Unit No. 3 Digestive System:

Alimentary Canal and Accessory respiratory organs dentition.

Alimentary Canal:

Digestive system:

All the living organisms utilize energy to carry out various biological activates. Energy is required to our body in regular intervals to sustain life. An alimentary canal or digestive tract in our body system help in providing source of energy first by ingestion followed by its digestion of protein, carbohydrates, fats and vitamins and after absorption the indigestible material is egested out of body. In this process various enzymes are present in digestive juices which are secreted from digestive glands. The process of digestion by alimentary canal along with associated digestive glands is known as **digestive system.** The term alimentary canal or digestive tract in vertebrates refers to an internal tube, seldom straight and often tortuously coiled, running from an anterior mouth opening in head to a posterior anal or cloacal aperture at the base of tail. It is designed for ingestion, digestion and absorption of food stuffs and egestion of undigested wastes. The major parts of alimentary canal are

Oral cavity, Pharynx, Esophagus, Stomach, Small intestine and Large intestine,

The chief accessory organs associated with the alimentary canal are: tongue, teeth, oral glands, pancreas, liver, gall bladder, etc. Most of the modifications of alimentary canal in different vertebrates include

1. Length of alimentary canal depending on the types of food they consumed
2. Types of looping or coiling
3. Modification with enlargement as crop, caecum, stomach compartments
4. Development of internal folds as spiral valve, villi, typhlosole, papillae, rogae etc.

Histologically the walls of alimentary canal of vertebrates are made up of 4 different layers

a. **Serosa or serous** coat the outermost membrane made of thin layer of connective tissue.
b. **Muscularis** is composed of smooth muscle fiber arranged in outer longitudinal and inner circular muscle fibers which are rich with a network of automatic ganglionated myenteric plexus.
c. **Submucosa** lines beneath muscular coat and it is a connective tissue layer containing elastic fibres, nerves, blood and lymphatic vessels, and glands.
d. **Mucosa** this is the innermost layer and it is divided into two layers that is columnar epithelium and lamina propria or corium and muscularis mucosa.

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The innermost columnar epithelium is often glandular and ciliated, which is supported by a thin basement membrane. The middle thin connective tissue is called **lamina propria** which has rich blood capillaries, lectals and nerves and the outer longitudinal muscle fibres, called **muscularis mucosa**. This layer connects mucosa and submucosa.

Mouth:

The real digestive canal starts from oesophagus but there are few important structures called **mouth** which is the anterior opening leading into oral cavity and is subject to great deal of variations depending of types of animals eg in cyclostomes (lamprey) it is circular and in gnathostomes mouth is terminal in sharks. Mouth with true fleshy and muscular lips found in mammals which are mostly adapted for sucking. In most of the fishes, amphibians, and reptiles, mouth is surrounded by unmodified or heavily cornified skin forming immovable lips.

Oral cavity:

Oral cavity serves as a passageway for food, water, and for aquatic respiration. In amphibian and reptiles oral cavity is more compact and its muscular floor serves for swallowing food and also used in breathing in the absence of a diaphragm.

Few more organs are also found in oral cavity these are also known as derivatives or accessory orangs of oral cavity. They are organs like teeth, tongue, oral glands and anterior and middle lobes of pituitary.

Teeth are hard and pointed structures attached to jaw bones that aid in food-getting. There are two types of teeth.

Epidermal teeth which are horny projections of stratum corneum (cyclostomes) , conical projections from lips of tadpoles of some species of frogs, serrations on beaks of some turtles and birds, horny plates in duckbill, sirenians and baleen whales, and egg-tooth for cracking egg-shell before hatching in turtles, Sphenodon, crocodiles, birds and monotremes. True teeth is found in all the vertebrates except agnathans, sturgeons, some toads, sirens, turtles, modern birds etc. There are different types of teeth eg polyphyodont, acrodont and homodont in fish, amphibians and most reptiles, but they are diphyodont, thecodont and heterodont in mammals. Teeth are believed to have evolved from bony scales.

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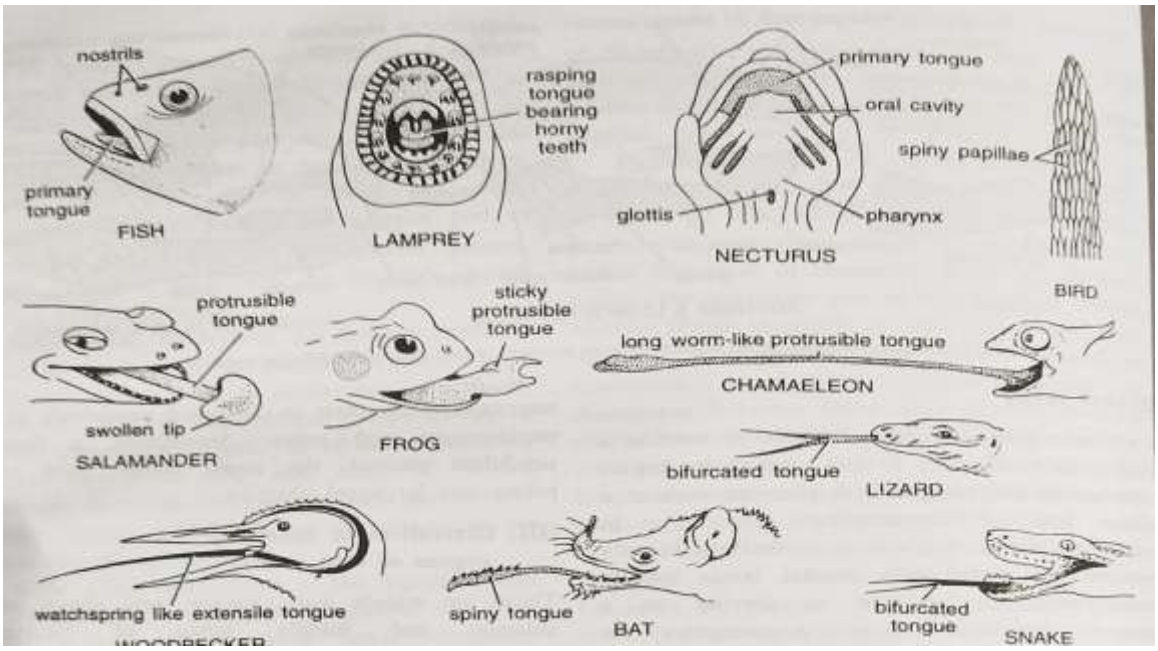
Tongue:

Tongue is found in the mouth nearly all vertebrates and they are of many diversity and not all are homologous with the mammalian organ. In cyclostomes it is a thick, fleshy, extensile, rasping organ on buccal floor, armed with horney teeth. Few animals have immobile, non-muscular, sensory elevation on buccal floor, bearing teeth in some teleost's e.g., tongue fish and necturus. The tongue of most amphibians (frogs, toads, salamanders) is sticky, attached at the anterior end and free at the posterior end. It can be thrust out of mouth suddenly by rapid injection of lymph, for capturing insect prey called definite tongue. In turtles, crocodilians, some birds and whales, birds and some mammals (anteaters). In most mammalian tongue is attached to buccal floor by a ligament, the frenulum. The main function is for manipulation and swallowing of food. It also bears numerous microscopic taste buds and also for speech.



Oral glands

Vertebrates exhibit a great varity of glands opening into mouth cavity and often named according to their location, and often name according to the location of their origin viz. palatine, lingual, subligual, maxillary, labial, parotid, etc. Fish and aquatic amphibians have only simple mucous glands. Poisonous snakes have large poison glands. The largest oral glands are enzyme-secreting salivary glands of mammals secretes enzyme called salivary amylase or ptyalin.

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Pituitary:

Adenohypophysis is the most important endocrine gland of vertebrates, consists of three lobes having dual embryonic origin. There are different parts

1. **Infundibulum** is a ventral invagination of diencephalons
2. **Pars Nervosa or neurohypophysis** this forms the posterior lobe of pituitary

Roethke's pocket: is a dorsal diverticulum of stomodaeum, which constricts of to form the anterior and middle lobes of pituitary or adenohypophysis.

Pharynx:

Pharynx is a region of foregut between oral cavity and oesophagus lined by endoderm. It is a dual function organ work for both respiration and digestion. It shows highest modification compare to other parts of digestive tract. In fishes it is extensive and perforated by gill slits for aquatic respiration to get dissolved oxygen from water. In tetrapod's it is short and a crossroad between respiratory and food passages. The wall of pharynx in embryo are derived spiracle, gill clefts, lungs, air bladder, tonsils and endocrine glands such as thymus, thyroid and parathyroid.

Oesophagus: (Alimentary canal)

The esophagus is the portion of the alimentary canal immediately after pharynx and it joins to the stomach at its other end. It is not surrounded by a layer of visceral peritoneum. The mucous membrane lining the esophagus is of stratified squamous type of epithelium rather than of the simple columnar type. In the upper part of the esophagus the muscle fibers changes gradually from striated, voluntary type to the smooth, involuntary type. In the cud-chewing, mammals the striated muscle fibers extend throughout the entire length of the esophagus. Thus contraction of the esophagus in these forms is under voluntary control.

Cyclostomes:

In the lamprey the esophagus is lined with numerous folds, from the mouth cavity two tubes extend posteriorly one as dorsal esophagus and a ventral pharynx which ends blindly and is entirely concerned with respiration. The condition of esophagus is in hage fish much as in other vertebrates and the esophagus merely extends posteriorly from the pharynx.

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Fishes:

In fishes the esophagus commonly bears longitudinal folds which permit a considerable degree of distention. It is very short, its junction with the stomach being almost imperceptible. But in case of elasmobranchs and *Squalus* numerous backward-projecting papillae line the esophagus and first part of the stomach.

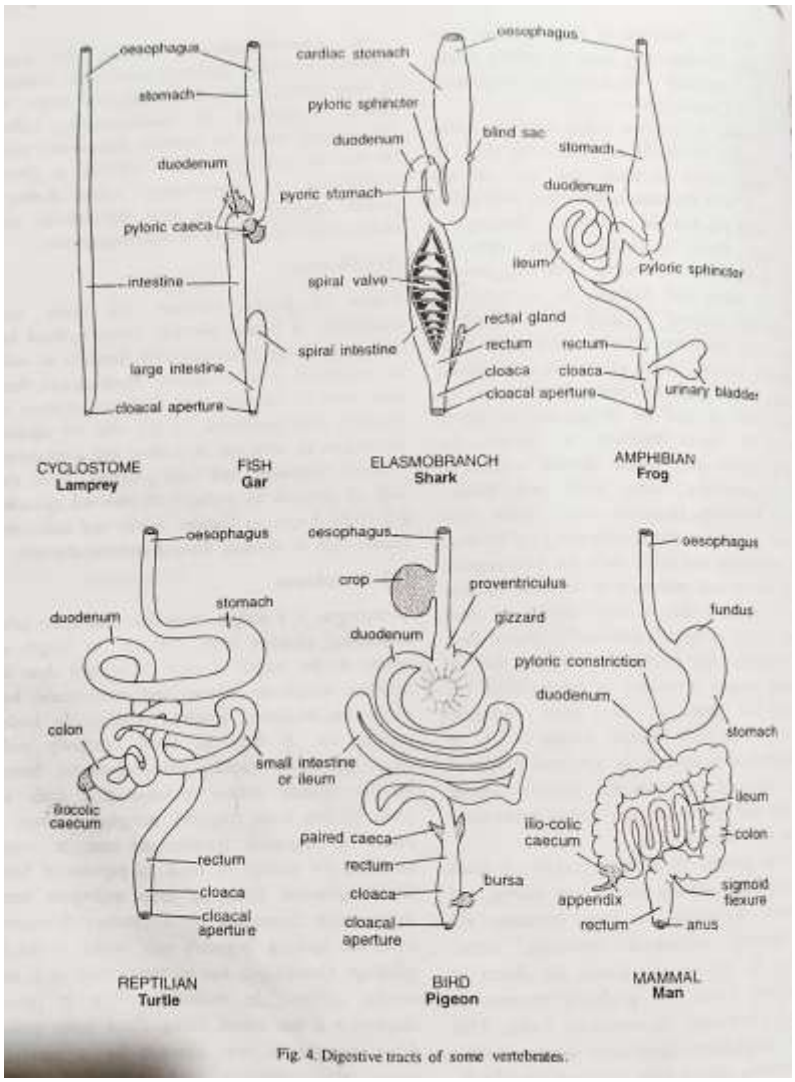

Fig. 4. Digestive tracts of some vertebrates.

Amphibians:

The oesophagus of amphibians are extremely short and consists of little more than a constricted area of the alimentary tract. The lining of esophagus and mouth are ciliated which help small food particles are carried to the stomach. The secretions from epithelium of esophagus by secretory cells have a digestive function.

Reptiles:

In case of reptiles the esophagus is generally longer than in lower forms. Longitudinal folds in the walls permit considerable distention, which is of special use in snakes, thats why snakes are capable of swallowing large objects. The lining of the esophagus of a certain marine turtle is covered with cornified papillae which point posteriorly.

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Birds

In many birds the esophagus is lined with horny papillae. In grain eating birds as well as birds of prey forms a large sac or a ventral pouch like outgrowth, called crop. The function of crop is to secure and store an abundance of food in a short period. It also enables the bird to compete with others for a limited amount of food. Although it is doubtful whether any digestion occurs here such food particles as grain may swell and are thus rendered more capable of being broken down and digested later easily. The crop release portions of its contents at intervals, the food passes on to the stomach with the support of furcula (wishbone). In pigeons both sexes, epithelial lining of crop undergoes fatty degeneration controlled by a pituitary hormone. Prolactin, forming “pigeon’s milk” which is fed to nestlings.

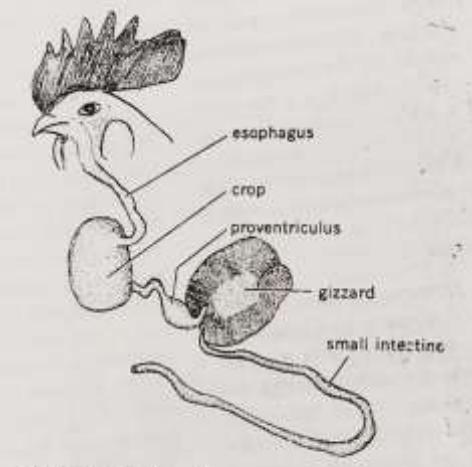

FIG. 9.18 Relation of crop and stomach regions of the domestic fowl.

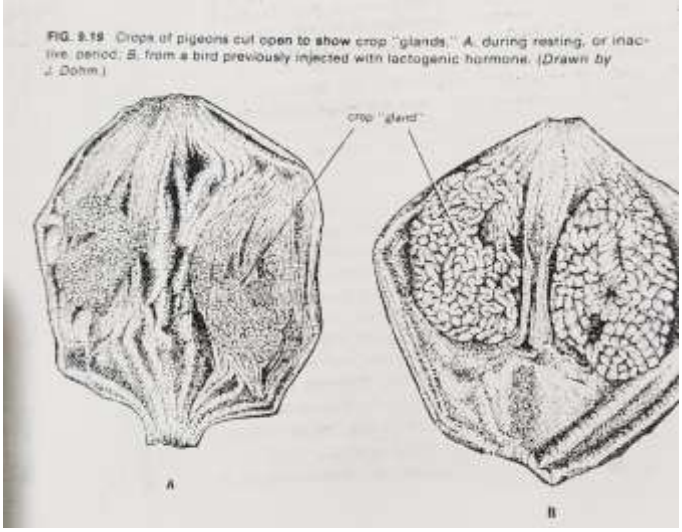
FIG. 9.19 Crops of pigeons cut open to show crop "glands." A, during resting, or inactive, period; B, from a bird previously injected with lactogenic hormone. (Drawn by J. Dohm.)

Mammals:

In mammals there is distinct and clear demarcation between oesophagus and stomach. Length of the oesophagus varies with the length of neck , eg camel has the longest oesophagus of all. It pass through the diaphragm to meet the stomach. Therefore the region of oesophagus those are lying below the diaphragm is covered by visceral peritoneum.

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STOMACH:

Stomach is in most vertebrates has assumed a transverse position and is U-shaped or J-shaped. Stomach is lined with epithelial cells. This internal epithelial lining of the stomach is highly folded and is richly provided with numerous mucous cells. It has become twisted so that the cardiac end is on the left side of the body and the pylorus on the right. The expansion of cardiac end of the stomach, formed by the greater curvature, is the saclike fundus. The muscular walls of the stomach, particularly of the pyloric end, contract in such a manner as to mix, or churn, the contents of the stomach thoroughly. Peristaltic waves originate near the body of the stomach and pas through the pyloric end down to the intestine, forcing the contents along. The rate of peristalsis and the strength of the contractions vary with the type and amount of food eaten.

The shape of the stomach depends upon the shape of the body of the organism. It may extend longitudinally in animals like snakes, whereas it assumes a clear cut transverse position in wide-bodied animals.

There are three parts of stomach

1. **Cardiac**: the parts of stomach towards oesophagus end near the heart.
2. **Pyloric:** the terminating end of the stomach which opens into the intestine which are guarded by a pyloric valve. It consists of the fold of the mucus membrane lining surrounded by a thick sphincter muscle.
3. **Fundus**: it is the main body of the stomach lies between the cardiac and pyloric portion.

Cyclostomes:

The cyclostome stomach is very partly developed and consists of little more than an almost imperceptible enlargement at the posterior end of the esophagus. It is poorly developed and reduced in size.

Fishes:

There is practically no distinction between esophagus and stomach in fishes. And the longitudinal folds of the former may exptend for some distance into the stomach. Different variety of stomach is seen in fishes some are simple, straight tubes without any digestive function, as in Dipnoi, chimaeras, and a number of teleosts. In few other fish e.g., Polypterus, the cardiac and pyloric limbs have fused along the line of the lesser curvature so that the stomach appears much as a blind pouch. A J-shaped stomach in found in elasmobranchs. The pyloric end is smaller than the cardiac portion. In elasmobranchs there is a blind sac at the

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junction of cardiac and pyloric portions. Generally many other fishes have similarly shaped stomachs. Teleost's exhibits a great variety of stomach shapes; some even have a ciliated lining. In bony fishes, the stomach is a curved U-shaped tube as in elasmobranchs which is differentiated into cardiac and pyloric regions. In bony fish cardiac portions are very large in comparison to the pyloric region which is very small. A true stomach is present in elasmobranchs, amphibians, reptiles, birds and mammals. In bony fish the stomach is a curved U-shaped tube as in elasmobranchs which is differentiated into cardiac and pyloric regions.

Amphibians:

In frogs the cardiac end of the stomach is wide, there is no fundus, and the pyloric end is short and narrow. In certain salamanders the stomach is straight. All the stomach of amphibian have a digestive function. The stomach of frog serves all the three main functions of a typical stomach i.e. storage, mechanical treatment and partial digestion. The stomach is differentiated into wide anterior cardiac region and the posterior short and narrow pyloric region. The usual fundus region is absent. In frog, the stomach is highly muscular and therefore, distensible.

Reptiles:

The stomach is slightly U-shaped with its concavity lying on the right side. A typical stomach of lizard is located in the left half of the body. It is differentiad into cardiaa and pyloric portions. Stomach is wider and thicker than oesophagus and its internal lining is done with glandular longitudinal folds. The pyloric stomach opens into the intestine by pyloric valve. Depending on the shape of body stomach is spindle-shaped in some lizards and almost all the snakes. There is clear cut demarcation between the stomach and the oesophagus. In *Testudo gracia* the stomach is tubular and U-shaped. The stomach of crocodilians is considerable distinct from rest of the reptiles and the shape of stomach is much more similar to birds. The stomach modified into a gizzrd-like muscular region.

Birds:

The avian stomach is highly specialized to compensate the absence of teeth. It is differentiated into tow portions externally as well as internally. The anterior glandular portion is known as pro-ventriculus or glandular stomach, which is a digestive part of the stomach, where the food is mixed with the digestive fluid. While the posterior portion dominated with muscular part of stomach is known as gizzard or muscular stomach. It is used to grid the food grains as its internal lining is very hard and keratinized. The

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gizzard muscles form a pair of disc-like area with tedious centers. The bumps (tubercles) on the surface of gizzard help in the grinding of food. Pieces of small stones or gizzard stones are often found inside gizzard. The seed eating birds have a greatly enlarged and highly developed gizzard where as birds with prey nature has reduced and least developed gizzard. In reality gizzard is a modified pyloric stomach.

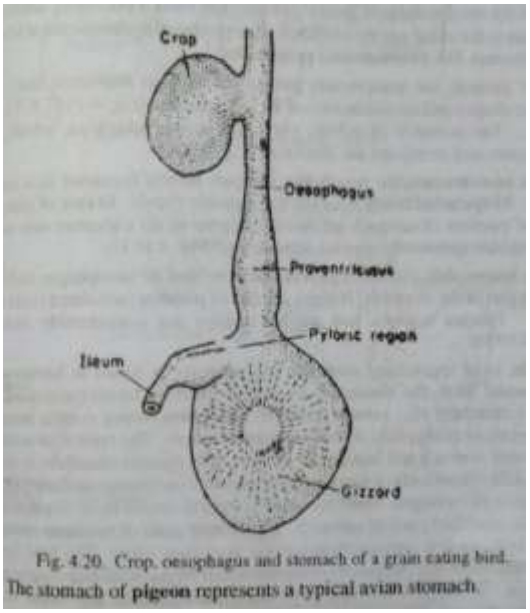

Fig. 4.20. Crop, oesophagus and stomach of a grain eating bird. The stomach of **pigeon** represents a typical avian stomach.

The stomach of pigeon is a typical avian stomach with a thin walled wide sac called crops which is generally found at the base of the neck in **grainivorous** birds that is used as storage organ. During the breeding season this organs produced a white fluid called crop milk for feeding the young ones. Crop is not a real stomach it is a modified part of oesophagus.

Mammals:

In general the transversely placed stomach in mammals may so diverse shapes and modifications of its various parts. The stomach of rabbit, pig, monotremes, kangaroo, whale, cow (ruminant) and carnivore.

The stomach of rabbit is differentiated into three main regions

1. Left large lobe- **cardiac portion**
2. Right small lobe- **Pyloric portion**
3. Middle largest part-**fundus.**

The internal lining of the stomach of rabbit is thrown into longitudinal folds. These folds are beset with gastric glands (cardiac gastric glands, pyloric gastric glands and fundic gastric glands). In all these folds deep gastric pits receive ducts of gastric glands. The fundus portion of stomach usually secrete gastric secretions (hydrochloric acid) and enzymes like prorenin and propepsin. In monotremes, the pouch-like stomach merely functions, as a storage organ. Its epithelial lining does not have gastric glands. In case of platypus, the two portions of stomach are fused along the lesser curvature side so that the structure apparently appears as wide sac.

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In marsupials, cardiac region is placed behind the oesophagus and is the largest part of the stomach. It bears a series of peculiar sacculated folds in its walls. Fundus regions and pyloric region are considerably reduced.

Some of the most specialized stomach in mammals is found in herbivorous ruminants which is complex structure which consists or four distinct chambers .

Rumen (pounch): Among the four parts of ruminant stomach, rumen is the largest compartment serving as storage organ. The food (grain, grass, other herbiage material) is churned about by the muscular contractions of rumen. Besides this some degree of bacterial treatment also occur in the chamber. As a requlr, synthesis of cerntain proteins and viutamins of B-complex may take place. While at this process the ruminant cattle chews its cud at leisure. From rumen, food may pass in small anounts into reticulm or it may be regurgitated through oesophagus into the mouth along with a fair amount of fluid contents. This regurgitated substance is known as cud (Bolus). While chewing the food, the animal swallows the fluid part in the first instance back into the rumen. The remaining cud this is properly masticated which are then mixed well with salivary secreations and is swallowed back into the rumen. From rumen, the bolus is passed into the reticulum then to omasum and finally to abomasum.

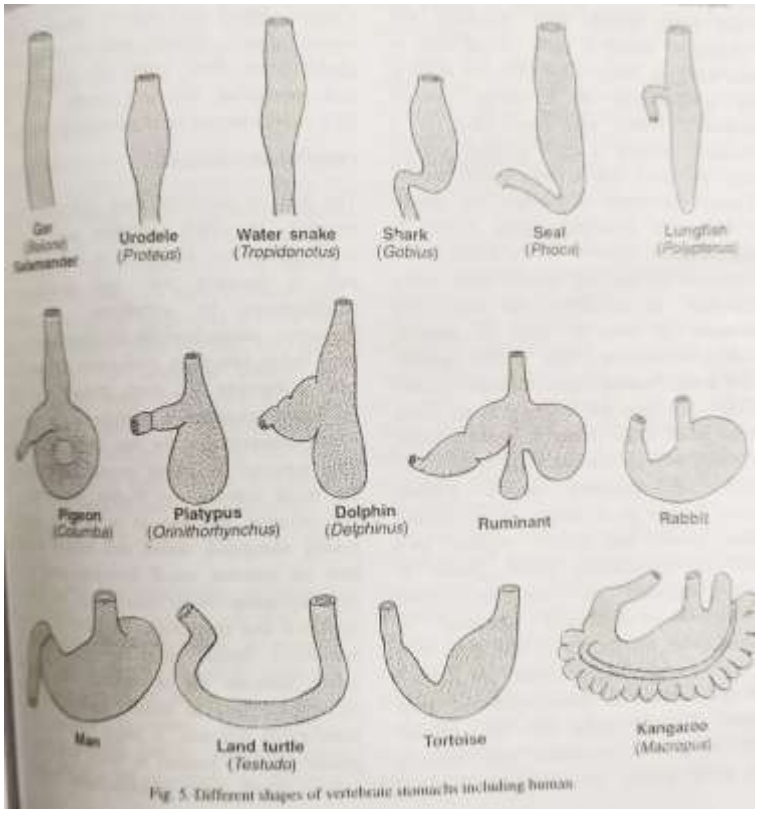

Fig. 5 Different shapes of vertebrate stomachs including human

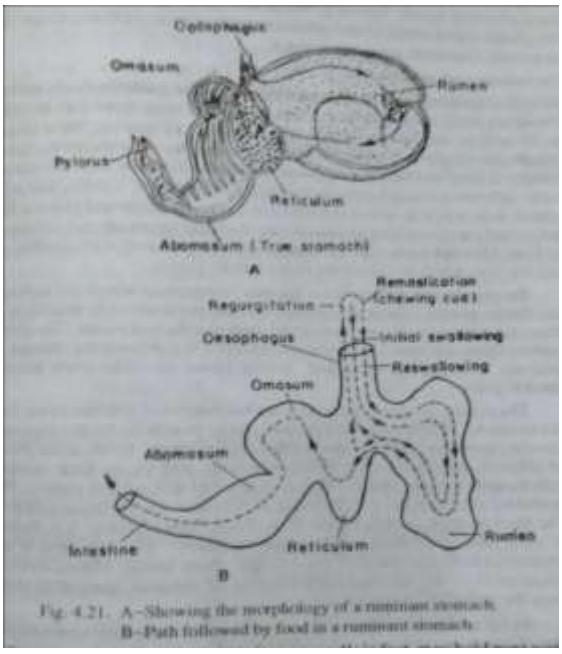

Fig. 4.21. A–Showing the morphology of a ruminant stomach.
B–Path followed by food in a ruminant stomach.

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Reticulum (honey comb): the bolus from rumen reached reticulum then to omasum and finally abomasum

Omasum (Psalterium): in camel omasum is absent.

Abomasum (rennet) the gastric glands are present only in the abomasum region.

The so called water cells are found in the rumen and reticulum portion in camel stomach. In case of mammals like hippopotamus and whales, stomach is divided into several compartments. One more example is that of a blood sucking bat-Desmodus wherein the pyloric portion of stomach is elongated into caecum-like structure which gets filled up with blood during feeding hours. Another example in case of edentates, the glands get concentrated towards the greater curvature only. In rodents, horse and *Bradypus,* the cardiac as well as pyloric chambers are quite distinct. Mucous neck cells, zymogen cells and parietal (acid secreting cells) are the three kinds of cells found in the fundic glands. Partially digested food then passes from the stomach into the small intestine through the pyloric opening which is partly open most of the time depending on two factors that is Peristaltic movement and degree of food contents converted into semi-fluid.

INTESTINE:

Intestine is one of the most important portion of digestive tract because its main function as a true digestive organ. Where enzymes completely converted the ingested food into easily absorbable simpler units more over the main role of digestive system that is absorption of the hydrolyzed food material takes place in small intestine.

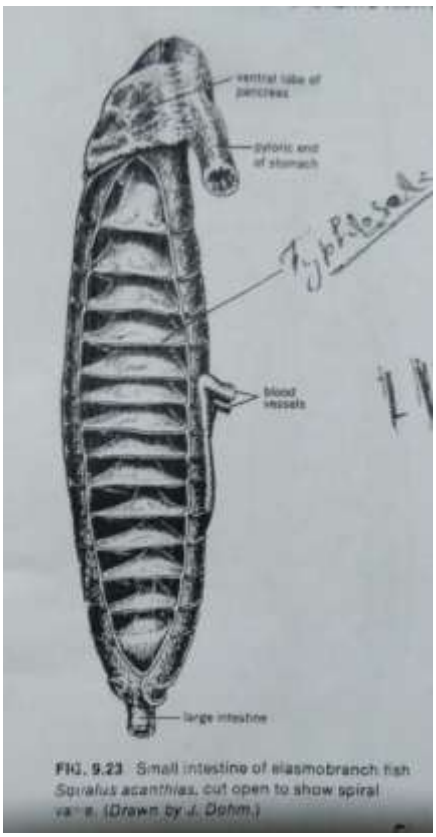

FIG. 9.23 Small intestine of elasmobranch fish *Squalus acanthias*, cut open to show spiral valve. (Drawn by J. Dohm.)

Cyclostome:

The intestine is straight in cyclostome but a slightly enlarged rectum is found at the posterior end of intestine which opens into the anterior end of the cloacal depression.

Fishes:

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The intestine is strangely shorter than the stomach in case of elasmobranches. It is straight and considerably wider. In the elasmobranch spiral valve is present which a characteristic feature. The large intestine of elasmobranches refers to the short passage between the small intestine and the cloaca. A rectal gland is also present at the junction of small and large intestine. Eg *Squalus acanthias*, Dipnoi, Paleopterygii like Amia

Spiral valve is very complex in its internal structure; it is a fold of epithelium and connective tissue running from one end to other small intestine to the other. The name suggest is true because there are numerous twishts in a spiral fashion all across the wall of the small intestine. In teleost fish the length and size of intestine are different. In mirgala an Indian major carp has a huge long intestine which is very coiled in nature and they are detrivore fish in few carnivore fish the intestine is large and short in length eg. Catfishes.

Amphibians

A very slight degree of coiling is found in the intestine of caeclian amphibians. There the small intestine is not differentiated into regions.

In urodeles the intestine is greatly coiled. It is short straight and differentiated clearly from the other regions in case of salientians and few caudates. There is an additional structure called urinary bladder attached as a ventral diverticulum to the posterior part of the gut in amphibians. Few amphibians also have circular folds called valvulae conniventes in their small intestine.

Reptiles:

The small intestine of reptiles is uniform in its diameter and most of them are elongated and coiled. Whereas the large intestine are greater in diameter as well as straight and opens into the cloaca. The small and large intestine are joined with the help of **ileocolic** valve marked by presence of Colic caecum (except in Crocodilians) .

Birds:

Most of the birds have a longer small intestine which may be coiled but the larger intestine usually short and straight which finally terminates in the cloaca. There is no expansion in the size expect at the cloacal region. The remainder of the digestion occurs in the duodenum, and the released nutrients are absorbed mainly in the lower small intestine. The length of most of the birds are approximately eight time the whole body length. Colic caeca are absent in birds like parrots, woodpeckers etc. Despite the name, the large intestine is actually shorter than the small intestine. The large intestine is where the last of the water reabsorption occurs.

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Mammals:

The coiling pattern of small intestine of birds is not only maintained by mammals but also carried a step further. In larger herbivorous animals, the sum total of the small intestine far exceeds the eight time mark of the birds. The small intestine can be divided into three different regions viz.

1. Duodenum
2. Jejunum
3. Ileum

Duodenum means twelve which means its combined length equivalent to the breadth of twelve fingers as measured by the all anatomists.

Jejunum is a Latin word which means empty it is generally found empty immediately after death. It is about 2/5th of the total length of small intestine.

Ileum is the last portion of small intestine that is in the part lying between jejunum and large intestine. Ileum may be 3/5th of the small intestine. In case of man 2 percent of intestines have a pouch-like structure called **Meckel's diverticulum** which is about 2 inches. If it is abnormal it may extend upto 7 inches. The length of small intestine may extend from 16-26 feed and in woman form 11-24 feet.

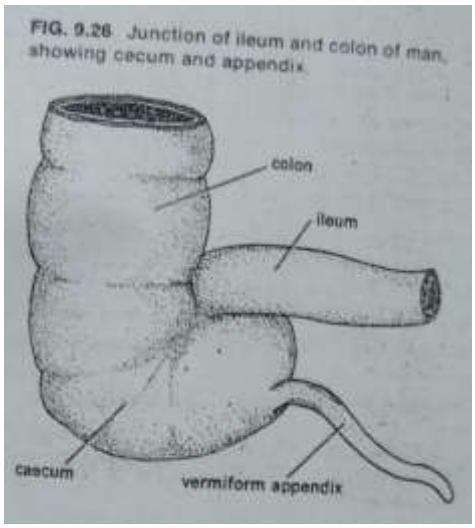

FIG. 9.26 Junction of ileum and colon of man, showing cecum and appendix.

In herbivorous animals like cow, it may be around 165 feet. In horse it is approx.. 95 ft. in length. In carnivorous animals intestine are as long as 5 to 6th times of the body length. The ileum and colon joints in a valve called ileocoilic valve which regulates the passage of material from the intestine to large intestine. In case of man, there is a distal end that is degenerated and is represented by vermiform appendix. It is also reported in many others animals like monkeys, civets, and few rodents. The caecum assumes enormous size in marsupials, herbivores and some rodents. Caecum serves as an additional place for the activities like colon.

Glands of Lieberkuhn: it is a tubular gland, which are spread across the entire length of small and large intestine that help in digestion.

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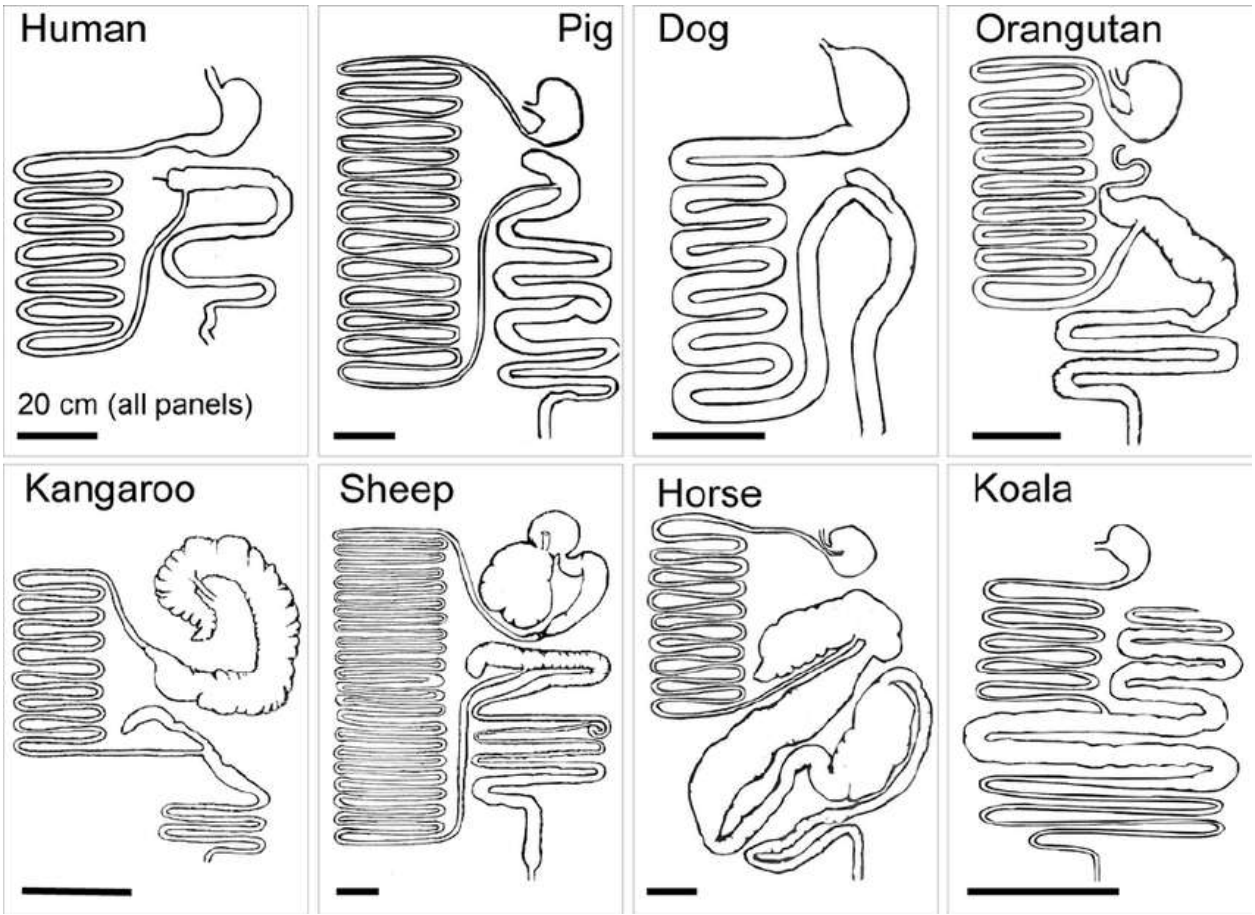
Glands of Brunner: it is a branched, tubular, mucous gland which are found only in the duodenal region.

Succus entericus: the secretion of the intestinal glands having enzymes like erypsin, lipase, sucrose, maltase, lactase, along with trypsin activator called enterokinase.

Peyer's Patches: these are numerous villi and nodules of lymphoid tissue which are found in small intestine as devices to collect the products of digestion.



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