetic nerve fibers to esophagus, stomach, small intestine and upper part of large intestine pass through vagus nerve. Preganglionic nerve fibers to lower part of large intestine arise from second, third and fourth sacral segments (S2, S3 and S4) of spinal cord and pass through pelvic nerve. All these preganglionic parasympathetic nerve fibers synapse with the postganglionic nerve cells in the myenteric and submucus plexus.**

**Functions of parasympathetic nerve fibers-**

- **Parasympathetic nerve fibers accelerate the movements and increase the secretions of GI tract. The neurotransmitter secreted by the parasympathetic nerve fibers is acetylcholine (Ach).**

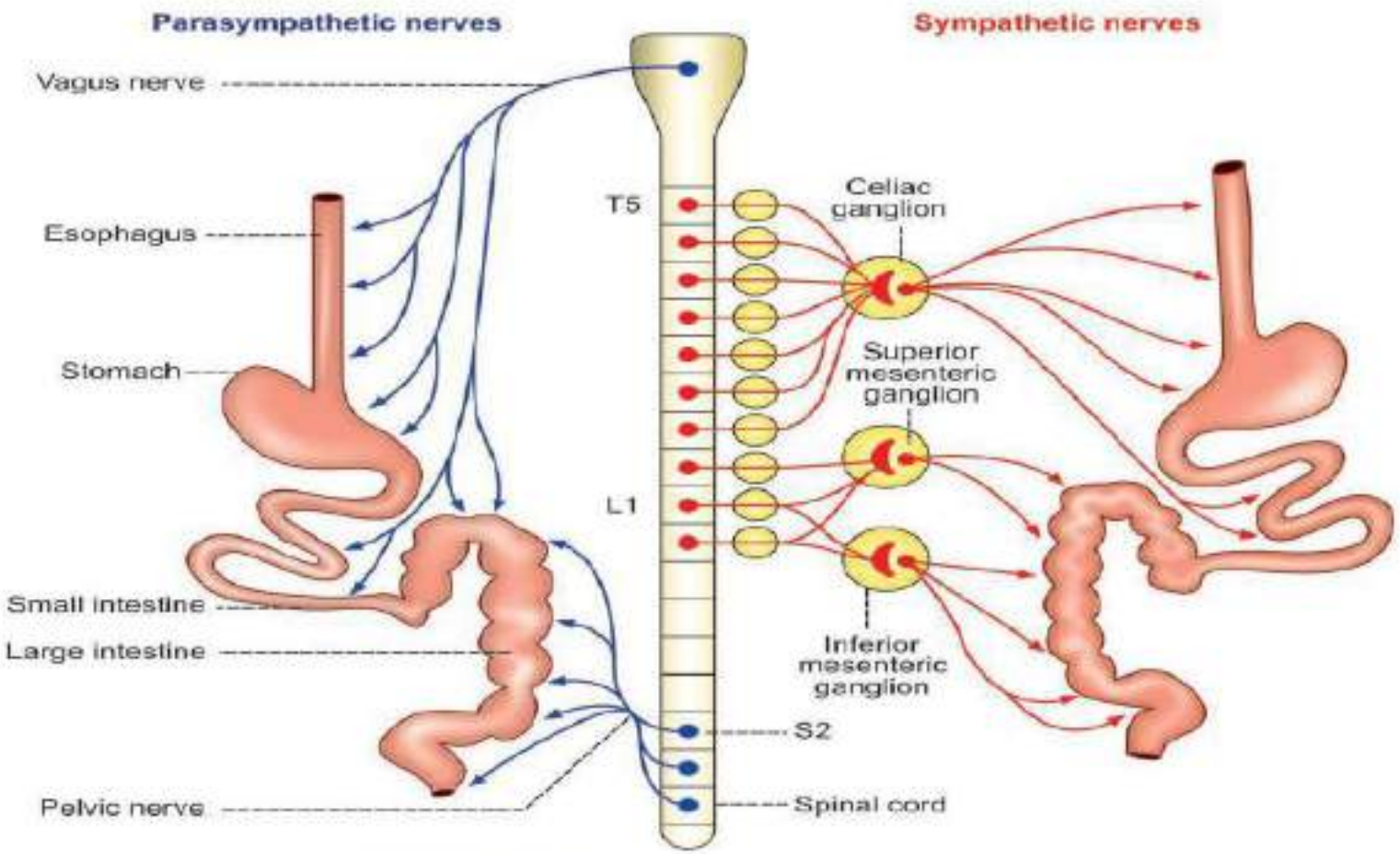



**FIGURE 36.3:** Extrinsic nerve supply to GI tract.
T5 = 5th thoracic segment of spinal cord
L1 = 1st lumbar segment of spinal cord
S2 = 2nd sacral segment of spinal cord

# Thankyou for your patience