CHAPTER THREE
Digestive System

The digestive tract: an overview

Gastrula is an early embryonic stage resulted from the gradual invagination of the blastula to form an elongated organism with central cavity called the gut or archenteron. As the embryo elongated and proceeds in its development, this presumptive embryonic digestive tract, the gut distinguishes into three regions: The part containing the yolk, when present, or to which the yolk sac is attached, is the **midgut**. Caudal to the midgut is the **hindgut**, and anterior to the midgut is the **foregut**. The foregut elongates to form part of the oral cavity, the pharynx, oesophagus, stomach and much of the small intestine. The hindgut becomes the remainder of the intestine. Little of the midgut remains in adults.

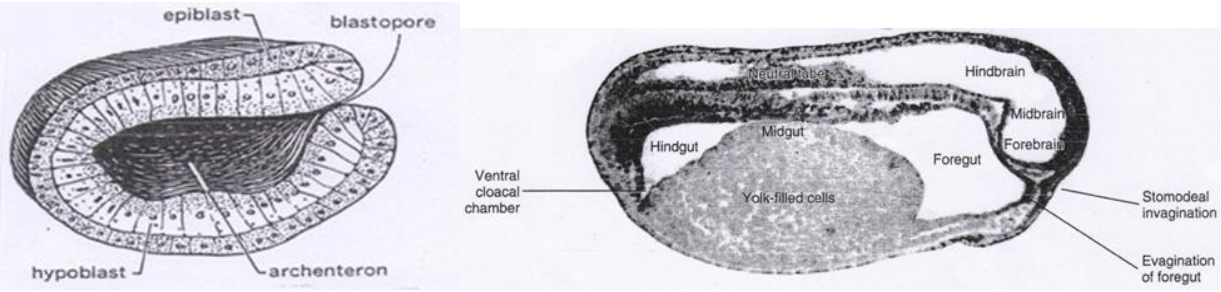

FIGURE 1: Gastrula and early embryonic stage showing the gut formation.

Three regions of the digestive system

It is preferable to divide the digestive system into three main regions (Fig.2):

1. Buccal (in water breathing vertebrates) or buccopharyngeal cavity (in air breathing vertebrates).
2. Digestive tract or alimentary canal. Starts from pharynx or esophagus and ended by cloaca or anus.
3. Digestive glands. Includes glands related to alimentary canal, which are salivary glands, liver and pancreas, whereas gall bladder is not a gland but just a reservoir for bile which is a liver secretion.

Functions of the digestive system

1. **Ingestion** and **grinding** take place in buccal or oral cavity,
2. **Swallowing** by the pharyngeal skeletal muscles.
3. **Fermentation** and **main digestion** in the stomach, where the glands in its lining (mucosa) secrete enzymes and Hcl.
4. **Complete digestion** in small intestine, where the liver and pancreas pour their secretion, bile and pancreatic juice respectively. Here complex food molecules break down to smaller or simple molecules, where carbohydrates change to

monosaccharides; protein to amino acids and lipids to fatty acids and glycerol. **This process enables the cells of intestine to absorb these small food molecules.**
5. **Absorption** in the small intestine and part of large intestine. They may be long, coiled and have projections, such as **valves**; **ceca**; **villi** to increase the surface of absorption.
6. **Elimination** or **egestion** of the undigested and unabsorbed food as waste products via the skeletal muscles of the rectum.

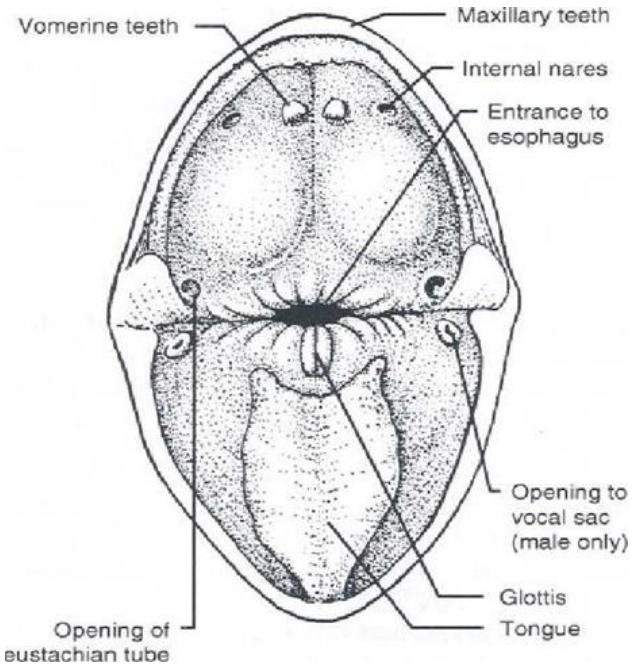

FIGURE 2: Frog buccopharyngeal cavity.

Teeth

Study of teeth and their arrangement is called dentition. The significance for study of dentition in mammals are:

1. The number of teeth present gives an idea of the approximate age of the mammal.
2. Dentition provides information about the diet of the mammal.

Two types of teeth

i. True or **bony teeth**. This type of teeth is found among most vertebrates with few exceptions. and some species lack true teeth, Like some bony fishes, a few amphibians, all turtles and birds; and among mammals, whalebone whales, South Americans scaly anteaters, and the adult monotreme. Edentates are either toothless or else have degenerated teeth, without enamel.

ii. Keratinized or **horny teeth**. On their apical pointed parts are keratinized; although they function sometimes like true or bony teeth but they completely differ in origin and structure (i.e. analogous organs). Teeth of lamprey, adult monotremes are of this type.

Structure of true tooth

The part of the tooth projecting above the gum line, or gingiva, is the crown; the region below is the **base**. If the base fit into a hole, or **socket** (alveolus) within the jaw bone, the base is referred to as a root. Within the crown, the pulp cavity narrows when it enters the root, forming the root canal, and opens at the tip of the root as apical foramen. Mucous connective tissue or **pulp** fills the pulp cavity and **root canal** to support blood vessels and nerves that enter the tooth via apical foramen (Fig.3). The **cusps** are tiny, raised peaks or ridges on the surface of crown.

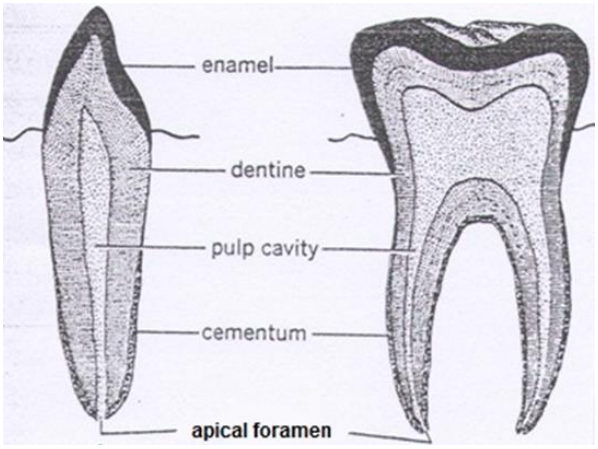

FIGURE 3: Structure of true teeth.

1. Teeth morphology. Morphologically teeth can be distinguished as homodont or heterodont.

i. Homodont dentition. Generally, in most vertebrates other than most mammals, all the teeth are similar in general appearance, shape and size, throughout the mouth.

ii. Heterodont dentition. Teeth of most mammals, except those with aquatic mode of feeding as toothed whales and dolphins, are differing in appearance throughout the mouth. Heterodont teeth are distinguished into several types known as: ***incisors, canines, premolars*** and ***molars***. Premolars and molars called cheek teeth.

2. Teeth attachment. The manner of attachment of teeth at their bases with the jaw bones varies throughout vertebrates (Fig.4):

i. Acrodont dentition. It is the simplest method of attachment. The tooth is rootless and attached to the jaw cartilage or bone by a tough, fibrous, mucous

membrane which cover the jaws. Acrodont teeth are attached at the outer surface or apex of the jaw. Most teleost, sharks, skates, rays and snakes have this attachment.
ii. Pleurodont dentition. In this condition, common to urodeles, anurans and lizards, Teeth are rootless and attached to the inner side of jaw bone by their base.

iii. Thecodont dentition. Such teeth are characteristic of mammals. Teeth have well developed roots implanted in individual pits or sockets called alveoli or theca, in the jaw bone. Thecodont teeth also occur in some fishes, crocodilians. The sockets are deepest in mammals.

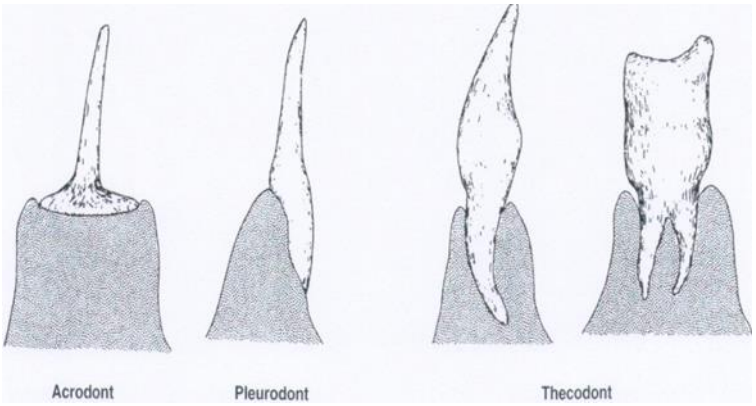

FIGURE 4: Manners of teeth attachment with jaws.

3. Teeth replacement or succession. According to their replacement (succession), teeth fall into 3 categories:

i. Polyphyodont dentition. All vertebrates, except mammals, have a succession of teeth, and the number of replacements during a lifetime is numerous.

ii. Diphyodont dentition. In most mammals teeth develop during life in two successive sets. Teeth of the first set are called ***deciduous***, ***lacteal*** or ***milk teeth***. In human milk teeth consist of: incisors, canines and molars, but no premolars.

iii. Monophyodont dentition. In some mammals only one set of true teeth develops as in platypus, marsupials, mole, sirenians, toothless whale, etc.

Dental formula

In mammals, number of teeth varies in different species. Number of teeth is constant and characteristic for every species. Therefore, number and kinds of teeth in a species of **mammals** can be represented by equation, which is called **dental formula**. Since two halves of each jaw is identical, only the teeth of one side are recorded. Those of upper and lower jaws are separated by a horizontal line; the teeth of the upper jaw are placed as numerators and in the lower jaw as denominators. Kinds of teeth are denoted by their initial letters i, c, pm and m,

representing incisors, canines, premolars and molars, respectively. Sum of the n umber of teeth shown in the formula multiplied by 2 gives the total number of teeth in a species. Dental formulae of some familiar mammals are as follows:

Typical: Horse, Pig and Mole	3.1.4.3/3.1.4.3 =44
Dog	3.1.4.2/3.1.4.3 =42
Cat	3.1.3.1/3.1.2.1 =30
Cow, sheep and Goat	0.0.3.3/3.1.3.3 =32
Rabbit	2.0.3.3/1.0.2.3 =28
Man	2.1.2.3/2.1.2.3 =32

Unusual forms of teeth

The elongated unusual teeth are called **Tusks**, they are most commonly canine teeth, or may be incisors. Present in male or in both sexes (Fig.5).

Elephant tusks are modified incisor teeth. Both male and female have tusks. Tusks of, both sexes, **walruses** are modified canines. The long upper canines of male **musk deer** are modified canines. Both sexes of **warthog** of Africa bears 4 upward curving tusks. Males generally have both larger tusks and warts than females. **Babirusa** a pig found throughout much of Africa, often have four tusks. The tusks grow vertically and curve backwards the forehead. The upper tusks passing through the skin of the upper lip and penetrate it. They are usually absent or much smaller in females.

FIGURE 5: Animals with unusual forms of teeth.

The **narwhal**, or narwhale (*Monodon monoceros*), is a medium-sized toothed whale. The animal's most distinguishing characteristic—its 9-foot-long tusk, which is found only in males (Fig.6). The left canine in the upper jaw after first year of a male narwhal's life grows outward spirally, so the narwhal males are distinguished from female by a long, straight, helical tusk, where it rotate as a drill. Some narwhals have up to two tusks, while others have none.

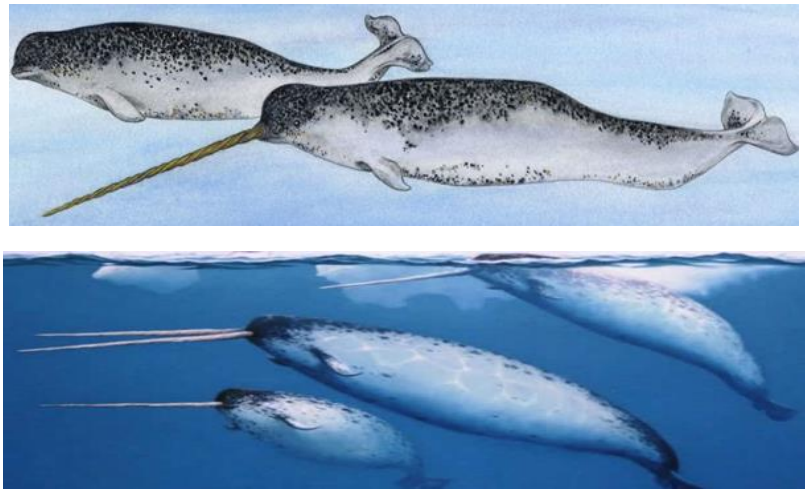

FIGURE 6: Narwhales, toothed whales, males have one or two unusual teeth, females lack them.

II. Alimentary Canal or Digestive Tract

The tube like gut is differentiated along its length into many organs with various degree of dilation. The main organs of alimentary canal are: **pharynx**, **esophagus**, **stomach**, **intestine** and **cloaca**. In higher vertebrates the intestine is differentiated, accordance to its diameter, into small and large intestine and each has its own subdivisions. The design of the alimentary canal suits the diet of the organism.

Key for the study of the comparative anatomy of the digestive system

Study the of various chordate groups can be easy to study depending on the following statements:

1. Length and degree of folding or coiling of alimentary canal.
2. Pharynx and modification in esophagus, especially in birds and mammals.
3. Presence, absence, or highly differentiated stomach.
4. Differentiated or undifferentiated intestine and its different regions.
5. Number and location of cecae, which are structures mostly for increasing the surface of food absorption.
6. Terminal opening of the alimentary canal, either it is cloaca or anus.
7. Presence or absence of digestive glands (salivary glands, liver and pancreas), associated with alimentary glands.

Amphioxus

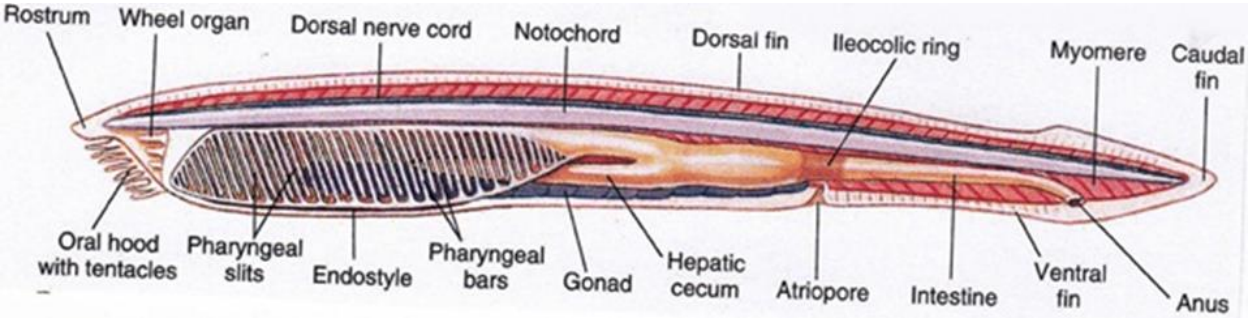

FIGURE 7: Amphioxus digestive system.

1. Short and straight alimentary canal (Fig.7).
2. Pharynx is wide and occupied by gill bars and gill slits.
3. No stomach, due to lack any glandular epithelium except mucous glands.
4. Intestine is undifferentiated.
5. No cecae.
6. Alimentary canal terminated in anus, because there are no urinary and genital ducts to share with intestine.
7. Lack true liver and pancreas. Midgut diverticulum does the function of the liver. No gall bladder exists in the amphioxus.

Lamprey

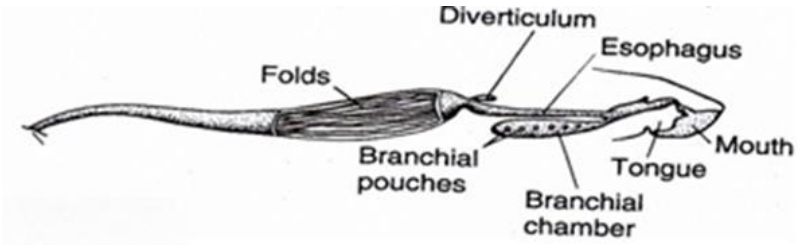

FIGURE 8: Lamprey alimentary canal.

1. Straight alimentary canal and slightly curved posteriorly (Fig.8).
2. Pharynx of adult is in a form of blind pouch separated from esophagus, its wall occupied by gills and gill slits.
3. No stomach.
4. intestine is undifferentiated.
5. Numerous longitudinal folds in the mucosal wall of intestine, which dramatically increase the intestinal absorptive area.
6. Intestine terminates into cloaca.
7. Single-lobed liver and gall bladder present in larva and disappear in adult, no true pancreas.

Dogfish

1. Alimentary canal somewhat long and curved (Fig.9).
2. Pharynx wide and with gills and gill slits in its wall.
3. Stomach curved j-shaped, with long cardiac limb and short pyloric limb.
4. Intestine is undifferentiated because posterior part is narrower than anterior part.
5. Anterior wider part of intestine with spiral valves increasing the digestive and absorptive area.
6. Alimentary canal terminates into cloaca.
7. liver is a large bilobed organ occupying much of the body cavity. The left lobe is frequently shorter than the right. The gallbladder is usually almost completely embedded in the small median lobe of the left lobe. Pancreas includes two separated lobes, a larger elongated dorsal lobe which lies between the pyloric limb of stomach and the intestine and smaller ventral lobe lying close against the intestine at its junction with pyloric limb. From the ventral lobe arises the pancreatic duct entering the intestine.

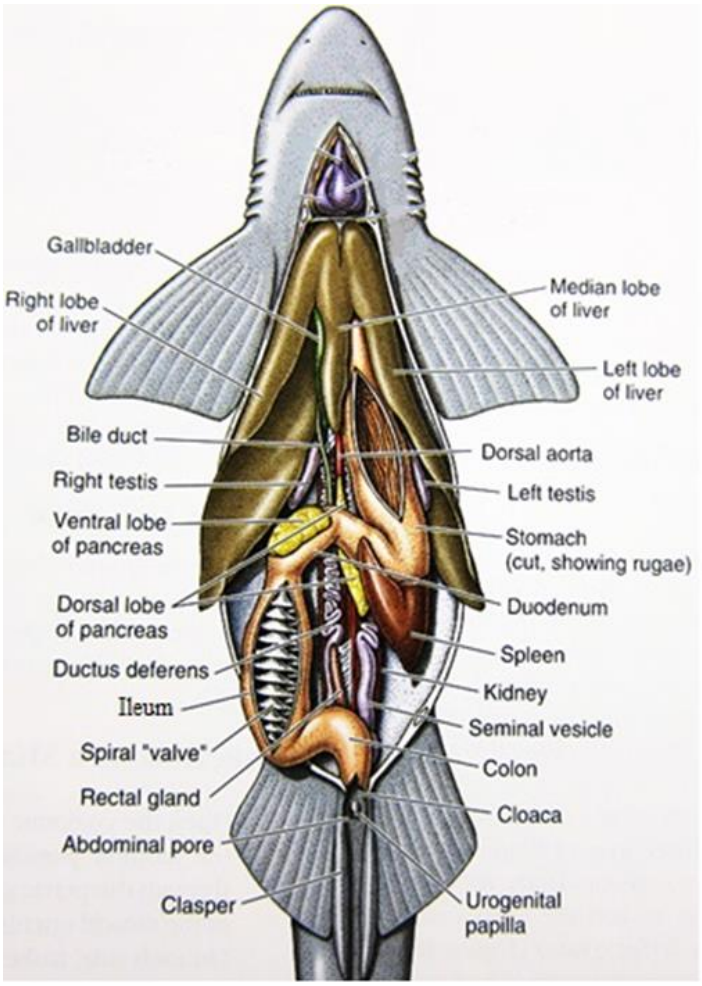

FIGURE 9: Dogfish digestive system.

Frog

1. Alimentary canal is long, curved and moderately coiled (Fig.10).

2. Pharynx communicates with mouth to form buccopharyngeal cavity.
3. Stomach slightly curved, with anterior cardiac portion and posterior pyloric.
4. Intestine is differentiated, anterior called portion is duodenum and posterior wide portion is rectum or colon.
5. There are no cecae or valves but the small intestine lined by villi to increase the surface of absorption.
6. Alimentary canal terminates into cloaca.
7. Liver is a large organ consisting of two main lobes, between the two main lobes lies the spherical ***gall bladder***. The **pancreas** which lies in the mesentery between the stomach and duodenum in form of two lobes.

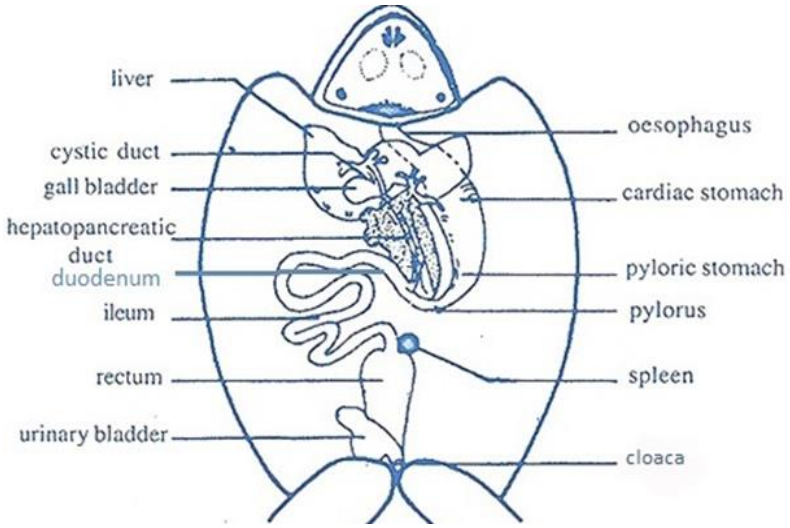

FIGURE 10: Frog digestive system.

Lizard

1. Alimentary canal is long, curved and moderately coiled (Fig.11).
2. Pharynx communicates with mouth to form buccopharyngeal cavity.
3. Stomach slightly curved, with anterior cardiac portion and posterior pyloric.
4. Intestine is differentiated, anterior called portion is duodenum and posterior wide portion is rectum or colon.
5. At the junction of duodenum and rectum there is a short ***rectal cecum***. The small intestine lined by villi.
6. Intestine terminates with cloaca.
7. Liver is large and consists of two lobes. A small rounded ***gall bladder*** is embedded in its right lobe. Pancreas is an elongated whitish structure lying in the mesentery between stomach and duodenum.

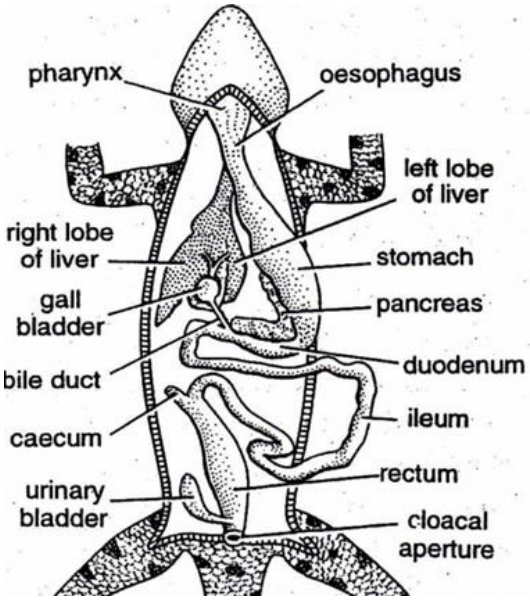

FIGURE 11: Digestive system of lizard.

Birds

1. Alimentary canal is long, curved and moderately coiled (Fig.12).
2. Pharynx communicates with mouth. Esophagus widen to form crop, store and moist food and produces milk as in pigeon called pigeon milk.
3. Stomach of two parts, anterior one produces enzymes called proventriculus, the posterior one is muscular for grinding the food called ventriculus or gizzard.
4. Intestine is differentiated into small intestine (duodenum and ileum) and large intestine called rectum.
5. The junction of ileum and rectum is externally marked by the presence of a pair of small conical, blind pouches, the ***rectal cecae***. The small intestine lined by villi.
6. Alimentary canal terminates into cloaca.
7. Liver is relatively large, compact, dark-red and bilobed, consisting of larger right lobe and smaller left lobe. Common pigeon lack gall bladder may be as adaptation f or flight. Pancreas is a compact reddish gland, lying between the two arms of the duodenum.

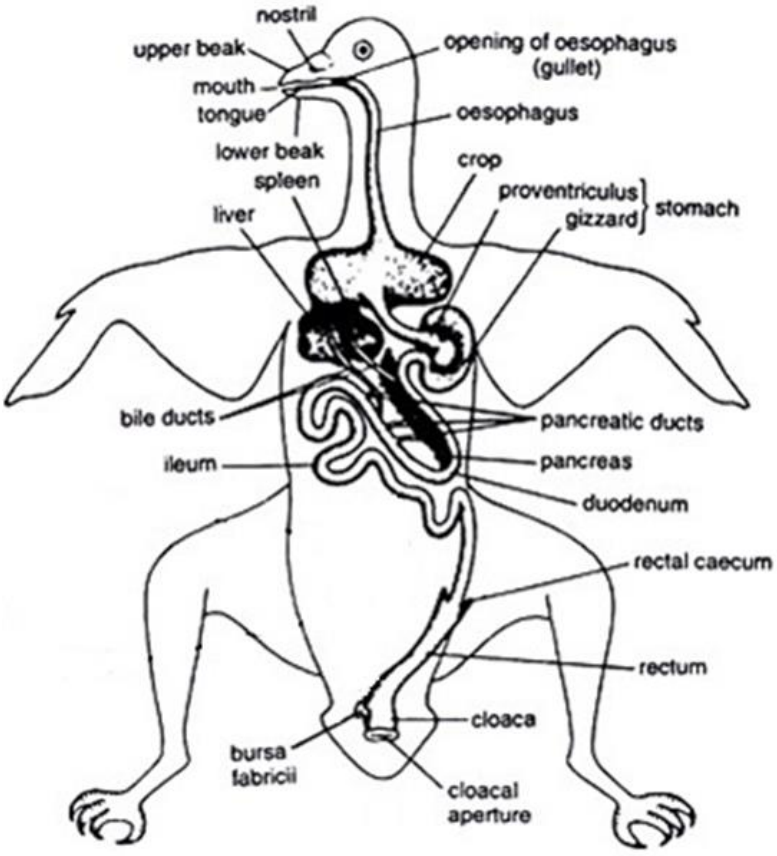

FIGURE 12: Digestive system of bird.

Rabbit

1. Alimentary canal is long and highly coiled tube (Fig.13).
2. Pharynx communicates with the mouth.
3. Stomach curved transversely and with portions: cardiac, fundic and pyloric.
4. intestine is long, coiled and differentiated into small intestine (duodenum, jejunum, ileum) and large intestine (colon and rectum).
5. One large and wide cecum present ended by long vermiform appendix.
6. Alimentary canal ended into anus.
7. **Liver.** It is a very large, it consists of 5 lobes: the ***right central***, the ***left central***, the ***caudate***, the ***left lateral*** and the small ***Spigelian lobes***. The right central lobe is grooved for the reception of the ***gall bladder***. **Pancreas** lies between the two limbs of duodenal loop. It is somewhat diffuse, creamy in color.

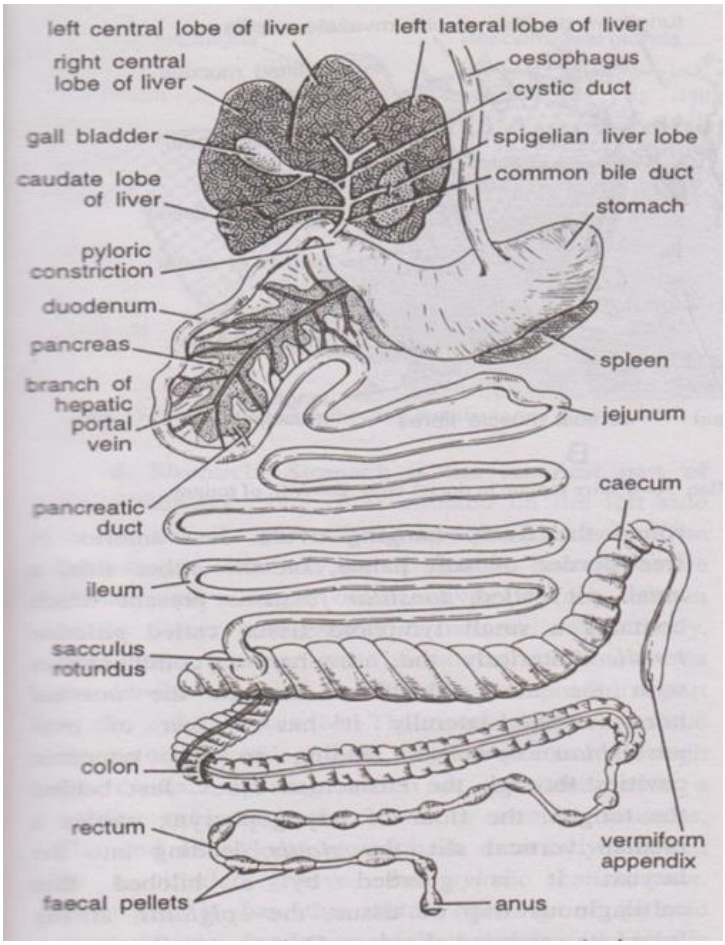

FIGURE 13: Rabbit digestive system.

Specialization in stomachs of vertebrates

Stomachs of various vertebrates have two regions: glandular and nonglandular. The glandular region of stomach includes gastric glands and often exhibits three divisions: cardiac, fundic and pyloric. They lined by simple and glandular epithelium, while the nonglandular region of the stomach is lined with stratified epithelium and devoid of gastric glands. Nonglandular stomach varies in size in different vertebrates especially mammals (Fig.15).

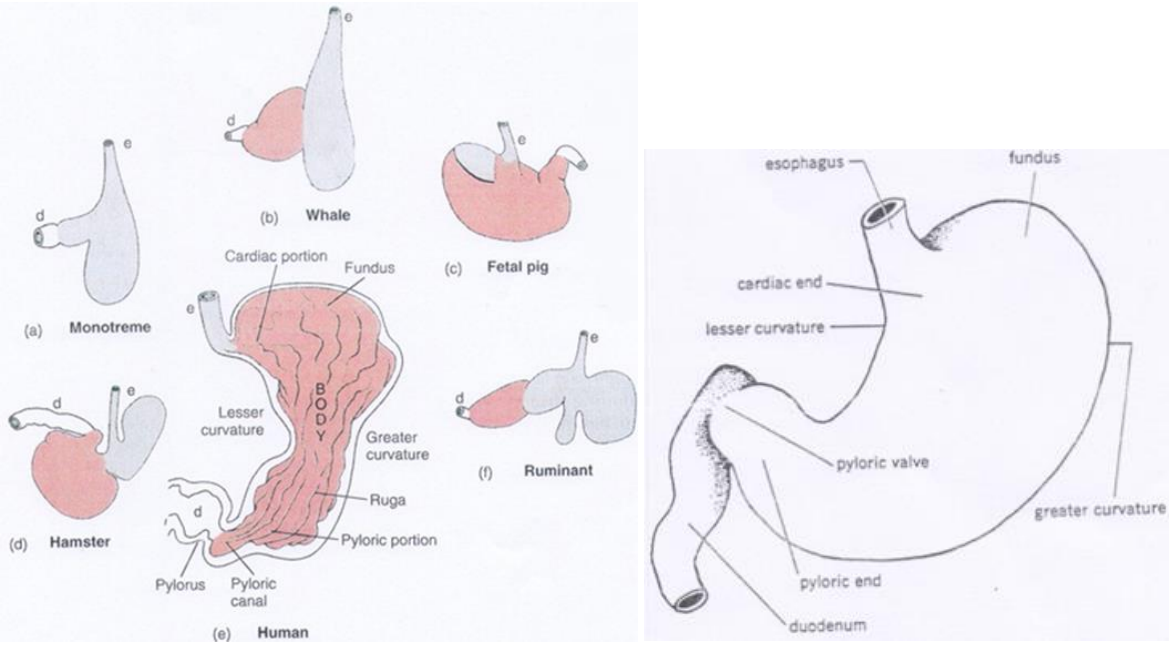

FIGURE 15: Various forms of mammalian stomachs.

Ruminants' stomach

The stomach of a ruminant (cattle, sheep, deer and giraffes, other artiodactyles except pigs), adapted for processing cellulose. Grasses are taken into the mouth, and swallowed without processing. They pass down the esophagus and into the **rumen**. There the food becomes mixed with mucus and with cellulase, an enzyme secreted by anaerobic bacteria that live there that digests cellulose molecules into simpler carbohydrates. At intervals, some of the contents pass to the **reticulum**, so named because the lining is honeycombed (reticulated) by ridges and deep pits. Here the process of cellulose fermenting continues, and small boluses or cuds are regurgitated for further maceration by the teeth, then masticated mash is swallowed, and it passes to the **omasum**, a temporary holding site, before it is moved to the **abomasum**, which is the true glandular stomach where gastric enzymes are added to the mash. These three former regions are nonglandular regions and their linings also like that of esophagus are of stratified squamous epithelium. Camels' stomach, like those of ruminants, but consists of three compartments: rumen, reticulum and abomasum, lacking omasum.

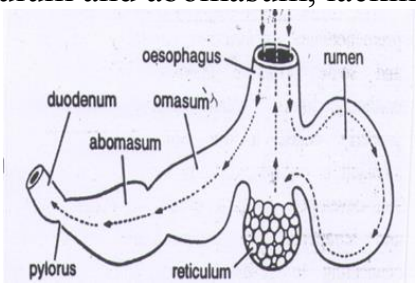

FIGURE 16: Ruminants' stomach.