INTRODUCTORY PHYSIOLOGY OF DOMESTIC ANIMALS

THEORY NOTES

FOR

VETERINARY AND LIVESTOCK DEVELOPMENT DIPLOMA (1st year)

BY

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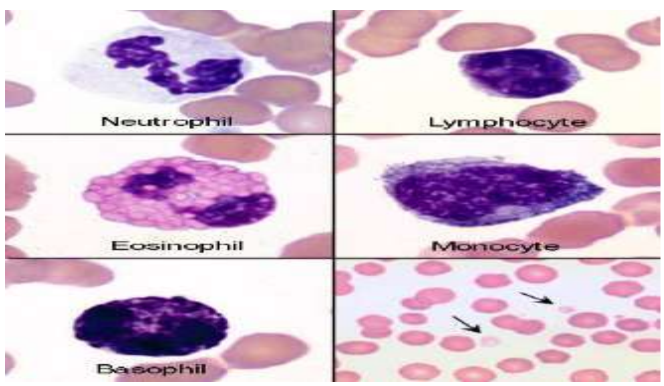

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THE DIGESTIVE SYSTEM

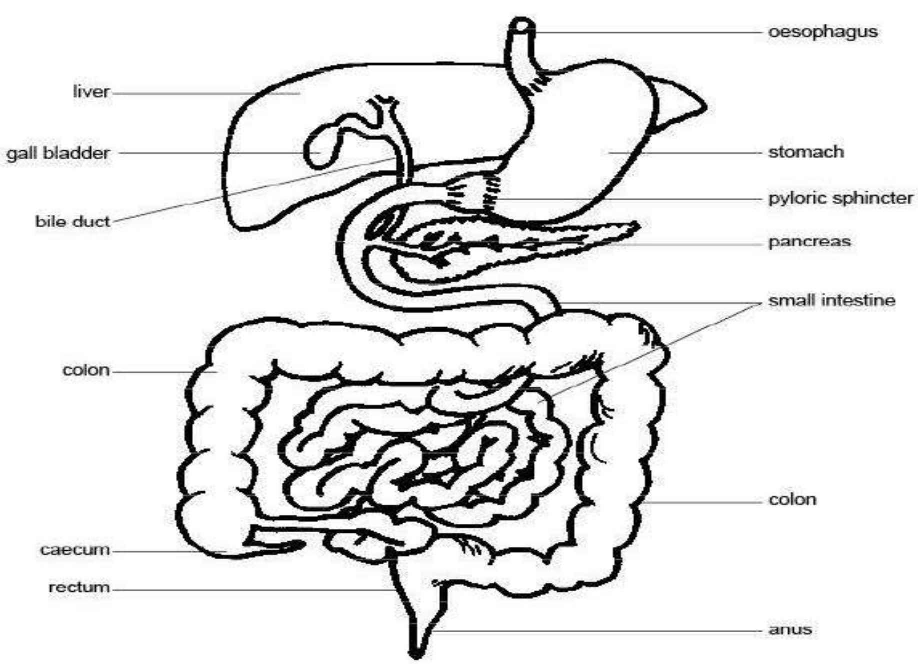
Digestion :-is the process of breakdown of complex food into simpler form by the activities of the alimentary tract and glandular secretions for absorption of nutrients

- Whether an animal eats plants or flesh, the **carbohydrates**, **fats** and **proteins** in the food it eats are generally giant molecules and are broken down into simpler forms to meet the nutritive requirements of an animal.
- Herbivorous animals (Cattle, sheep, horse, goat etc.,) derive their nutritive requirements from plant sources.
- Carnivorous animals (dog, cat etc.,) obtain their food from animal sources.
- Omnivorous animals (man, pig, etc.) get their foods from both animals and plants sources.

Gastrointestinal tract : -

It extends from the lips, mouth, pharynx, oesophagus, stomach, small intestine (Duodenum, jejunum and ileum), large intestine (Caecum, colon and rectum) and anus.

- In carnivores, alimentary tract is small and simple.
- In ruminants (cattle, sheep and goat), the stomach is extensively large and complex, whereas the large intestine is relatively small, hence they are known as fore-gut digesters.



GIT of Monogastric Animal

Functions of GI tract

1. Transporting the food and to prepare nutrients for digestion.
2. Processing the food physically by breaking it up (chewing), mixing, adding fluid etc.
3. Processing the food chemically by adding digestive enzymes to split large food molecules into smaller ones.
4. Absorption of water.
5. As excretory organs to help in elimination of waste products.

Mouth

- The mouth takes food into the body. The entrance into the mouth is defined by the **lips** (**labia**), the lips hold the food inside the mouth during chewing and allow the baby animal to suck on its mother's teat. The upper lip of small ruminants is deeply grooved with a midline **philtrum**.
- The lips of sheep, goats, and horses are soft and flexible and aid in picking up food, whereas those of cattle and pigs are stiffer and less mobile. The oral cavity ends at a narrowing (the **isthmus faucium**) near the base of the tongue, where the digestive tract continues as the pharynx.
- The dorsal wall of the oral cavity comprises the **hard palate** rostrally and the **soft palate** caudally. The sight or smell of food and its presence in the mouth stimulates the **salivary glands** to secrete **saliva**. The fluid in saliva moistens and softens the food making it easier to swallow. It also contains the enzyme, **salivary amylase**, which starts the digestion of starch.
- The **tongue** moves food around the mouth and rolls it into a ball for swallowing. **Taste buds** are located on the Tongue. The cow's tongue is prehensile and wraps around grass to graze it.

Saliva and Salivary Glands

- Saliva consists of water, electrolytes, mucus, and enzymes. The water and mucus soften and lubricate the ingesta to facilitate mastication and swallowing. **Lysozyme** is a salivary enzyme with antibacterial actions. The starch-digesting enzyme **amylase** is present in the saliva of omnivores (pig) and to a limited degree in horses but absent in ruminants and carnivores (dog).

REGULATION OF SALIVARY SECRETION

- When food enters the mouth, secretion of saliva takes place by reflex stimulation of the salivary glands through the buccal receptors and secretory centers. The olfactory nerves function as afferent/sensory pathways for this reflex activity.

FUNCTIONS OF THE SALIVA

- It lubricates food for easy mastication and swallowing.

- The mucin content provides an adhesive to food to form bolus for swallowing.
- Salivary enzyme aid in digestion of food.
- In ruminants, saliva provides a proper media for the bacterial growth and activity in the rumen.

Salivary gland and secretion

- Saliva is the mixed secretion of three pair of main salivary glands, namely **parotid**, **sub maxillary** or **sub mandibular** and **sublingual** and also many small glands found in the mucous membrane of the mouth.
- Glands in general are divided into serous, mucous and mixed types.
- The absorptive and secretary activities of the cells lining the ducts affect the composition of the saliva.
- In most of the mammals, parotid glands are serous. In some animals the secretion of these glands is devoid of enzymes.
- The sub maxillary gland is mixed in ungulates, dogs and cats but it is serous in rodents.
- The sublingual gland of the horse, ox, pig, dog and cat is a mixed gland and that of rodents is mucous.

Salivary glands of ruminants

- Parotids, sub maxillary and sublingual are the major salivary glands of ruminants.
  - In addition, sheep and cattle have two inferior molar glands, small and numerous buccal and labial glands in cheek and lips, palatine glands in hard and soft palate and pharyngeal glands in the pharynx and roof of the tongue.
  - Inferior molar is a serous gland
  - Buccal, Pharyngeal and Palatine are mucous glands
  - Labial is a mixed gland

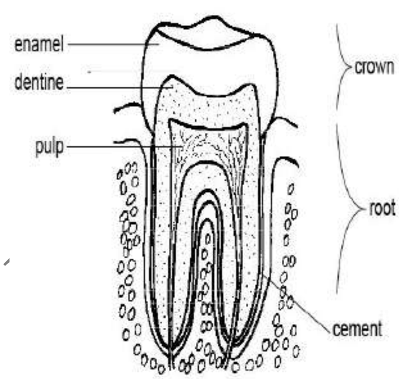
Pattern of secretion

- The parotid glands secrete spontaneously and continuously. Its secretion is rapid during feeding and rumination on the side of bolus chewing. Its flow is about 2ml/min. at rest and 30 to 50ml/min. during rumination.
- Flow of saliva in cow is 60 to 160litres/day; in sheep 6.0 to 16litres/day.
- In dogs, submaxillary and sublingual glands show free flow of saliva during chewing of normal meat (no secretion by parotid), whereas dry meat powder excites abundant secretion from the parotid.
- In horse, parotid secretion occurs only during feed intake, whereas in ruminants, parotid secretion is continuous.
- Salivary secretion is continuous.
- Flow of saliva varies with activity and increase with feeding and rumination to aid deglutition.

- Type of ration influences rate of salivation.
- Saliva is predominantly of two types i.e. serous and mucus.
- Serous saliva is rich in carbonate ions and is secreted continuously.
- Mucus saliva helps to reduce foaming by increasing surface tension and is secreted when animal is feeding and is rich in mucopolysaccharides.

Teeth

- Teeth seize, tear and grind food. They are inserted into sockets in the bone and consist of a crown above the gum and root below.
- The crown is covered with a layer of **enamel**, the hardest substance in the body. Below this is the **dentine**, a softer but tough and shock resistant material. At the centre of the tooth is a space filled with **pulp** which contains blood vessels and nerves.
- The tooth is cemented into the **socket** and in most teeth the tip of the root is quite narrow with a small opening for the blood vessels and nerves.
- Mammals have 2 distinct sets of teeth. The first the **milk teeth or deciduous teeth** are replaced by the **permanent teeth**.



Pregastric Physiology: - The act of bringing food into the mouth is **prehension**. The teeth, lips, and tongue are used as prehensile organs by domestic animals. The lips of the horse, the tongue of the cow and sheep, and the snout of the pig are used in obtaining food.

MASTICATION: - Extensive chewing of the feed causes mechanical reduction in the size of the food .

- In **herbivores**, mastication of food material is by lateral movement of the lower jaw and to-and-fro movement.
- In **herbivores**, the upper jaw is wider than the lower jaw and mastication of food occur on only one side at a time.
- In **ruminants**, the upper incisors are absent, but modified as dental pad.

DEGLUTITION (Swallowing) :-

Deglutition is the act of passage of food from the mouth to the stomach through pharynx and oesophagus.

- It takes place in three phases
  - From mouth to pharynx (voluntary act) :- The tongue acts like a plunger driving bolus towards pharynx
  - From pharynx into the oesophagus :- Propulsion of the bolus via relaxed pharyngeo- oesophageal sphincter to the esophagus
  - From the oesophagus into the stomach:- The **oesophagus** transports food to the stomach. Food is moved along the oesophagus, by contraction of the smooth muscles in the walls that push the food towards stomach, This movement is called **peristalsis**

OESOPHAGUS :- Oesophagus is a muscular tube like structure extends from the pharynx to the stomach. The pharyngeo – oesophageal junction is normally closed by oesophageal sphincter.

- During swallowing, the peristaltic wave travels from pharyngeo - oesophageal sphincter towards cardiac sphincter which is located at gastro-oesophageal junction.

Cardia

- The point of opening of oesophagus into the stomach is called cardia.
- It is provided with a sphincter muscle known as cardiac sphincter.
- It prevents back flow of food from stomach to oesophagus.
- Cardia is ordinarily closed except during swallowing and regurgitation.
- The cardiac sphincter is well developed and powerful in horse.

Stomach

The **stomach** stores and mixes the food. Glands in the wall secrete **gastric juice** that contains enzymes to digest protein and fats as well as **hydrochloric acid** to make the contents very acidic. The walls of the stomach are very muscular and churn and mix the food with the gastric juice to form a watery mixture called **chyme**.

- It functions as a reservoir of food.
- Controls the rate of passage of food to the small intestine for final digestion and absorption.
- Actively involved in grinding the food to reduce their size.

GASTRIC GLANDS :-

- Secretions of gastric glands
  - Cardiac glands secrete only mucus
  - Parietal/fundic glands secrete HCl and pepsinogen
  - Pyloric glands secrete mucus and gastrin.

- Fundic gland contains three main types of cells.
  - Body chief cells or peptic cells are locate at the base of the gland secrete proteolytic enzymes (Pepsin and Rennin)
  - Parietal or oxyntic cells are present at the upper third of the gland is the site of HCl secretion.
  - Neck chief cells, placed near the surface epithelium near the upper part of the gland secret mucus and a mucoprotein "Intrinsic factor" required for Vit.B_{12} absorption from the intestine is necessary for erythropoiesis.

- The pyloric glands are structurally similar to the parietal glands has body chief cells and neck chief cells only.

GASTRIC JUICE – COMPOSITION

- It is a colorless fluid, containing HCl, enzymes and mucus. Concentration of HCI in the stomach content varies with the nature of food, stage of digestion, amount of saliva to be neutralized etc.
  - **Hydrochloric acid: -** It is actively secreted by the parietal/oxyntic cells of the fundic glands, Activates pepsinogen, the inactive form of enzyme into active pepsin, Also function as antiseptic in the stomach.
  - **Pepsin: -** Proteolytic enzyme, involved in hydrolysis of proteins into polypeptides Synthesized as "Pepsinogen" (inactive form of pepsin), Pepsinogen is activated by HCl, Optimum pH of 1.5 – 3 is required for pepsin activity.
  - **Rennin(Chymosin, Rennet) :-** It is a milk coagulating enzyme, present in young animals(Calf, Lamb, piglet etc.,), Secreted as prorennin (inactive form of rennin), Prorennin is activated by HCl, Rennin reacts with casein (Milk protein) in the presence of calcium ion forms calcium paracaseinate to delay the passage of milk through stomach for prolonged action of pepsin on casein .
  - **Gastric lipase: -** Acts on emulsified fat, Hydrolysis fat in to fatty acids and glycerol, Require the optimum pH of 5.5 – 7.5, Its concentration in carnivores is low, Absent in birds and ruminants**.**

CONTROL OF GASTRIC SECRETION :-

- In man and horse, the secretion of gastric juice is continuous but it is intermittent in dogs and cats.

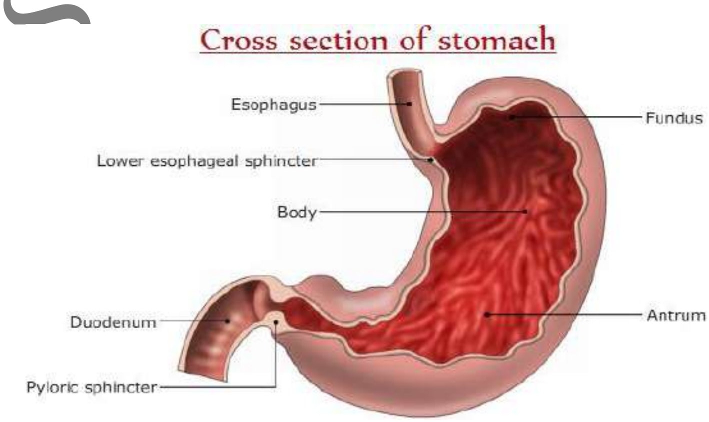
- The rate of secretion increases during feed intake.
- The secretions of gastric glands are regulated by nervous and chemical mechanisms.
- The gastric secretion takes place in three phases

  - Cephalic phase: - Stimulation of sensory endings in mouth and pharynx or psychic/conditioned reflex due to the impulses originating from the smell, sight of food sensation provokes the cephalic phase of secretion. It contributes about 45% of gastric secretion. The extent of psychic secretion is well developed in dogs and also present in pigs.
  - Gastric phase : - Entry of food into the stomach causes copious secretion of gastric juice. This contributes about 45% of the gastric secretory response.

    Basically two principle stimuli are responsible for gastric phase

    - Mechanical stimuli :- Stimulation of intrinsic nerve system, Vago-vagal reflex from fundic area
    - Humoral /hormonal stimuli: - Major portion of gastrin, a gut hormone is produced by the "G" cells of the pyloric glands.

  - Intestinal phase: - Accumulation of food in the intestine excites gastric secretion by humoral mechanism due to entry intestinal gastrin and cholecystokinin (CCK) from duodenum into gastric gland through blood stream. This phase contributes about 10% of the gastric secretion



- Based on structure and function of stomach, domestic animals fall into two general classes.
  - Non-ruminants/ simple stomach animals – Horse, cat, dog, and pig.
  - Ruminants – Cattle, sheep , goat, camel and buffalo
- The stomach of non-ruminants is simple consisting of only one compartment, whereas the stomach of ruminants is complex, consisting of four compartments (rumen, reticulum, omasum and abomasum) of which only abomasum secretes the gastric juice.
- The stomach is a hollow, sac like organ made up of four layers - serous, muscular, sub mucosa and mucosa from outside to inside.

RUMINANT STOMACH

- Ruminants are animals capable of regurgitating their food from their stomach and remasticate them.
- Bacteria, protozoa and fungi in the rumen are responsible for extensive fermentative digestion in the rumen. It is supported by the mechanical activity of the three compartments (rumen, reticulum and omasum).
- Only the abomasum, the true stomach secretes gastric enzymes and HCl.
- In adults, rumen and reticulum occupies 69%, omasum 8% and abomasum 23% of the stomach portion
- Omasum is not well developed in sheep and goat, it is absent in Camel.
- Abomasum is the largest compartment in new born ruminants.
- As age advances, the rumen and reticulum grow at a faster rate than abomasum.
- Oesophagus opens into the rumen through cardia.
- In calves, reticular groove/oesophageal groove acts as a bypass route for the passage of milk directly from the oesophagus into the omasum and abomasum. During suckling the receptors in the pharynx and mouth get stimulated causes reflex closure of reticular groove to conduct liquid and milk directly from the oesophagus into reticulo – omasal orifice, bypassing rumen and reticulum

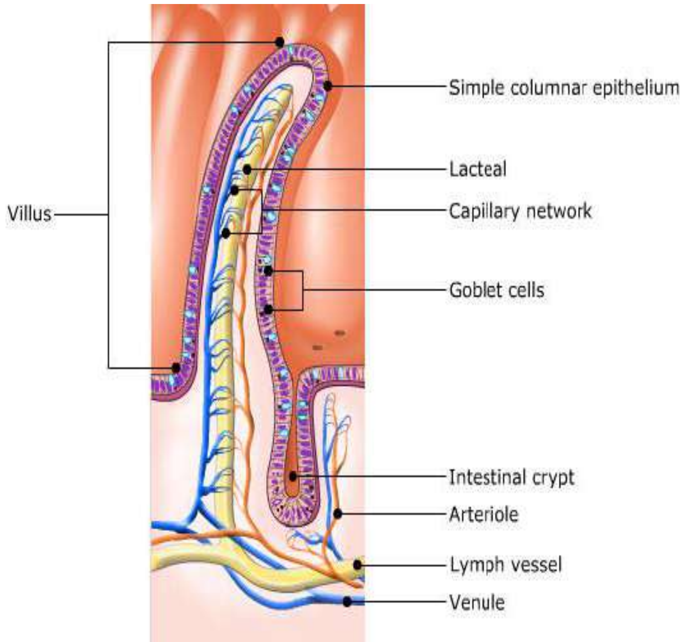
GASTRIC SECRETION IN RUMINANTS

- Abomasum is the only part of the ruminal stomach secreting digestive juices.
- Fundic abomasums is rich in HCl, pepsin and in young ruminant rennin- a milk coagulating enzyme is found.
- Regulation of abomasal secretion is complex. It involves humoral and neural factors

SMALL INTESTINE

- The small intestine is the primary site of chemical digestion and absorption of nutrients. The **exocrine** secretions of the pancreas contain most of the enzymes for chemical digestion in the lumen of the small intestine, but the epithelial cells that line the small intestine (**enterocytes**) also have in their cell membranes enzymes that participate in the final steps of chemical digestion. The primary digestive function of the liver is to provide **bile salts**, which facilitate the enzymatic digestion of lipids. The liver is not a source of digestive enzymes.

- Has three major portions namely **duodenum, jejunum and ileum**



- It is composed of 4 layers-serosal (outer), muscular, submucosa and innermost mucosal layer. Mucosa is the functional layer involved in digeston and absorption

Optimum pH in various compartments of the G.I tract

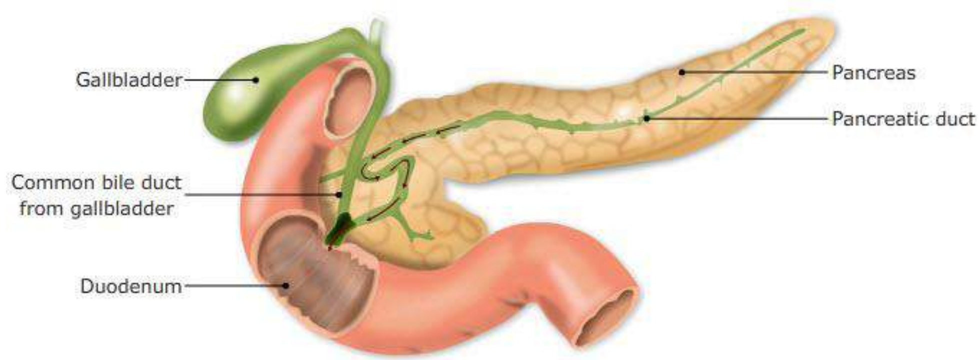
- Stomach contents: 4.60
- Duodenum : 7.30
- Jejunum : 7.47
- Ileum: 7.55
- Caecum: 7.09
- Colon: 7.09
- Rectum: 6.24

Small Intestine Secretions and Motility

- **Intestinal juice** is derived from intestinal glands in the wall of the small intestine. These include **crypts** or **crypts of Lieberkuhn**, scattered throughout the entire small intestine and **duodenal glands**, which contribute mucus and are found only in the duodenum. The intestinal juice contains salts and water derived from blood capillaries in the wall of the intestine.

- Food in the intestine stimulates secretion by these intestinal crypt glands. The two primary types of movement by the small intestine are **segmentation** and **peristalsis**. Segmentation movements, which occur when food is in the small intestine, are characterized by alternating local areas of contraction and relaxation.

- These movements mix the digesta with intestinal juice and digestive enzymes and increase the contact between digesta and the epithelial surface of the small intestine. The increased contact provides more exposure to enzymes associated with epithelial cells and to the absorptive surface of the epithelial cells. Strong peristaltic contractions of the small intestine in fasting animals or several hours after a meal propel ingesta down the tract, presumably to clean the small intestine of undigested foodstuffs before the next meal.



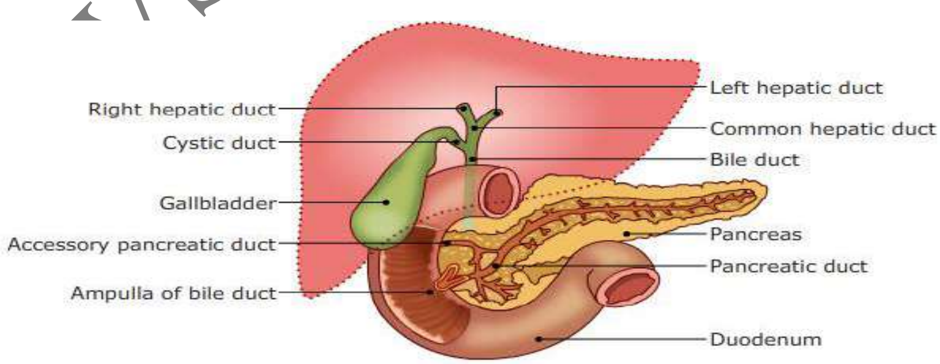
Pancreas

- Pancreatic exocrine secretions primarily consist of a variety of digestive enzymes and sodium bicarbonate. Pancreatic **acinar** cells secrete the enzymes, and cells that line ducts in the pancreas secrete the sodium bicarbonate.
- These ducts empty into one or two pancreatic ducts, which empty into the duodenum. The sodium bicarbonate raises to an acceptable pH the chyme entering from the stomach. The small-intestinal epithelium is not protected from an acidic solution by a thick layer of mucus, as is the stomach. The higher pH is also better for the action of the pancreatic digestive enzymes. Pancreatic proteolytic enzymes include **trypsin** and **chymotrypsin**.

- Similar to pepsin in the stomach, these are secreted as inactive precursors, **trypsinogen** and **chymotrypsinogen**. Trypsinogen is activated by an enzyme, **enterokinase**, a component of the luminal cell membranes of small intestinal cells (enterocytes). Trypsin can activate chymotrypsinogen and more trypsinogen. The ultimate end products of protein digestion are amino acids, but the pancreatic proteolytic enzymes may stop digestion when the peptides reach a length of two or more amino acids. If this occurs, peptidases associated with enterocyte cell membranes can complete hydrolysis of the peptides to individual amino acids for absorption.
- Unlike the proteolytic enzymes, **pancreatic amylase** and **lipase** are in the active forms when secreted from the pancreas. Amylase digests starches to **oligosaccharides** (a carbohydrate composed of a small number of monosaccharides, usually two to four). The enzymes **maltase** and **sucrase**, components of enterocyte cell membranes, further digest the oligosaccharides to monosaccharides. **Lactase**, to digest lactose (milk sugar), is present in enterocytes of young mammals but not in all adults.

- Lipase hydrolyzes triglycerides into fatty acids and glycerol. This action is most effective after the fats have been emulsified by bile. Control of pancreatic exocrine secretion depends on stimulation by vagal autonomic nerves that innervate the pancreas and on three intestinal hormones, cholecystokinin, secretin, and gastrin. Seeing or smelling food stimulates vagal stimulation, and food in the stomach prompts release of gastrin. The greatest amount of pancreatic exocrine secretion occurs when the acid chyme and food components in the duodenum stimulate the release of cholecystokinin and secretin from cells in the duodenal mucosa (**intestinal phase** of control). These two duodenal hormones also feed back to the stomach to decrease secretions and slow down the activity and emptying of the stomach until the duodenal chyme has been degraded by the enzymes and adjusted in pH by the pancreatic bicarbonate.

Liver Digestive Function and Secretion of Bile



- Liver cells (**hepatocytes**) are responsible for bile formation. Bile is a greenish-yellow salt solution consisting primarily of bile salts, phospholipids, and bile pigments (**bilirubin**).
- Hepatocytes synthesize the bile salts from cholesterol. These salts assist in digestion and absorption of lipids (triglycerides), and the production and secretion of these salts is the most important digestive function of the liver.
- **Micelle** is the term for the small droplets formed in the intestinal chyme that contain lipids, bile salts, and products of lipid digestion. In all farm animals except the horse, bile is stored in the **gallbladder**. Since the **horse has no gallbladder**, the bile passes directly from the liver to the duodenum by way of the bile duct.
- Most of the bile salts released from the liver remain mixed with the digesta as it passes into the terminal part of the small intestine (ileum). Here, enterocytes reabsorb bile salts, which enter the blood. The reabsorbed bile salts are transported to the liver via the hepatic portal vein, and here hepatocytes take up the bile salts from the portal blood. These bile salts can then be secreted by the hepatocytes into bile for reuse. An increase in bile salts in portal blood, such as during the digestion of a meal, is the primary stimulus for bile salt secretion by hepatocytes. The recycling of bile salts between the digestive tract and the liver is **enterohepatic circulation**. The liver is capable of synthesizing **cholesterol**, and the liver makes much of the cholesterol in bile. The liver can also eliminate excessive dietary cholesterol via the bile.

Large Intestine:-

- The **large intestine** consists of the **caecum**, **colon** and **rectum**.
- The chyme from the small intestine that enters the colon consists mainly of water and undigested material such as cellulose (fibre or roughage).
- In omnivores like the pig the main function of the colon is absorption of water to give solid faeces. Bacteria in this part of the gut produce vitamins B and K. The caecum, which forms a dead-end pouch where the small intestine joins the large intestine, However in horses, the caecum is very large and called the **functional caecum**. Feces are also stored in the terminal portions of the colon prior to their movement into the rectum for defecation. In omnivores (e.g., pig) and some herbivores (e.g., cattle and sheep) the cecum and colon are also sites of some limited fermentation and microbial digestion.
- In cattle and sheep the cecum and colon are proportionally larger and more complex than in carnivores, but the fore stomach is the much more important site of fermentative digestion in these herbivores. Several times daily, strong and extensive mass movements of the colon move fecal material into the rectum.
- Distension of the rectum stimulates the need to defecate. The act of defecation requires contractions of smooth muscle in the wall of the rectum, and these result from a spinal reflex stimulated by distension of the rectum. Conscious control of defecation involves inhibition of the spinal reflex and contraction of the external anal sphincter, which is composed of skeletal muscle. Contraction of abdominal muscles increases intra-abdominal pressure, which also assists with emptying the rectum.

Caecum and Colon of the Horse

- The extremely large and complex caecum and great colon of the horse are the primary sites of fermentation and microbial digestion of cellulose. Roughage passes relatively quickly through the stomach and small intestine of the horse, but fermentative digestion and passage through the cecum and great colon may take days.
- Complex movements of the cecum and great colon mix the contents to promote fermentative digestion and to expose the contents to the epithelial surface for absorption of volatile fatty acids. When consumed with roughage, some starches and sugars escape digestion in the equine stomach and small intestine and pass into the cecum and colon. Microbial digestion of these and the cellulose in the roughage produces volatile fatty acids that can be absorbed and used for energy.
- Microbes in the cecum and colon can also use non protein nitrogen sources (urea) for the production of microbial proteins. However, these have limited nutritional value to the horse, because the gastrointestinal mechanisms necessary to digest proteins and absorb the resulting amino acids are not readily available in the cecum or colon. Some urea is made available to microbes by diffusing into the cecum and colon from the blood. Fermentation and microbial digestion produce volatile fatty acids, which could lower the pH of the caecal and colonic contents to potentially harmful levels. The colonic epithelium secretes bicarbonate ions to buffer the pH of the contents. Additional bicarbonate is secreted by the epithelium of the ileum, and this lowers the pH of the caecal content.

DIGESTION OF NUTRIENTS

- Enzymatic digestion of nutrients takes place in two phases
  - Luminal phase
  - Membranous phase
- Chemical digestion of each major nutrient is by hydrolysis glycosidic bonds in carbohydrates, peptide bonds in proteins, ester bonds in fats and phophodiester bonds in nucleic acids by the insertion of water molecule.
- Hydrolysis of nutrients in the digestive tract is catalysed by the action of enzymes secreted by salivary, gastric and pancreas glands. These glands pour their enzymes in the lumen of the GI tract for mixing with ingesta hence referred to as **luminal phase** of digestion. This phase of digestion results in incomplete hydrolysis of nutrients leads to the production of short-chain polymers of original macromolecule.
- In the **membranous phase** of digestion, the enzymes are synthesized within the enterocytes and transported to the apical membrane. Direct contact of these enzymes in the epithelium with the substrates derived from luminal phase of digestion exhibit final break down of the products of the short-chain polymers of luminal phase of digestion into monomers inside the epithelium of small intestine, hence referred to as membranous phase of digestion.

- It is followed by the absorption of end products of nutrients across the intestinal epithelium. .

Carbohydrate digestion

- Dietary carbohydrates are mainly monosaccharide's (Glucose, galactose and fructose) disaccharides (lactose and sucrose) and fibrous carbohydrates (cellulose, hemicellulose).
- Oligosaccharide's (maltose, isomaltose and maltotriose are rarely present in the diet, but they are formed in the gut during the course of carbohydrate digestion.
- Starches is present as amylose and amylopectin.

- In luminal phase of digestion, alpha amylase is secreted by the salivary glands (e.g. pig, dog and rabbit), and pancreatic amylase hydrolyses starches to yield oligosaccharides, whereas fibrous carbohydrates (e.g. Cellulose and hemicellulose) can not be hydrolyzed by alpha amylase of mammals.

- The oligosaccharides, di- and tri-saccharides are hydrolysed by saccharidases enzymes like maltase, isomaltase, sucrase and lactase in the membranous phase.
- In the glycocalyx of enterocytes, these enzymes hydrolyse the oligosaccharides (eg. maltose, sucrose and lactose) to monosaccharide's (glucose, galactose, and fructose).
- Most of the monosaccharide's are absorbed into the portal blood and carried to liver. some are also absorbed through lymph stream.

PROTEIN DIGESTION

- The proteolytic enzymes present in gastric, pancreatic and intestinal juices break the proteins in simpler form.
- In the luminal phase of digestion, gastric proteases (e.g. pepsin and rennin) and pancreatic proteases (e.g. trypsin, chymotrypsin, carboxy peptidase) yield oligopeptides and some amino acids.
- These oligopeptides are further hydrolysed by oligopeptidases in the glycocalyx to produce amino acids, di- and tri- peptides.

- In the membranous phase of digestion, the exopeptidases present on the enterocyte apical membrane act at the ends of peptide chain to release free amino acids at the surface of mucous membrane.
- Some long-chain peptides are incompletely hydrolysed leading to the production of di- and tri-peptides.
- These di- and tri-peptides are easily absorbed by the epithelial cells; where they are subsequently hydrolysed by the intracellular peptidases, forming free amino acids.
- Thus, the free amino acids are produced at two sites: on the surface of the enterocytes and the second within the cell.

LIPID DIGESTION

- Lipids make up a large portion of diet in carnivores, where as they form only a minor portion of diets in herbivores.
- Primary dietary lipid is triglyceride; other lipids include cholesterol and cholesterol esters from animal sources, waxes from plant sources and phospholipids from both plant and animal sources.
- Lipid digestion occurs in four phases; emulsification, hydrolysis, micelle formation and absorption**.**
- Emulsification is a process of reducing lipid droplets to a smaller size for their suspension in water.
- In the gut, lipid globules are broken down to droplets by the mixing and agitating actions of distal stomach.
- Emulsification is completed in the small intestine by the detergent action of bile acids and phospholipids.
- Bile salts reduce the surface tension of the lipid droplets and further, reduce in size of the fat droplets.
- The bile coated or emulsified droplets are subjected to hydrolytic enzyme action.
- Triglycerides are the major dietary lipid, undergo hydrolysis by the action of gastric, pancreatic lipase and co-lipase, which are secreted as active form.
- The co-lipase "make a pathway" through the bile product coating the emulsified lipid droplet, giving access to the lipase to reach the underlying triglyceride.
- Lipase cleaves the fatty acids from the end of triglyceride molecule resulting in the formation of two free nonesterified fatty acids and a monoglyceride.
- Cholesterol esterase and phospholipase are the other lipid digesting enzymes of pancreas.
- The products of these enzymes are nonesterified fatty acids, cholesterol and lysophopholipid**.** The fatty acids, monoglycerides etc., combine with bile acids and phospholipids to form very small lipid droplets, micelles . The micelles are water soluble allow the lipids to diffuse through glycocalyx and into close contact with absorptive surface of the enterocytes.

ABSORPTION

- It is the process whereby the products of digestion and the digested foodstuff form the lumen of the gut is transferred to the blood or the lymph across the epithelial cell membrane.

Site of absorption

- No absorption of food or end products of digestion in the mouth and oesophagus
- In the monogastric animal, absorption in the stomach is very limited.

- However certain drugs can be absorbed from the pharynx and to a limited extent from the oesophagus.
- The small intestine is the chief site of absorption in the carnivores and omnivores.
- Villi is the the chief site of absorption in small intestine
- The large intestine is the chief organ of absorption in all herbivores (eg. horse) and to a limited extent in the carnivores and man where it is restricted to the initial colon.
- In ruminants, the digestion and absorption of contents is of special importance in the anterior part of the digestive tract.
- The large intestine has specific absorptive sites with respect to water and electrolytes.
- In herbivores, especially in equines, the large intestine absorbs volatile fatty acids and ammonia.

ROUTES OF ABSORPTION

Small intestine has extremely well developed lymphatic and blood system which function as a route of absorption of digestive products.

- Lymph
  - In the core of the villus lymph capillary originates as lacteal near the tip of the villus and enters into a plexus of lymph vessels lying just on the inner side of the muscular coat. Branches of these plexus then enter into the submucosa and form a loose plexus of large lymphatics, finally pass into mesentry.
  - The lymph capillaries drain their content into large lymph vessels, which intern empty into the mesentric vessels. These mesentric vessels are then connected with mesentric lymph nodes. The contents of the mesentric vessels empty into the cisterna chyli which is continued forward as thoracic duct, finally empties into the venous system anterior to heart.
  - Glycerides, long chain fatty acids, cholesterol and the immuno globulins during the first 24 hours of life are absorbed by the lymphatic system. The rate of lymph flow increases after a meal.
- Blood
  - Each villus contains several small arteries, which enter the base of the villus and form a dense capillary network immediately under its epithelium. Near the tip of the villus, one or two veins arise from a capillary network and run downward.
  - The venules and veins, drain into the portal vein. The portal vein enters into the liver where its blood is mixed with that of hepatic artery. The hepatic vein conveys the blood from the liver to the posterior vena cava.
  - Amino acids, monosaccharides, free glycerol, water, inorganic salts and short chain fatty acids are absorbed through blood route. After a meal, rapid flow of blood causes increased absorption rate, but this increase is less than that of lymph

MECHANISM OF ABSORPTION

- The possible mechanisms of absorption are broadly classified into three groups:
  - Non-carrier mediated transport (passive diffusion)
    - It depends on the electro-chemical gradient, occurs through channel pathways of ions.
    - Non-carrier mediated process aids in the absorption of short chain fatty acids, inorganic salts and lipid soluble compounds.
  - Carrier mediated transport – includes
    - Facilitated transport from higher to lower concentration
    - Exchange diffusion Na+/H+ exchanger: transports H+ out and Na+ into the cell
    - Active transport against concentration gradient with expenditure of energy
      - The carrier-mediated process may help water-soluble materials to pass the lipid layer of the cell membrane, whereas glucose and amino acids are absorbed by active transport.

Pinocytosis transport of intact luminal materials in the form of vacuoles into the mucosal cells. This is important for absorption of intact proteins and intact triglycerides.

CARBOHYDRATE ABSORPTION

Carbohydrate absorption

- Monosaccharides (eg. glucose, fructose) are absorbed by active transport mediated by carrier and sodium pump

Absorption of glucose

- Glucose gets attached to specific transport proteins that lie on the luminal side of the enterocytes. These transport proteins have two binding sites one for glucose and one for sodium.
- Once glucose and Na^+ occupy the binding sites, the transport protein moves across the cell membrane and unload the glucose and Na^+ into the cell. Hence, this process is referred to as sodium co-transport.
- The transport of glucose will not occur unless Na+ is present.
- Within the cell, glucose moves down by concentration gradient through the basoleteral membrane by facilitated diffusion, to extra-cellular space and then into the blood and finally to liver where the monosaccharides are stored as glycogen.

- Galactose is absorbed more rapidly than glucose but fructose absorption is slower than glucose absorption.
- Fructose absorption is by facilitated diffusion and not energy dependent. Hence, fructose can not be absorbed against concentration gradient.
- Mannose, xylose and arabinose are poorly absorbed by diffusion.
- Maltose, sucrose and lactose as such are absorbed very slightly.
- Disaccharides do not generally enter into the blood stream because of the presence of disaccharidases in the brush border of mucosa, which converts them to monosaccharides.

PROTEIN ABSORPTION

- The free amino acids are readily absorbed chiefly by active transport requiring Na -co transport system
- Three types of carriers are involved in the transport of acidic, basic and neutral amino acids.
- L-isomer forms of plant and animal protein are more readily absorbed than D-isomers, acidic basic and meutral amino acids
- Some di and tri peptides are also absorbed. Intracellular peptidase hydrolyses these peptides to amino acids.
- Intracellular amino acids diffuse across the basolateral membrane to reach liver via portal blood, whereas intact proteins are absorbed via lymph pathway.
- Immediately after birth immunoglobulins from colostrum are absorbed by a process of pinocytosis particularly in lambs, piglets, kids, calves and pups.
- The immunoglobulin absorption decreases with time after birth and ceases after 24-36 hours.

LIPID ABSORPTION

- Lipid absorption begins in the dental duoderium and ends in proximal part of the jejunum.
- As the micelles come in close contact with surface of enterocytes, the lipid components diffuse through the glycocalyx to the apical membrane by a special fatty acid binding proteins which aids the transport the fatty acids across the cell membrane.
- Other components in the micelle such as monoglycerides, cholesterol and vitamin A diffuse into the apical membrane.
- Bile salts get detached from the micelles during fat absorption and remain in a free state. In the ileum, Na-co transport system function as specific bile acid transport which nearly complete the absorption of bile salts.
- After absorption, the bile salts are transported to liver by the portal blood.
- The liver extracts bile acids and maintains the normal concentration of bile acids in systemic blood. This process of recirculation of between liver and intestinal lumen is referred as enterohepatic circulation of bile.

- Glycerol is absorbed by passive diffusion into the mesentric venous blood.
- Short chain fatty acids up to C^{10} are water-soluble get into mesentric portal blood.
- Monoglycerides and long chain fatty acids enter the microvilli and pass on to the lacteal by simple diffusion.
- Only free form of cholestrol can be absorbed, whereas cholestrol esters must be hydrolyzed by pancreatic brush border hydrolases..
- Cholesterol is absorbed less efficiently than triglycerides. Presence of hydro cholesterol or plant sterols inhibits cholesterol absorption.
- In the epithelial cells, cholesterol is re-esterified before their transfer to lacteals.
- Before absorption phospholipids are hydrolysed to free fatty acids and lysophospholipids by phospholilpase of pancreas and intestinal epithelium.
- Within the epithelial cells, long chain fatty acids are converted into fatty acyl-CoA involving co-enzyme A and ATP.
- The fatty acyl co-enzyme reacts with monoglycerides to form di and tri glycerides.
- The newly formed triglycerides differ from that of dietary fat. GlycerolPO_4 derived from glucose metabolism provides glycerol residue for the triglyceride synthesis.
- In addition, phospholipids and cholesterol esters are produced in the epithelial cells. Small amounts of proteins are added to the lipid droplet before their transfer from epithelial cells to lymph.
- Chylomicrons are the products containing high amount of triglycerides, low level of phospholipids, cholesterol esters and proteins. They leave the cell by reverse pinocytosisand enter into the lacteals.
- Lipid absorption begins in the distal duodenum and completed in the proximal jejunum.
- The absorbed fat is in the form of an emulsion and imparts a milky appearance to the lymph,called as “chyle”**.** This leave the cell by reverse pinocytosis and enter in the lacteal. Though lymphatic channel and thoracic duct it is added into the blood for its distribution to tissues.
- Short chain fatty acids are absorbed by blood from colon and caecum in sheep and horse and ceecum in pigs

MECHANISM AND ABSORPTION OF MINERAL AND WATER

- Sodium is transported as sodium co-transport along with glucose and amino acids.
- Sodium transport is also coupled transport with chloride ion
- Sodium ion also shows diffusion across the electrochemical gradient.
- Potassium is transported by passive diffusion across the concentration gradient
- Bicarbonate ions are transported actively or rarely with sodium ion.
- Magnesium ion is transported actively, but poorly absorbed.
- Calcium ion is also transported actively by the calcium-binding protein produced under the influence of vitamin D_3
- Phosphorous is actively absored related to calcium absorption.
- Copper ion is absorbed in small quantities.

- Cobalt and manganese ions are readily absorbed.
- Iron absorption is related to its level in mucosal cells and is mediated by apoprotein carriers.
- Water is transported passively

ABSORPTION OF VITAMINS

Absorption of vitamins

- Fat soluble vitamins (A, D, E, K) pass through the intestinal mucosa by passive diffusion.
- Water soluble vitamins (except B12) are also absorbed by passive diffusion but may also be transported actively.

  - Vitamin B12 requires an intrinsic factor, secreted by the gastric glands of the stomach, for its absorption by and active transport process

THE RESPIRATORY SYSTEM

Respiration is the process of exchange of gases in which oxygen is inhaled/inspired in and carbon di oxide is exhaled/expired out.

Functions of Respiratory system:

Primary functions of the Respiratory system is delivery the oxygen (O_2) in and removing the carbon dioxide (CO_2) out. Exchange of gases between blood and lungs at the level of alveoli.

Secondary functions of respiratory system include:

1. Regulation of pH of body fluids.
2. Assists in the control of body temperature.
3. Production of voice i.e. phonation.

Respiratory acidosis:

Accumulation of CO_2 in the blood because the respiratory system not able to remove it is called respiratory acidosis. As the amount of acid accumulation.

Respiratory Alkalosis:

Blood pH increases if the respiratory system removes more CO_2 than appropriate and blood level of CO_2 are lower than the normal.

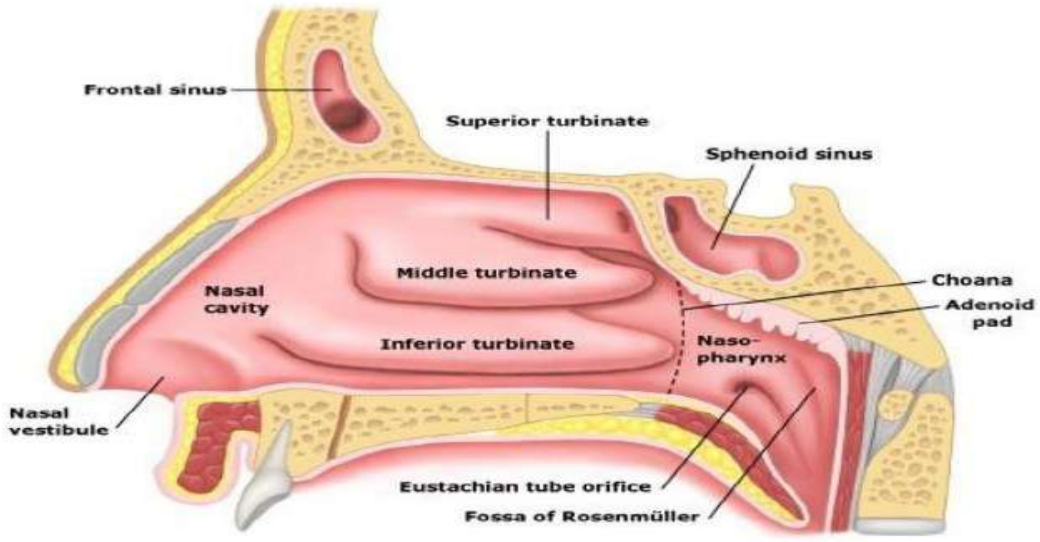
The changes in the CO_2 and pH are closely linked because of the chemical reaction shown in the equation: $\mathrm{H_2O + CO_2 \rightleftharpoons H^+ + HCO_3{}^-}$

The bicarbonate ions and water molecules are readily available in the body fluids. The respiratory system consists essentially the lungs and the passage that conduct air into and on inside the lungs: the passage includes nostrils, nasal cavity, pharynx, larynx, trachea and bronchi.

Nasal Cavity:

Nasal cavity is separated from the mouth by hard and soft palates and is separated into two halves by a median nasal septum which is cartilaginous. Nose of the animals, comprises parts of the face rostral to the eyes and dorsal to the mouth. The external nares (nostrils) the external opening of resp. system are highly variable in size and shape, nostrils largely have nasal cartilages.

The nasal cavity is lined by mucous membrane that covers number of scroll like conchae (turbinate bones). The two major conchae (dorsal conchae and ventral conchae) occupy the rostral part of the nasal cavity. It contains the sensory endings of olfactory nerve (cranial nerve) power to small.



Nostrils:

There are 2 nasal nares, nostrils. Nasal cavity has two wings (alae) which make commissures. The upper one superior or upper commissure which is short. The lower one is interior or lower commisure which is long and round. There opens a naso lacrymal duct.

The air space of each half of the nasal cavity is divided by the conchae into several meatuses.

- The **dorsal nasal meatus** is between the dorsal conchae and the roof of the nasal cavity.
- The **middle nasal meatus** is between the two conchae.
- The **ventral nasal meatus** is between the ventral conchae and the floor of the nasal cavity.
- The common nasal meatus communicates between others and is adjacent to the nasal septum.

Pharynx:

The pharynx is a common soft tissue meant for food and air, lying caudal to the oral and nasal cavities opening into the pharynx include:

- Two caudal nares (choanae)
- Two auditory (Eustachian tubes) from the middle ear
- The oral cavity
- The larynx and
- The esophagus

The walls of the pharynx are supported by the striated muscles whose action assist in deglution (swallowing) and phonation.

Larynx:

Larynx is the gatekeeper to the entrance of trachea it maintains a rigid, boxlike shape via a series of paired and unpaired cartilages. These cartilages move relative to another by striated laryngeal muscles.

Functions:

- To regulate the size of airway
- To prevent any kind of entry of food into trachea
- Capable of increasing the diameter of the air passage way during exercise (forced inspiration)
- Organ of phonation (vocalization) common name voice box.

Contraction of muscles in the larynx changes the tensions on ligaments that vibrate and thus vibration produces the voice.

- To dorsal side is pharynx and esophagus
- Ventral side is skin and muscles
- Lateral side – parotid glands and mandibular glands
- Medial side has muscles.

Mucous membrane lined by cartilages make up the larynx of domestic animals.

Arytenoid cartilages: are two irregular shape, contraction in arytenoid cartilages are meant to tighten or loose the vocal cords

Crycoid cartilage:

Shaped like signet ring that is attached to first cartilaginous ring of the trachea caudally.

Thyroid cartilage:

The largest part of larynx, make its base and attached to muscles.

Epiglottis:

Acts like a lid that opens up at the entry of air from larynx to trachea it closes when food passes from pharynx to the esophagus.

All cartilages are joined with ligaments and member.

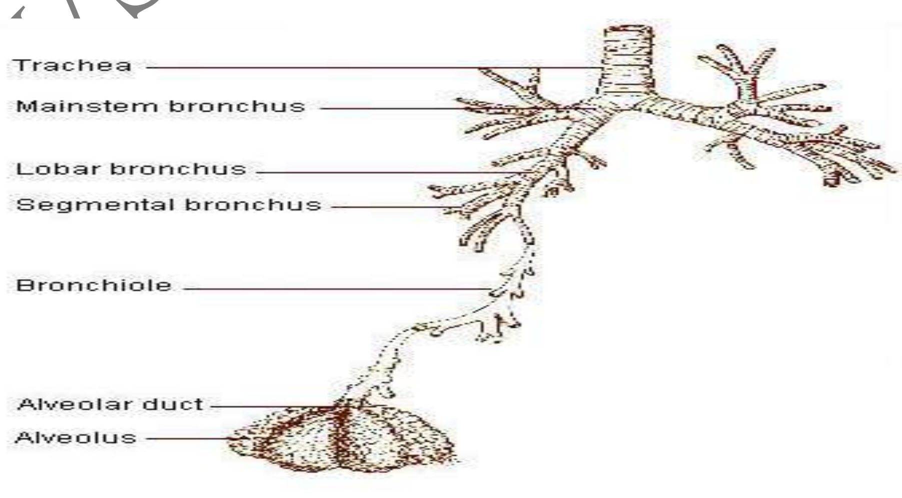
Trachea:

Trachea extends from the caudal end of the larynx to bronchi. It is formed by the series of **C** shaped hyaline cartilage that provide rigidity to prevent the collapse of trachea. They are joined by one to another by elastic annular ligaments that provide trachea considerable flexibility to follow movements of the neck.

Bronchi:

The trachea passes as far as the base of the heart where it divides into two principal branch one for each lung. The ruminants and pigs have additional branches.

Arising cranial to principal bronchi, it supplies the cranial lobe of the right lung. The principal bronchi branch into secondary then tertiary bronchioles subsequently smaller and smaller cartilaginous plates are there to support the walls of these bronchi. Every tertiary or respiratory bronchiole divides into alveolar ducts. The duct then branches into alveolar sacs, the alveolar sac ultimately dividing into several alveoli. It is here that the exchange of gas with blood takes place.



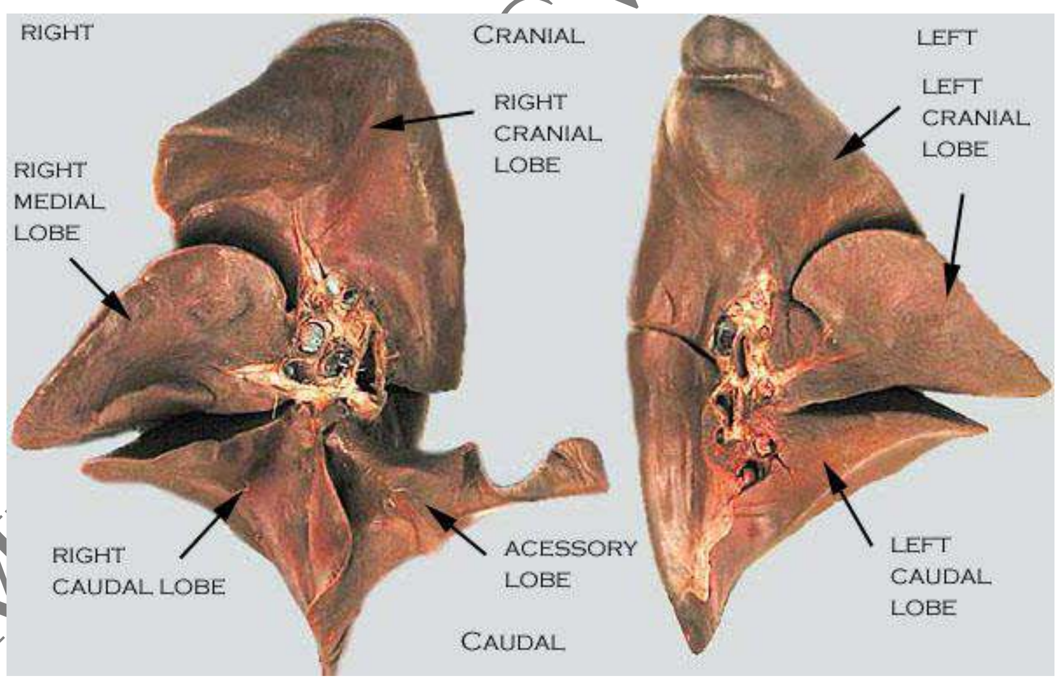
Thoracic cavity is bound cranially by first pair of ribs, first thoracic vertebra and the cranially by sternum. The dorsal part is lined by the thoracic vertebrae and epaxial muscles and ligaments and the ventral part by the sternum. The ribs and costal cartilages linked by the intercostal muscles make the lateral walls.

Lungs:

Each lung is roughly conical with the base resting against the cranial side of the diaphragm while the apex upwards. The medial aspect of each lung features an indentation the hilus, where the principal bronchus, pulmonary vessels, lymphatic's and nerves enter and leave the lung.

In ruminants the left lung is divided into cranial (apical) and caudal (diaphragmatic) lobes and cardiac middle lobe. The right lung in these animals is divided into four lobes, cranial and caudal lobes on the left plus a middle lobe between these and an accessary lobe or intermediate lobe.

A distinct gap between lobes along the ventral margin of the lungs is identifiable. This is called cardiac notch and it tends to be larger on the right side.



Para nasal Sinuses:

Many of the cranial bones that contain air filled cavities, Para nasal sinuses that communicate with the nasal cavity. These sinuses provide some protection and insulation to the head. All farm animals have maxillary, frontal, sphenoidal and palatine sinuses in the bones of the same name. In horses, several upper teeth project into maxillary sinuses, which may become infected with/by diseased teeth. The frontal sinus is especially capacious, in horned cattle, an extension of the frontal sinus, the corneal diverticulum, extends well into the bony core of the horn. The exposure of the frontal sinus leads to infection, when dehorning of animals of more than ¾ months is done.

PLEURA: - The thoracic cavity is lived by a serosal layer, the pleura. The smooth surfaces of the pleura are lubricated with scanty amount of serous fluid, facilitating frictionless movement of the lungs during respiration.

The pleura consist of two separate sacs, one surrounding each lung. The pleura that lines the thorax is the parietal pleura and the pleura that covers the lungs is the visceral pleura. The space between the parietal and visceral pleura, the pleural cavity. This pleural cavity contains small amount of serous fluid; conditions that introduce fluid or gas (e.g. pus, blood, air) into pleural space compress and may collapse the lung, in that space.

The junction of the two pleural sacs near the middle line of the thorax forms a double layer called the mediastinum, in which are found the heart, great vessels, esophagus and other midline structures lungs. The caudal vena cava and the right phrenic nerve (nerve innervating the right side of the diaphragm) are enclosed in a distinct fold of pleura, the plica venae cava.

Spirometry- Measurement of various volumes of air breathed in and out and measured by spirometer.

Pulmonary volumes and capacities:-

- **Tidal volume/Pulmonary ventilation (VT):-** It is the volume of air that is taken in or giving out during normal breathing.
  Pulmonary ventilation is the product of tidal volume and respiratory rate.

Pulmonary ventilation = $V_T \times$ Respiratory Rate

- **Inspiratory capacity:-** this is the volume of air that can be inspired after normal expiration.

$I_C = V_T + IRV$

- **Inspiratory Reserve Volume (IRV):- It** is the extra volume of air that can be inspired in addition to normal tidal inspiration.

$IRV = I_C – V_T$

- **Expiratory Reserve Volume (ERV) :-** It is the amount of air that can still be expired by forceful expiration after the end of normal tidal expiration.
- **Vital Capacity (VC):-** It is the maximum amount of air that can be inhaled after maximum amount has been exhaled.

$V_C = V_T + IRV + ERV$

- **Residual volume (RV) :-** it is the amount of air which remains in lung after maximum expiration.

$RV = TLC – VC$

- **Total Lung Capacity (TLC) :-** It is the amount of air total inhaled, exhaled and that remained in lungs after forceful expiration.

$TLC = VC + RV$

- **Functional Residual Capacity(FRC) = ERV + RV :-** It is the volume of air remaining in lungs after a normal expiration.

$FRC = ERV + RV$

- **Dead Space Volume (VD):-** it is the amount of air locked up in the air passages i.e. nasopharynx, trachea and bronchi and this air does not participate in respiratory processes.
- **Minute Ventilation (MV)/Pulmonary ventilation/Respiratory Minute Volume:-**

It is the volume of air breathed in or out in one minute during quite respiration

$V_T \times$ Respiratory Rate = Minute Ventilation

- **Alveolar Ventilation (AV) :** The volume of air actually involved in gaseous exchange in alveoli in one minute.

(VT - VD) × Respiratory Rate = Alveolar Respiration/Alveolar Ventilation

- **Maximum Voluntary Ventilation (MVV) :** It is the volume of air which can be moved in or out of lungs with maximum voluntary effort during one minute.

MVV = VC × Respiratory Rate

- **Breathing Reserve:-** It is the extra capacity of lungs to inspire and expire additional to normal breathing in one minute.

B. R. = MVV – MV

- **Breathing Reserve Index or Dyspnea Index:-**

$$\frac{\text{MVV} - \text{MV}}{\text{MVV}} \times 100$$

Normal Dyspnea index is 90 – 92% and if it is 60 – 70% , then Dyspnea condition will be there and individual will be patient.

Diffusion capacity of lungs:

It is the quantity of a gas that diffuses each mm Hg difference in partial pressure of this gas across the respiratory membrane.

It is 20 ml per minute per mm Hg for oxygen.

It is 10-30 ml/min/mm Hg at rest for CO_2 .

Spirogram:- Record of Respiration obtained by spirometer is called spirogram.

Broncho constriction: - Induces the resistance to air flow and this occurs because of some parasympathetic nervous system activation and release of acetylcholine takes place which causes constriction of smooth muscle.

It occurs in case of asthma and allergy. Artificially it can be done by PGE_2 broncho constrictor.

Some bronchodilators are used to compensate bronchoconstriction which is accomplished by sympathetic nervous system.

Drugs:-

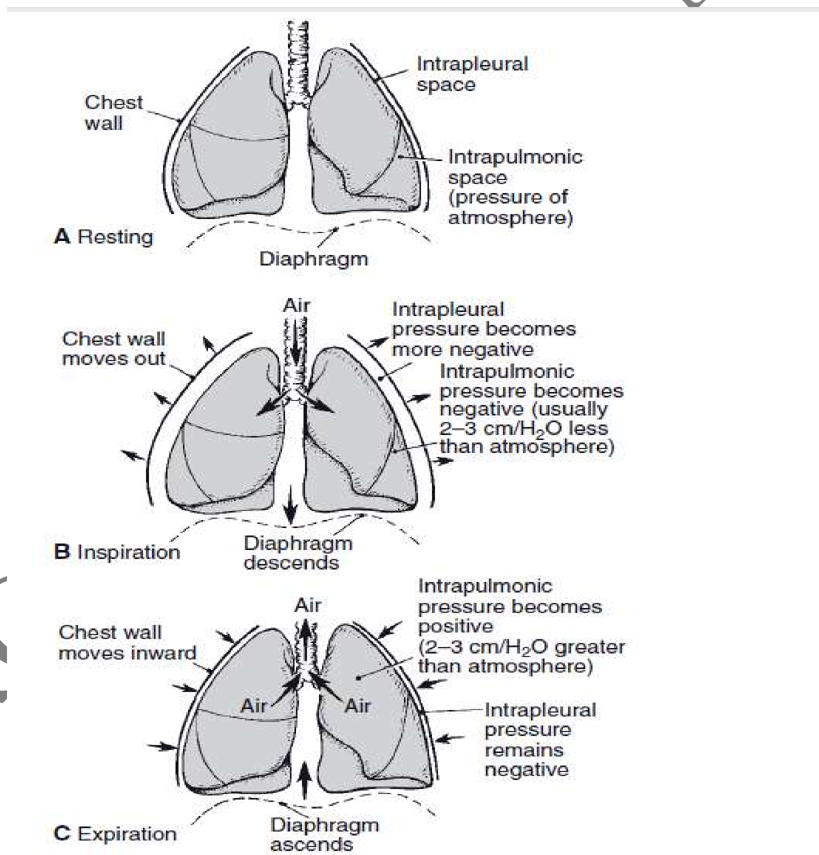
Short acting beta against	–	Salbutamol
Long acting beta agonist	–	Formoterol
Anti-cholinergic	-	Ipratropium bromine

These drugs regulate the diameter of bronchi by bronchodilator by acting on different receptors present on bronchi.

- **Total ventilation:-** is how much gas is been exchanged per unit time.
- **Minute Ventilation:-** MV = Tidal volume × Respiratory Rate
- **Dead space volume**: Amount of air which is not related with exchange of gases.

- **Anatomical dead space** is the space in the respiratory track which stores gases which is not associated with gas exchange.
- **Physiological dead space** is the extra volume of air stored due to fibrosis of alveoli or bursting of alveoli etc.
- **Panting:-** Air is not taken deep into lungs. It is a condition of shallow and rapid rate of respiration due to increased physiological dead space.
  Panting regulates the body temperature by evaporating water from moist mucus membrane.
- **Perfusion**- it is the supply of gases in blood

Ventilation: -**Ventilation** is the process by which air is moved into (**inspiration**) and out of (**expiration**) the lungs.



Gas Laws:

1. **Boyle's Laws** - Volume of gas is inversely proportional to pressure when mass and temperature is kept constant.

2. **Charles's Law** – where volume of gas is directly proportional to temperature at constant pressure.
3. **Henry's Law** – volume of gas dissolved is directly proportional to pressure and solubility coefficient. CO_2 is 22 times more soluble than O_2 and nitrogen is half that of O_2.

Partial Pressure: Pressure exerted by a gas in the mixture of gases. Sum of all partial pressures is called total pressure.

E.g. O_2 concentration at 760 mm Hg in atmospheric air is 20.93%

So PO_2 = $760\frac{20.93}{109} = 159\text{mm Hg}$

Enlargement of the thoracic cavity is accomplished by contraction and flattening of the dome-shaped **diaphragm** and a forward and outward movement of the ribcage by the contraction of appropriate thoracic muscles. These are skeletal muscles innervated by somatic motor nerves. **Forced expiration** is an active process that forces more air from the lungs than would occur during a normal passive expiration. Forced expiration requires contraction of abdominal muscles to force viscera against the diaphragm and contraction of other muscles to pull the ribs caudally.

Fick's Law of Diffusion :-

According to this law, the amount of gas transported across the membrane is directly proportional to area of sheet and inversely proportional to thickness of sheet.

$$\text{amount of gas} = \frac{\text{area of sheet}}{\text{thickness of sheet}}$$

Gas Exchange

The oxygen and carbon dioxide concentrations in air can be described in two ways: **partial pressures** and **percentages.** Room air is approximately 21% oxygen and 0.3% carbon dioxide. The primary component of room air is the inert gas nitrogen (about 78%). The partial pressure of an individual gas in a mixture of gases is the product of the percentage of the individual gas in the mixture and the total **barometric** or atmospheric pressure.
Thus, at sea level, where atmospheric pressure is 760 mm Hg, the partial pressure of oxygen in room air is approximately 160 mm Hg.

Gas exchange between the blood and alveolar air in the lungs occurs across the walls of alveoli. At its thinnest point, the alveolar wall barrier between blood
Plasma and alveolar air consists of the endothelial cell of pulmonary capillaries,

Exchange begins as soon as blood enters a pulmonary capillary from pulmonary arterial vessels and continues until equilibrium between alveolar air and plasma is reached.

Oxygen (O_2) Transport-

Majority of O_2 is carried by Hemoglobin and one Hb molecule contains 4 haeme and 4 globin chains and oxygen mixes with Hb due to its partial pressure and solubility which is called Henry's law.

Diffusion gradient occurs at lung and tissue levels when it reaches at tissue and lungs alveoli. Small amount of O_2 is transported by dissolving in plasma.

One mol Hb – carry 4 mol oxygen.

One gram of Hb carries 1.34 to 1.39 ml of oxygen.

Transport of CO_2 - CO_2 is easily diffused to lungs and tissue. About 10% of CO_2 dissolved in plasma form is transported.

CO_2 in Plasma: Dissolved and combined with NH_2 group of plasma protein and form carbamino compound. About 10% CO_2 is in the form of carbamino compound is transported because there are few free amino groups on plasma protein.

About 90% of CO_2 is transported through RBC because carbonic anhydrase enzyme is present which favours for formation of H_2CO_3 while this enzyme is absent in plasma and so CO_2 is not transported as H_2CO_3 in Plasma

Venous blood has more affinity for CO_2 than arterial blood.

- **Respiratory quotient** = $\frac{CO_2 \text{produce}}{O_2 \text{consumed}}$

  E.g. R. Q. = $\frac{4\%\text{volume}}{5\%\text{volume}} = 0.8$

  I.e.5 volume of O_2 is given to produce 4 volume of CO_2.

Exchange of gases at tissues:- Cells in peripheral tissues consume oxygen and produce carbon dioxide during normal metabolism. This maintains relatively low oxygen and high Carbon dioxide concentrations (partial pressures) in the extracellular fluid around capillaries. As arterial blood enters capillaries, partial pressure gradients promote the diffusion of oxygen out of the blood to the interstitial fluid and carbon dioxide from the interstitial fluid into the blood

Surface Area: - more is the surface area, more is diffusion and this is controlled by rate of respiration and it will be more in exercise condition when there is more requirement of oxygen.

Thickness of air blood barrier – more is thickness, less is diffusion.

Molecular wt. and solubility of gas -- more is solubility, more is diffusion.

Regulation of Respiration:-

1. **Respiratory Centre** present in brain stem which is distributed over pons and medulla oblongata region. This mechanism is involuntary and remains active itself.

Respiratory group present in medulla is responsible for inspiration and it sends signal through phrenic nerve to diaphragm to contract it.

Dorsal mechanoreceptors and chemoreceptors also sends signal through vagus and glossopharyngeal nerve to control inspiration.

Ventral respiratory group present in medulla is responsible for expiration mechanism and this group becomes more active during exercise to accommodate increased demand of O_2.

2. **Pneumotaxic Centre** – present in anterior pons and control inspiration by inhibiting it.
3. **Apneustic Centre –** present in posterior pons ,control deep inspiration and causes apneusis.

Neural control of Respiration –

1. **Inflation** of stretch receptors in air sacs and lungs sends signals through vagus nerve to respiratory Centre and inhibit inspiration and stimulate ventral respiratory group and increase expiration. This is to control over inflation of lungs. These receptors give a reflex called **hering – Breure reflex or Inspiration inhibitory reflex or inflation reflex.**
2. **During deflation** condition, when expiration is going on lungs will constrict and to control it proprioceptors sends signals through vagus nerve to dorsal respiratory Centre to stop or inhibit expiration and initiate inspiration. This is called hering breure deflation reflex or Inspiratory Reflex or Deflation Reflex.
3. **Skin Receptors** also control deep respiration through apneustic Centre. These are mainly present in new born. These receptors sends signal through peripheral

nerves to apneustic Centre and initiate respiration in new born, when it doesn't have respiration.

4. **Tendon and joint receptors** during muscle contraction sends signal to brain (Cerebral cortex) and there will be control of respiration.
5. **Receptors in upper respiratory tract** – normally these are inhibitory in nature.

Respiratory response to exercise-

When there is any type of stress to body and there will be increase in O_2 consumption and increase CO_2 production and this is met by increased ventilation and receptors of joints and muscles sends signal to brain to increase ventilation.

Splenic contraction- increase RBCs and there will be more transport of O_2 and seen in dog and equines.

Non respiratory lung functions-

Respiratory Clearance-

During air inspiration there are certain dust, bacteria, virus etc. in air and they are removed by lungs by different forces.

Physical forces-

1. Gravitational force- These are trapped by nasal cavity and tracheo bronchial tree.
2. Inertial force- in nasal cavity, pharynx and tracheobronchial tree.
3. Brownian motion – small airway and alveoli are present to stop movement of these particles.

Coughing – stretch receptors in bronchi comes in contact with foreign substance and then these are activated and remove mucus from trachea and bronchi from airways by coughing.

Hypoxia – decrease PO_2 in air, blood and tissue.
Anoxia – complete absence of O_2.
Hypoxemia – decrease O_2 conc. In arterial blood.

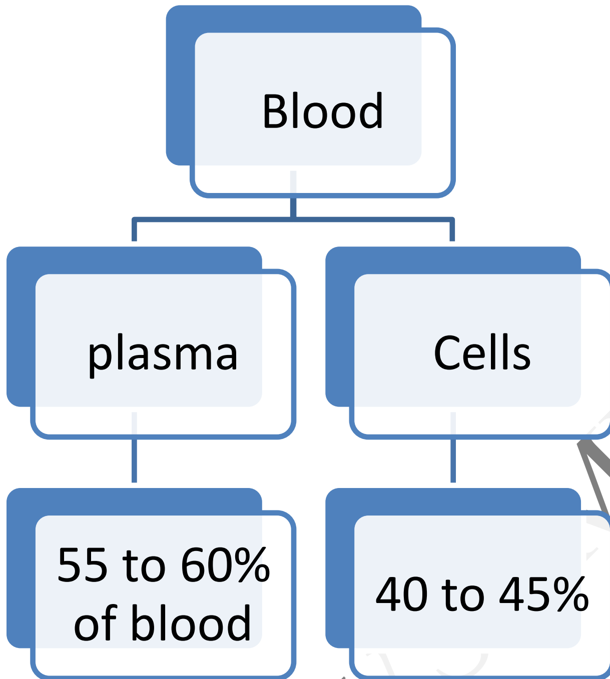
Types of Hypoxia-

1. Ambient hypoxia- decrease in PO_2 in atmospheric air e.g. at high altitude.
2. Anemic hypoxia- PO_2 may be normal but O_2 carrying capacity is decreased due to less Hb.
3. Stagnant hypoxia- due to obstruction in blood flow.

4. Histo-toxic hypoxia- when tissues are not able to utilize O_2 which is present at normal level in arterial blood due to this venous blood conc. Of O_2 is increased.

- Eupnoea – normal breathing
- Apnea – temporary stoppage of breathing
- Dyspnea – difficult/labored breathing due to injury of some muscles.
- Hyperpnoea – increase frequency, depth
- Tachypnea – increase respi. rate
- Bradypnea – decrease respi. rate
- Polypnea – increase respi-rate – rapid, shallow or panting.
- Hypercapnia (hypercarbia) – increase $PaCO_2$.
- Hypocapnia (Hypo carbia)- decrease $PaCO_2$.
- Cyanosis- due to decrease Hb – bluish mucus membranes
- Asphyxia – obstruction in airway or decrease in O_2 in air or increase in CO_2 in air and whole will lead to suffocation.
- Pneumonia – inflammation in lung alveoli and due to that accumulation of fluid will be there.
- Atelectasis – alveoli fail to open or remain open.

THE CIRCULATORY SYSTEM



Blood can be defined as a fluid connective tissue corpuscle and other particles suspended in colloidal medium called plasma.

Cells: There are three types of cells in the blood viz red blood cells (RBC), white blood cells (WBC) and platelets.

1.) **Plasma:** In plasma mainly water is present about 90%. Rest 10% are the minerals dissolved as sodium, potassium, chloride, amino acids, vitamins, fatty acids.

Plasma is yellow to colorless, depending on the quantity, species of animal and animal's diet. In some species, such as dog, cat, sheep, goat plasma is colorless or slightly yellow in cow and dark yellow in horses. Colour of plasma is due to the presence of varying quantity of bilirubin and carotene like pigment in blood plasma.

2.) **Blood cells:** Blood cells are mainly three types.

A.) **Red blood cells (Erythrocytes):** it as also known as Erythrocytes. These cells are biconcave and non-nucleated in animals including man. In birds these are round and nucleated in nature. In RBC water is present about 65% & protein is about 33% called hemoglobin. The average size of RBC is about 5-7µ (micron) and 1µ = 1mm/1000 cubic mm. In animals RBC are present about 7×10^6 (70 lakhs). Haemoglobin found in RBC's is a transport medium for O_2 and CO_2.

With O_2 Hb forms oxyhaemoglobin and with CO_2 it forms carboxyhaemoglobin.

Origin of RBC:

Stages of development	**Sites of RBC development**
Early fetal life	Yolk sac
Late fetal life	Liver, spleen, and lymph nodes
Young animals	Bone marrow of long bone
Older animals	Flat bones like ribs, sternum, vertebrae

The life of RBC is 120 days only.

RBCs are destroyed in spleen by phagocytosis. These dead cells are replaced by new cells.

B.) **White Blood Cell (leukocytes):** leucocyte is a combination of two words that are leuko and cytes it means white cells. WBCs are comparatively lesser in number than RBCs. Life of WBC is in hours for granulocytes and in months to year for agranulocytes.

Classification of WBC:

Granolocytes	Agranolocytes
Neutrophil	Lymphocytes
Eosinophil	Monocytes
Basophil	

a.) **Neutrophil:** The nucleus of each mature neutrophil is generally divided into lobes or segments connected by filaments. The cytoplasm contains granules that stain with neutral dyes. The size of these cells is double of RBC i.e. about 12µ. These cells are produced in the bone marrow. They make 35 to 55% of total number of WBCs.

b.) **Eosinophil:** These are larger cells containing numerous large sized cytoplasmic granules that stain with acid dyes. The nucleus of these cells is less lobulated and usually contains two lobes. This cell comprises 5 to 10% of total WBCs.

c.) **Basophil:** The basophils originate from the bone marrow and a very less in number in circulation. The nucleus of the cell is elongated or bends in "S" form. The basophilic granules within the cytoplasm of the cell vary among the species.

d.) **Monocyte:** The monocytes are agranular type of leukocyte. These cells are originated in spleen and bone marrow. These cells are originated from the monoblast with intermediate stage as promonocyte and ultimate mature cell is monocyte. It is the largest cell of the blood measuring 12-22µ in diameter with oval or horse shoe shaped nucleus.

e.) **Lymphocytes:** These cells are formed in the lymph nodes, lymph tissue, spleen, tonsil, thymus and Peyer's patches. The chromatin materials of nucleus take a deeper stain. The nucleus is larger and round and is placed a little eccentric with a thin rim of cytoplasm. This helps easy identification of lymphocytes in stained slide.

C.) **Platelets (Thrombocytes):** These cells are spindle shaped. These appear in the form of granules. Their size is less than RBCs and 2-4µ in size. Their number is about 4 lakhs (3.5-5.0 lakhs). They are formed in bone marrow. Platelets help in clotting of blood or coagulation of blood. Their life is 9-11 days and stored in spleen.

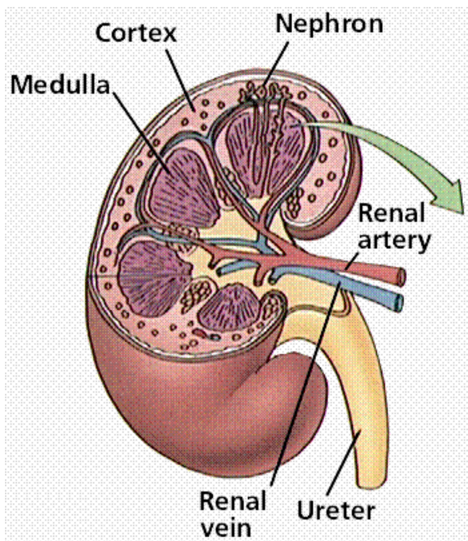
THE URINARY SYSTEM

The different end products which are harmful to the system are constantly excreted from the body through different channels.

The soluble non irritant solid substances and excessive water are excreted through kidney and skin. CO_2, ammonia, ketone bodies are excreted through the lungs and heavy metals through the GIT (gastrointestinal tract).

Kidneys and Associated Structures

Among all the channels of excretion kidneys are very important. Kidneys and Associated Structures are known as **urinary system.**



Structure of Kidney

Urinary system includes followings:

i) Two kidneys
ii) Two ureters
iii) One urinary bladder
iv) Urethra

The kidneys are situated in the **posterior abdominal cavity** it has a reddish brown peripheral structure called **Cortex** and central lighter is known as **Medulla.** Medulla is provided with an area called pyramids. A deep notch is present at the medial border of kidney called **hilus** through this region renal artery, vein, ureter and nerve passes.

The functional and structural unit of kidney is known as **Nephrons.**

Process of urine formation:

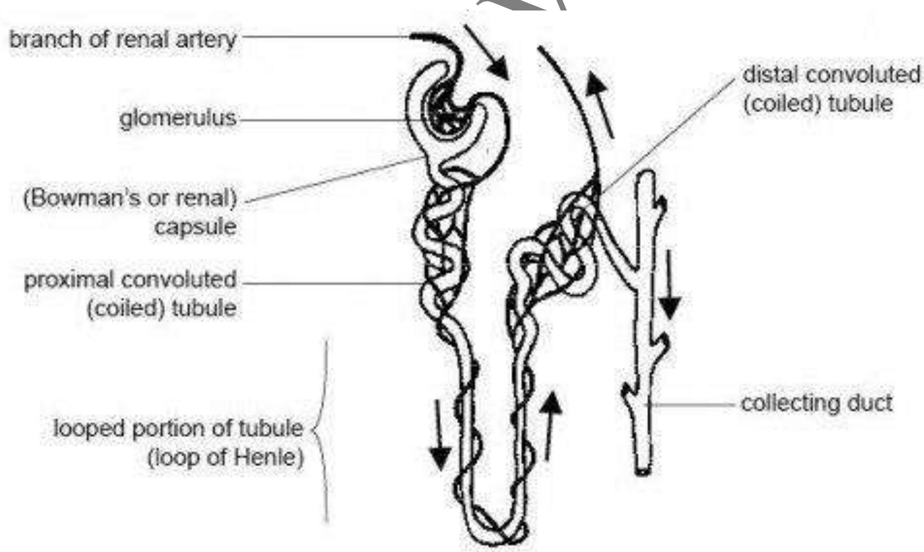
The formation of urine in the kidney takes place through three processes:

i) Glomerular filtration
ii) Tubular selective reabsorption
iii) Tubular secretion

Glomerular filtration and selective reabsorption:

The filtration of blood takes place in the glomerular capsule with a selective permeability within the vascular system and filtering out fluids containing electrolytes of plasma.

It is found that the characteristics other than size also affect the ability of the blood components for filtration. The net electric charge of the molecule has been found to influence the rate of filtration. Filtration is more in cationic form of the substance then neutral and then anionic form of the same molecule. This is possible due to presence of charge selective barrier in the glomerular capillary wall. However glomerular filtration rate is primarily determined by the effective filtration pressure.



Structure of nephron

Measurement of Glomerular filtration rate (GFR):

This measurement has clinical importance. Normally insulin clearance is considered to measure glomerular filtration rate and it has following physiological properties:

i) The substances should be easily filterable through the glomerular bed.

ii) It should be biologically inert i.e. it should be neither absorbed nor secreted by the renal tubule.

iii) It should be totally non toxic and should not influence the renal function in any ways.

iv) Suitable method should be available for the accurate estimation of the substance in the blood and urine.

Role of Antidiuretic hormone (ADH):- The availability of water permeability in collecting ducts under in the influence of hormone ADH. Under the condition of water excess in the body the ADH is practically absent and as a result of this collecting duct is impermeable to water. This leads to the formation of dilute urine as more water is excreted out and normal plasma osmolarity is maintained. But under condition of dehydration or depletion of body water or lower blood pressure in conditions like diarrhoea, vomiting, hemorrhage systematic vasodilatation, heart failure the secretion of ADH from posterior pituitary is stimulated and permeability of water in the collecting duct is increased. It leads to reabsorption of water volume.

Uric acid formation: the animals are divided into three groups depending upon the pattern of excretion of nitrogenous end products. The ammonia excreting groups of animals are aquatic. Urea is found in mammal and in amphibian that lives both in water and in land. During aquatic phase of their life the amphibian excretes ammonia and while in terrestial phase of life excretes urea. In reptiles and birds uric acid is formed instead of urea because embryonic development takes place within the egg and egg cells are impermeable to water. Further it is insoluble material and does not require water for their elimination. Uric acids are formed from ammonia in the liver and kidney. In birds ureters transport urine from kidney to cloaca which is a common passage for digestive, reproductive and urinary tract.

Micturition: it is a term used to indicate the process of emptying the urinary bladder. The urinary bladder behaves as a collecting bag. The urine pouring through two ureters gets accumulation in the bladder and at certain intervals it is evacuated. During passage of glomerular filtrate through different portion of nephron a series of compositional changes take place. In the nephron the fluid moves under the renal vascular pressure.

The two ureters open obliquely close together at a trigone where the urethra passed out. At the neck of bladder ureters is surrounded by smooth muscles which forms internal sphincter and near the meatus there is another set of smooth muscles that forms external sphincter of ureter.

The bladder is lined with epithelial cells as transitional epithelium. There is also longitudinal, transverse and circular band of smooth muscle known as detrusor muscle which can contract to complete empty the bladder.

Kidney: Two in numbers and are red brown in color. Kidneys are located in the abdominal cavity.

Right kidney: it is heart shaped and lies below the last two or three ribs. Its upper surface is raised called cortex. Most of the upper part is with the diaphragm while the lower portion touches the pancreas, liver and caecum. There is a depression on the medial side known as renal hilus through which renal artery and vein pass. Inside the kidney and below the hilus is some open space called renal sinus from where begins the ureters which comes out of the kidney. In male and female horses right kidney is almost same.

Left kidney: It is bean shaped and is larger and thinner than right kidney. This is situated below the right kidney and it is movable. It is attached to the diaphragm. Its lower surface is convex and attached to small part of colon, duodenum and pancreas.

Average kidney is approximately 700gms in weight, while right kidney is 50-60gms heavier than the left one. There is outer thin covering of the kidneys is known as renal capsule. On being cut kidneys show two parts:

i) Cortex
ii) Medulla

i) **Cortex**: this is the outer raised surface. It is reddish brown in colour. In it renal capsules are present. In fact urine is formed in this part of kidney.

ii) **Medulla**: It is inner surface of kidney. Middle part of medulla is yellowish in colour. Outside the middle part its colour is dark red due to presence of blood vessels. At the lower part of medulla renal crest is present. Renal crest is open into renal pelvis which is attached to ureter.

iii) **Ureter**: There originate a muscular tube from the lower part of the kidney called ureter. It begins at renal pelvis and terminates into urinary bladder and its diameter is 0.25 to 0.75 inches and its length is 28 inches in horse and mare. Finally it opens in the neck of the bladder on dorsal side of the neck. Its mucus membrane is cuboid transitional.

iv) **Urinary bladder:** This is one and its size and position depends on the quantity of urine. Bladder lies on the floor of the pelvic cavity when it is empty. Walls of the urinary bladder are comparatively thick.

On being filled it becomes round and attaining the position on the ventral side of the abdomen cavity. The quantity of urine is 3 to 4 liters. Its upper part is called vertex and lower part is body of the bladder. The terminal part is known as neck which is attached to the urethra.

v) **Urethra:** it begins with the neck of the urinary bladder and in mare it opens in vagina. The urine comes out from the body from urethra.

Urinary System in Cattle

i) **Kidneys:** there are two kidneys in the cattle i.e. left and right having 20 to 25 lobes. The average weight of kidneys is 500 to 700 grams. Left kidney is about 30-40 grams heavier than right. Shape of kidney is same as equines. There is only difference in renal crest's lobes and renal pelvis is absent that means ureter is smaller than equines.

ii) **Ureter:** Almost similar as equines.

iii) **Urinary bladder:** Comparatively larger and narrow rest is similar as equines.

iv) **Urethra:** similar as equines.

<u>Internal structure of kidney and its functions</u>

Nephron: Structural and functional unit of kidney.

There are more than ten lakhs (1 million) of nephron found in a kidney. These are small tubes where urine is formed. Cortex and medulla are made up of these Nephrons.

A nephron has four following parts:

1. **Bowman's capsule** 2. **Proximal convoluted tubule**
3. **Loop of Henle** 4.**Distil convoluted tubule**

1. **<u>Bowman's capsule:</u>** Nephron is also called renal tubule. It begins from a single nephron and is of a cup shape. Each arteriole enters this capsule and branches into a bunch of capillaries known as glomerulus. This Bowman's capsule and glomerulus together forms malphighian capsule or renal corpuscles appear as small dots in the cortex.
2. **<u>Proximal convoluted tubule (PCT):</u>** Ahead of nephron and Bowman's capsules is a tube shape wide and turning portion called PCT.
3. **<u>Loop of Henle:</u>** Lower part of PCT i.e. thin and straight which goes toward medulla before cortex and turns back towards cortex. This portion is known as loop of Henle (ascending to descending parts).
4. **<u>Distal convoluted tubule(DCT):</u>** Last part of the nephron is wide and turned called DCT.

<u>Cortex:</u> There are renal corpuscles or malphighian corpuscle, PCT and DCT in the cortex.

<u>Medulla:</u> There are nephron, loop of Henle and collecting duct in the medulla.

Every nephron opens up in the distal collecting duct (DCT) collecting duct that empty into renal crest. Urine formed in the nephron passing through these ducts reach renal crest via renal pelvis. The urine finally through the ureter collects in the urinary bladder.

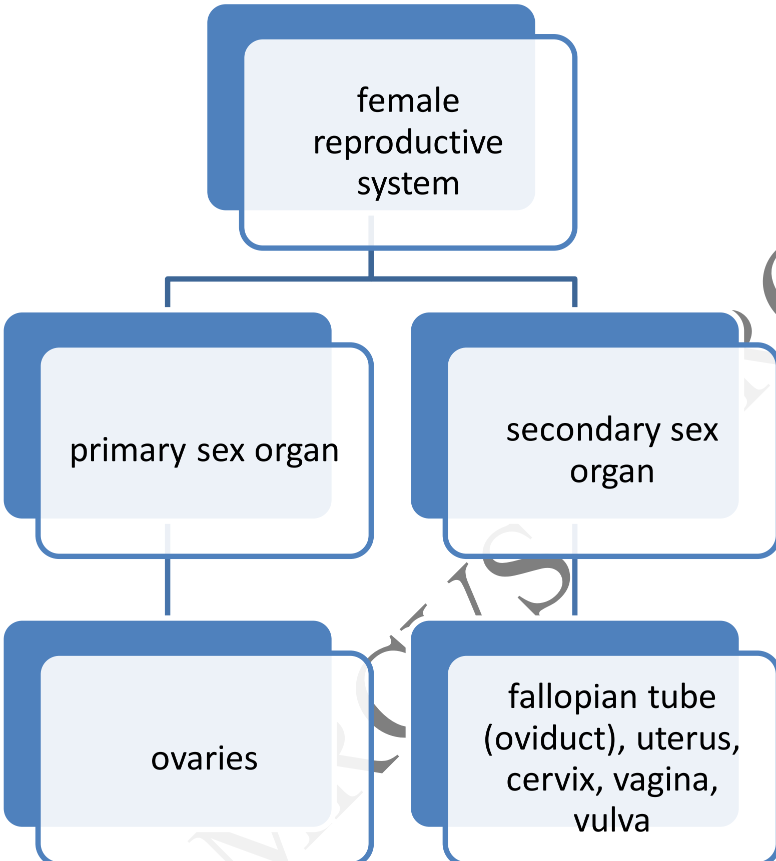
There is no renal pelvis in the cattle and thus urine goes directly to ureter and then in bladder.

Functions of kidney

1. To excrete out the waste products of the body.
2. To maintain the water balance of the body i.e. to maintain the retention and excretion of the water according to the body requirement.
3. To maintain the acid base balance of the body.
4. To maintain the electrolytes which are useful to body.
5. To help the maintaining the blood pressure of the body.

THE REPRODUCTIVE SYSTEM

Female Reproductive System



Female reproductive system consists of following organs:

a) Ovaries
b) Fallopian tube
c) Uterus
d) Cervix
e) Vagina
f) Vulva

a) **Ovaries:** These are female gonads. The ovaries remain within the abdominal cavity in the lumber region suspended by the broad ligaments and peritonium known as mesovarium. The ovary bears a covering is known as germinal epithelium which covers entire ovary except in mare a small area called ovulation fossa. In domestic animals except in mare the ovary is divided into cortex and medulla. In domestic animals ovary has oval shaped but in mare it is about kidney shaped due to presence of ovulation fossa, the only site of ovulation in mares.

Functions of ovary:

i.) Production of ova

ii.) Secretion of female hormones

b) **Oviduct or fallopian tube:** these are paired convoluted structures which start from the uterus and extend up to the ovaries. It divides into three portions that are isthmus, ampulla and infundibulum. They are present in Zig Zag fashion. The end of infundibulum is funnel and envelop ovary to a varying degree depending upon species.

Function of oviduct:

i) Catch the ova from ovary and send it up to uterus.

c) **Uterus:** The uterus of domestic animals is formed by a body and two horns. Each horn is connected with respective oviduct. The length of uterine horn is directly related with litter bearing capacity of the species. The uterus remains suspended by the broad ligaments. The uterus has three layers that are serous layer which is extension of peritoneum, myometrium, endometrial layer. The myometrium and endometrial layers are subjected to series of changes during estrous cycle and pregnancy under the influence of hormones.

Functions of uterus:

i) Secrete uterine milk

ii) It is acting as a gateway for the passage of spermatozoa from vagina or cervix to oviduct.

iii) Secretion of hormones during pregnancy

iv) Production of placenta for nutrition of fetus during pregnancy.

v) It plays some role in preventing rejection of embryo and fetus due to immunological ground.

d) **Cervix:** It is a thick wall muscular structure with sphincter like arrangement. The cervix serves as a connecting link between vagina and uterus. During pregnancy the cervix is closed by thick mucus called **cervical plug or pregnancy plug**. This mucous secretion that takes place by the goblet cells in under progesterone control.

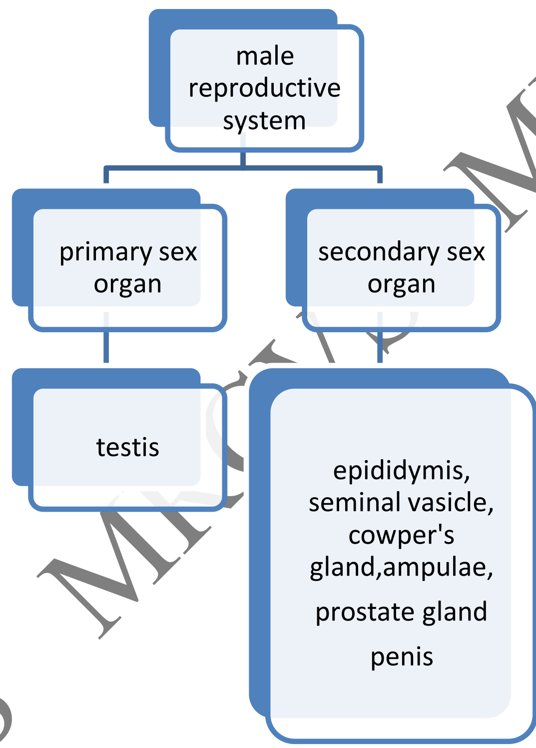
e) **Vagina:** the vagina is a passage which helps flow of semen to the uterus during the act of copulation and expulsion of fetus and fetal membrane during parturition. The cells of the mucous membrane of the vagina show changes under the influence of hormone estrogen during follicular phase and progesterone under luteal phase. During follicular phase the cells are stratified squamous but in luteal phase the epithelium shows many cuboidal cells.

f) **Vulva or external genitalia:** It includes labia majora, labia minora and clitoris. The former two are the embryological homologue of the scrotum in the male and later an erectile tissue and is a homologous of the penis in male. Labia respond to the effect of estrogen during follicular phase and appear swollen and congested indicating the time of estrus.

Male Reproductive System

Male reproductive system of domestic animals consists of:

A) Testis
B) Epididymis
C) Seminal vesicles
D) Cowper 's gland
E) Prostate gland
F) Penis



In all animals paired testis and epididymis is common.

A) **Testis:** The testis of domestic animals remains in a pouch like structure called scrotum, located outside the body. The testes of birds and elephant are located within the abdominal cavity. The testes are covered by the layer's of tunica vaginalis, smooth muscles and a layer of skin. The parenchyma of testes is covered with outer coat of tunica vaginalis and inner coat of tunica albuginea. The parenchyma is made up of seminiferous tubules arranged in the form of lobules and surrounded by a connective tissue. These connective tissues are extension of tunica albuginea. The seminiferous tubules drain the contents into small tubular structures known as rete testes. The rete testis connects through several tubular structures called efferent ducts with epididymis. The areas between the seminiferous tubules within each lobe are packed by interstitial cells or leydig cells and are profusely supplied blood vessels, nerve and lymphatic ducts. The leydig cells are capable of production of androgen (testosterone) and a small quantity of estrogen.

B) **Epididymis:** It is divided into three parts (i) caput or head (ii) corpus or body (iii) cauda or tail.

The rete testis transports spermatozoa and fluids of seminal vesicle to the epididymis at the level of caput.

Functions of epididymis:

a) Transport spermatozoa to vasadeferentia
b) Maturation of spermatozoa and passing ultimately through cauda with acquired fertilizing ability
c) It also serves as an extra gonadal sperm reserve.

The storage time of sperms in epididymis varies from 3 – 13 days in different species.

C) **Vas Deference:** it is a connecting passage from epididymis to pelvic urethra. The terminal portion of this duct enlarges to form a structure known as ampula particularly in species like bull and stallion. In other species is either absent or indistinct.

Functions of vasa deferentia: It acts as:

a) Connecting and transit passage for spermatozoa
b) Acts as site for temporary storage for spermatozoa
c) It adds volume, nutrient and buffer to the spermatozoa mass

D) **Seminal vesicle**: It lies lateral to ampulae and near to the neck of the bladder. It is present in all animals except dogs. It adds fluid content in semen.

Its fluid contains number of substances like:

a) Fructose: Major source of energy to spermatozoa and is derived mainly from seminal vesicles
b) Sorbitol
c) Insoitol is also produced in large amount in boar
d) Ergothionine which combat toxic effect on spermatozoa and many other substances like citric acid, amino acids, Na^+, K^+, lipids, prostaglandin.

E) **Prostate gland:** It is a compound tubule-alveolar gland in all domestic animals. It is intimately associated with pelvic urethra.

Prostate contains a number of compounds for instance prostaglandins F series causes smooth muscles contraction and helps passage of spermatozoa through female reproductive tract. Prostatic secretion contains fructose, citric acid, cholesterol and even free amino acids.

It contains number of enzymes like acid and alkaline phosphatase, proteolytic enzymes, and glycosidase and aspartate aminotransferase. A protein called sperm agglutinin which prevents head to head agglutination of sperms is also present in prostatic fluid. The secretory activity of accessory organs in general is mostly hormone dependent.