An immature Allen's humming bird (Selasphorus sasin) feeding a flower nectar. This humming bird's fluid-feeding behavior is one example of the many feeding adaptations discussed in this e-content.

COMPARITIVE ANATOMY OF DIGESTIVE SYSTEM IN VERTEBRATES

SEMESTER – IV

ZOO CC408

UNIT-2

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COMPARITIVE ANATOMY OF DIGESTIVE SYSTEM IN VERTEBRATES

- Digestive system is a series of organs involved in the digestion of food eaten, absorption of digested food and expulsion of undigested residue.
- Digestive system includes alimentary canal and associated glands.
- The basic plan of the digestive system is similar in all vertebrates. But within this basic plan, the specific components vary from one animal to another.
- The alimentary canal is formed early during embryonic development and is lined with the endoderm, except the mouth and rectum, which have an ectodermal lining.

The digestive tract of vertebrates include the following parts:

I. Mouth and Oral Cavity
- Teeth
- Tongue
- Oral Glands

II. Pharynx

lll. Oesophagus

IV. Stomach

V. Intestine

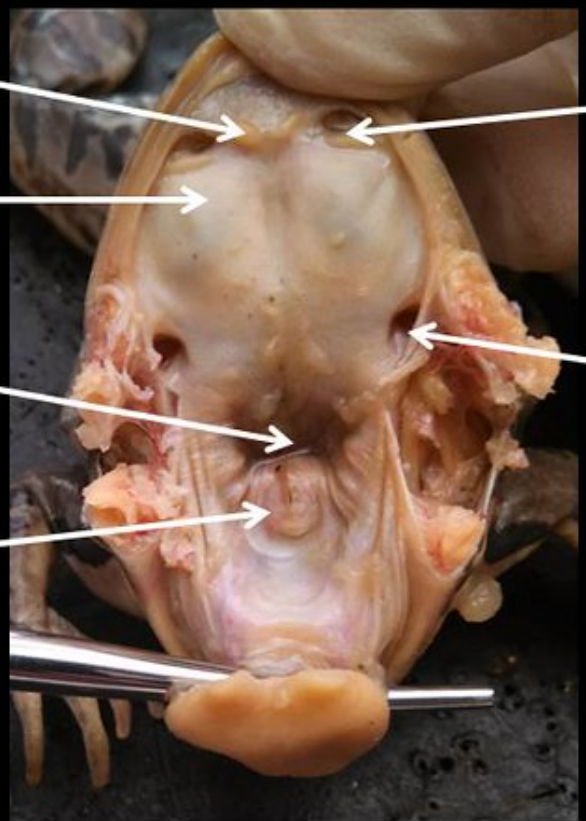
VI. Glands Associated with the Digestive System
- Liver
- Pancreas
- Gall Bladder and bile duct

I. Mouth and Oral (Buccal) Cavity

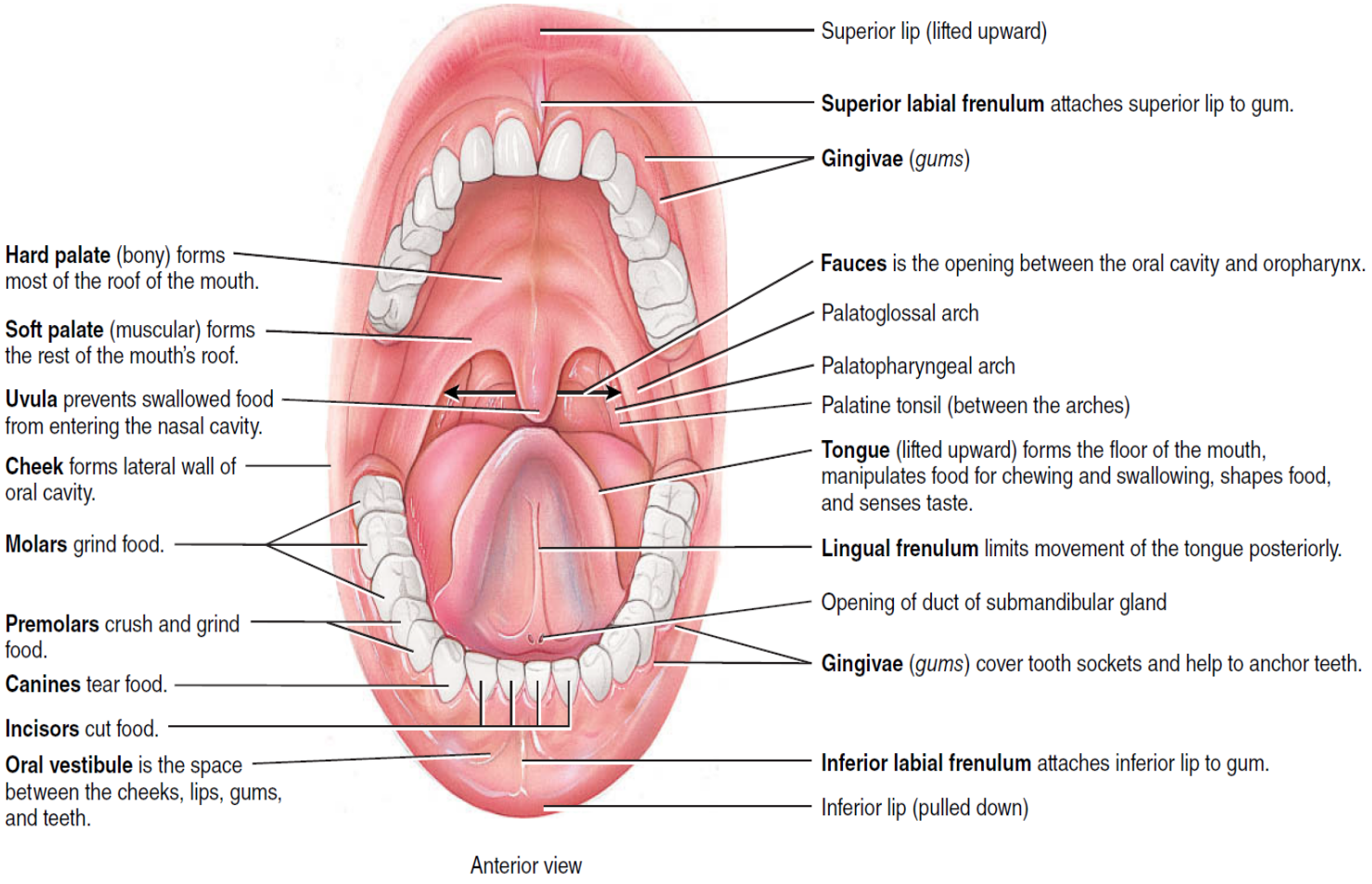
- Mouth is the anterior opening that leads into the oral cavity.
- In cyclostomes, the mouth is a circular opening.
- In gnathostomes, generally the mouth is terminal. However, in elasmobranchs and sturgeons, the mouth is ventral.
- In fishes, the mouth margins of amphibians and most reptiles have small lips.
- In turtles, the lips of birds and a few mammals have been transformed into a horny beak like structure or bill.
- In mammals, the mouth is bounded by muscular lips.
- The mammalian mouth is specialised to serve as suckling and masticatory organ (with muscular cheeks).
- The oral cavity begins at the mouth and ends at the pharynx.
- Fishes have a very short oral cavity, while tetrapods have longer oral cavities.
- In a majority of fishes, the nasal cavities do not open into the oral cavity by internal nares.
- In crossopterygians (lobe-finned fish) and amphibians, the internal nares open into the oral cavity,
- In reptiles and birds, the oral cavity is separated from the nasal passage by palatal folds.
- In mammals, the nasal passage has been completely separated from the oral cavity due to the formation of a bony secondary palate,
- Oral cavity contains teeth, tongue and oral glands.
- The space between the lips and jaws is called vestibule

- Buccal cavity is a large and spacious cavity situated behind the vestibule.
- Vestibule is present only in mammals but absent in fishes, amphibians, reptiles and birds.
- It is bounded above by the palate, below by the tongue and on the sides by the jaw cheeks.
- It is lined by stratified epithelium.
- Palate is divided into anterior hard and posterior soft palate.
- Hard palate contains transverse palatine ridges or rugae for gripping food.
- Soft palate is smooth and fleshy and posteriorly terminates into uvula or velum palate.
- Uvula closes internal nostril at the time of ingestion.

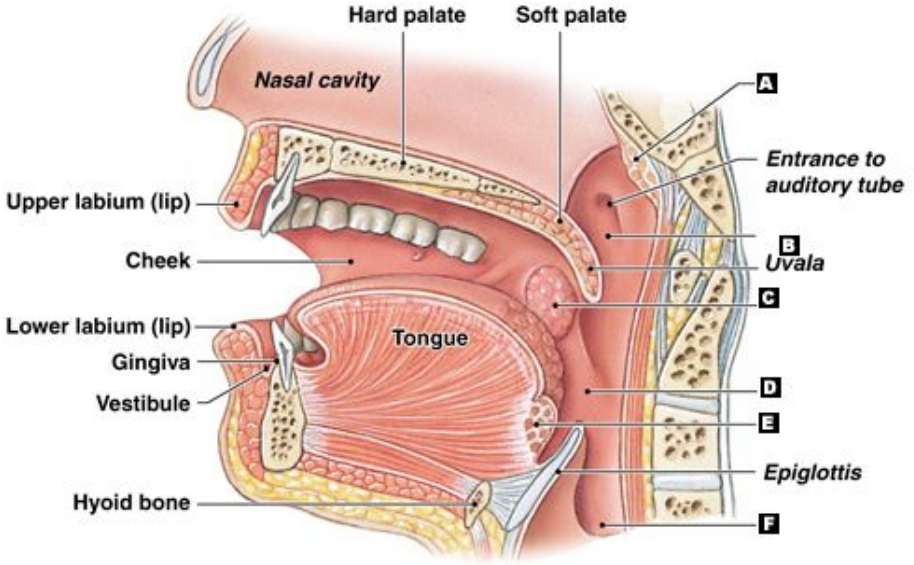
Frog (buccal cavity)

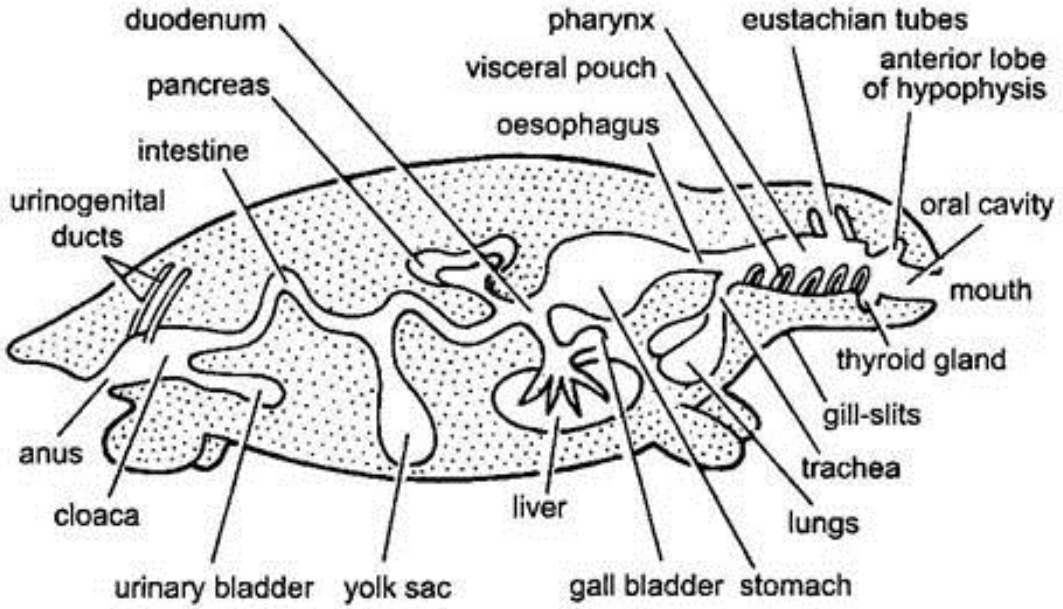


Mouth and Oral (Buccal) Cavity of Human

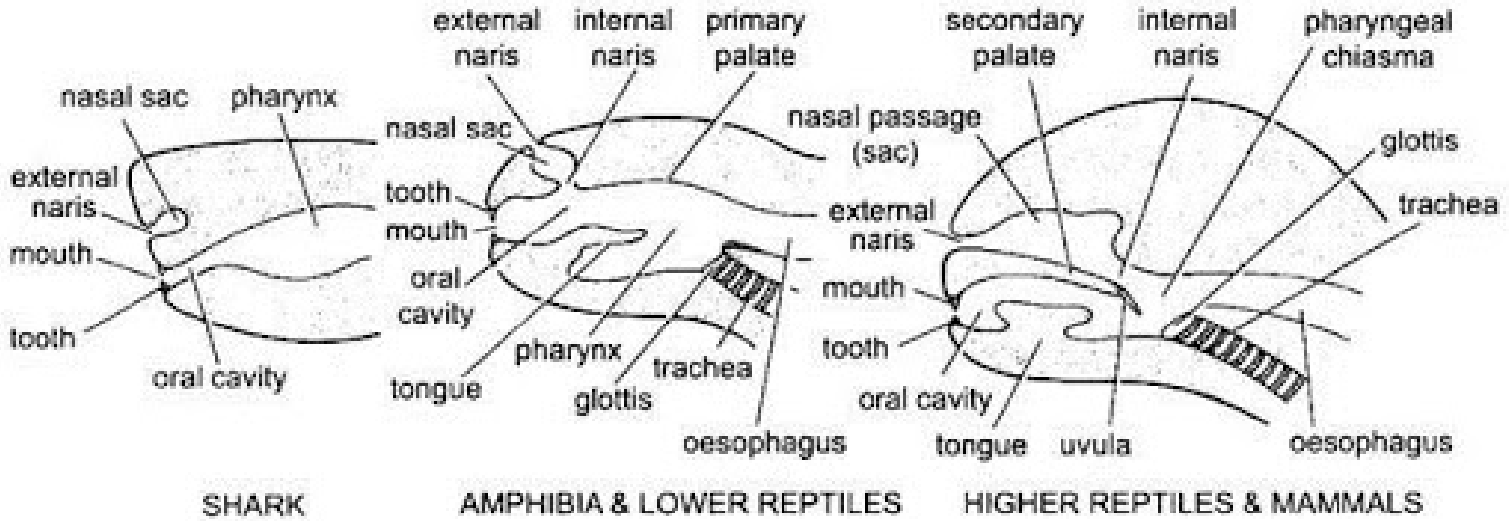


Anterior view





Alimentary canal and its chief derivatives in a vertebrate.



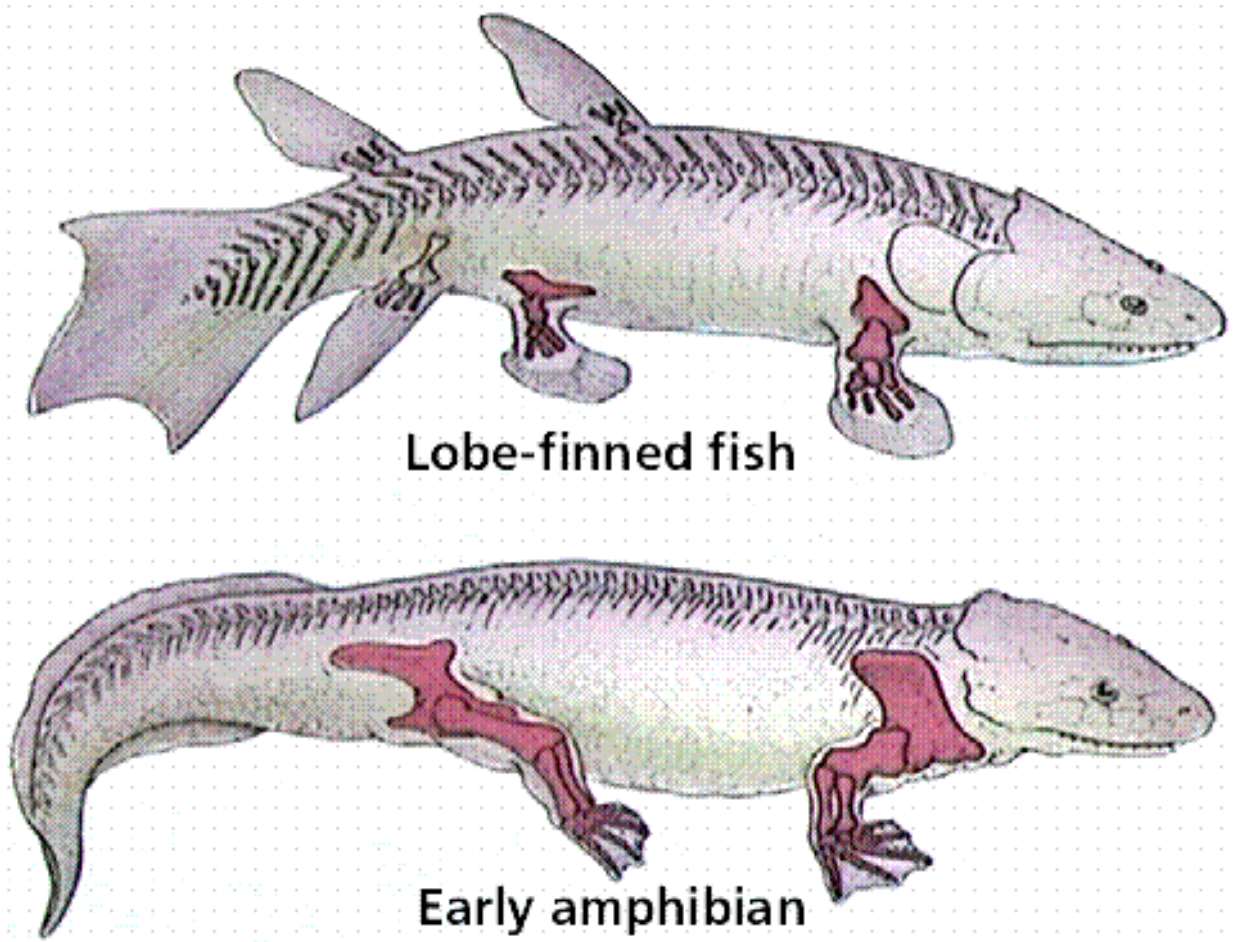
Relation of nasal passages to buccal cavities in different vertebrates.

Circular mouth of cyclostomes such as lamprey

Terminal mouth in gnathostomes (Jawed vertebrates)

Ventral mouth in elasmobranchs (cartilaginous fish)

The tongue of a woodpecker extracts insects from the bark of a tree


Lobe-finned fish
Early amphibian

1. Teeth

- Each tooth is divided into three parts, viz., upper crown, middle neck and lower root.
- Crown is the upper exposed part above the gums, which is covered by white, hard and shiny enamel.
- Neck is the middle small area covered by gums.
- Root is the lower part joined with the jawbone by cementing substances.
- The inner layer of teeth is the pulp cavity containing connective tissue, blood vessels and nerve fibres.
- Pulp cavity is lined by odontoblast cells that secrete dentine.
- Dentine is the middle layer present below the enamel and contains ameloblast cells that the secrete enamel.
- The enamel develops from the ectoderm while the other parts develop from the mesoderm.
- Cyclostomes lack true teeth but epidermal teeth are present in the wall of the buccal funnel and on the tongue.
- Tadpole larvae of anurans have serrated (saw like) epidermal teeth.
- True teeth are found in all vertebrates (except cyclostomes, sturgeons, some toads, sirens, turtles and birds).
- In fishes, amphibians and most reptiles, teeth are acrodont, homodont and polyphyodont. Teeth are modified placoid sclaes.
- In mammals, teeth are thecodont, heterodont and diphyodont.
- Teleosts have sharp teeth attached to jaw bones.
- In mammals, teeth exhibit morphological variation. Four types of teeth are found in mammals, viz., incisors (cutting), canines (piercing and tearing), premolars and molars (mastication).
- In human adults, 32 teeth are found in premaxilla, maxillae and mandible .
- Teeth are found in the socket of the jaw bone called thecodont.

- Teeth are deciduous or develop two times. Hence, these are called diphyodont. Human teeth are heterodont, i.e., of the following four types:

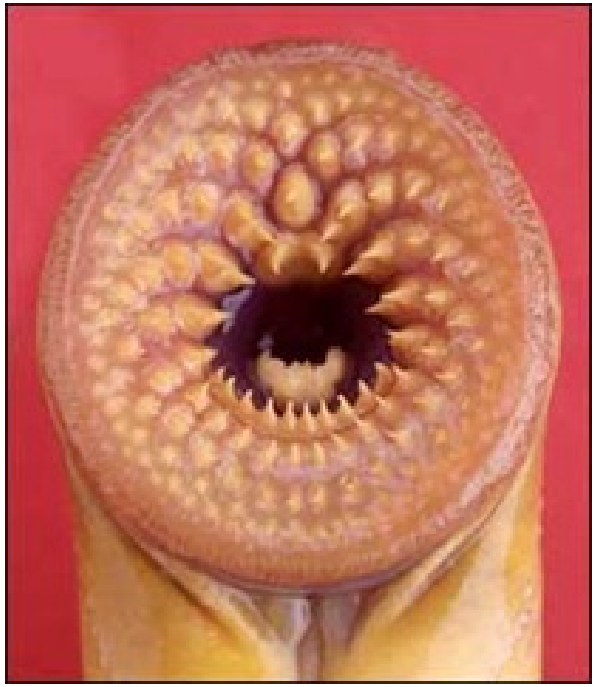
(a) Incisor	8
(b) Canine	4
(c) Premolar	8
(d) Molar	12
	32

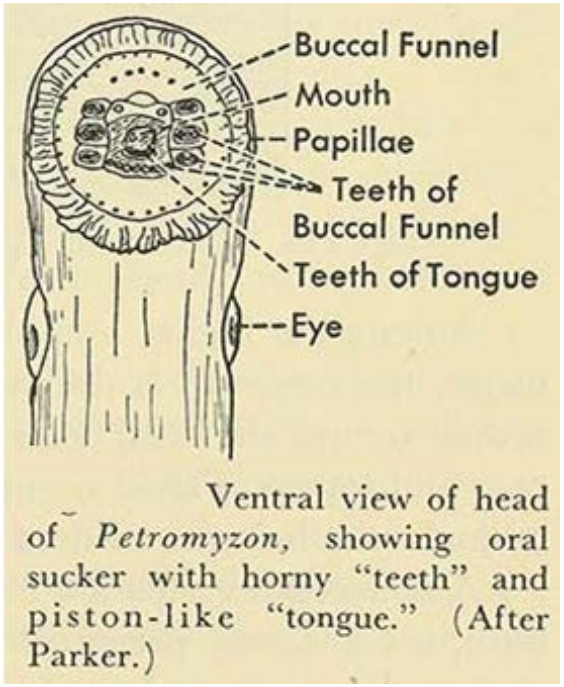
- Dental formula of humans is

$$^{2}/_{2},\ c\ ^{1}/_{1},\ pm\ ^{2}/_{2},\ m\ ^{3}/_{3} \times 2 = \frac{16}{16} = 32$$

- In humans, 20 teeth are diphyodont, i.e., grow twice in a lifetime, while 12 are monophyodont.

- Monophyodont teeth in humans are premolars. They are not found in their babies.
- Third premolars appear late in life and are called wisdom teeth.
- Premolars and molars are called cheek teeth.





Ventral view of head of *Petromyzon*, showing oral sucker with horny "teeth" and piston-like "tongue." (After Parker.)

Epidermal teeth Cyclostomes present in the wall of the buccal funnel and on the tongue

2. Tongue

- The tongue is a simple crescent-shaped elevation in the floor of the oral cavity.
- Tongue is the gustatory receptor.
- Tongue is narrow and free at the anterior end while broad and fixed at the posterior end.
- Tongue is composed of connective tissue, striated muscle, blood vessels, Ebner's gland and stratified epithelium.
- The human tongue contains the following three types of taste papillae:
    - Fungiform papillae - Mushroom, less numerous
    - Circumvallate papillae - V-shaped, largest, 8-12 in number
    - Filiform papillae - Conical, smallest, numerous
- The tongue is nonmuscular and non glandular in fishes. Taste buds also absent
- Some anurans are tongueless while in others, a muscular tongue is present with few taste buds present and is mainly used to capture pray.
- In snakes and some lizards, the tongue is well developed and bifid but in turtles and crocodiles tongue is poorly developed.
- In birds the tongue is well developed and have few taste buds.
- In mammals the tongue is well developed and taste buds are present on the tongue.
- In vertebrates, the tongue performs various functions, viz., capturing and gathering of food, swallowing, thermoregulation, manipulating fluids and solids in the oral cavity and assists in human speech.

(a)

(c)

(b)

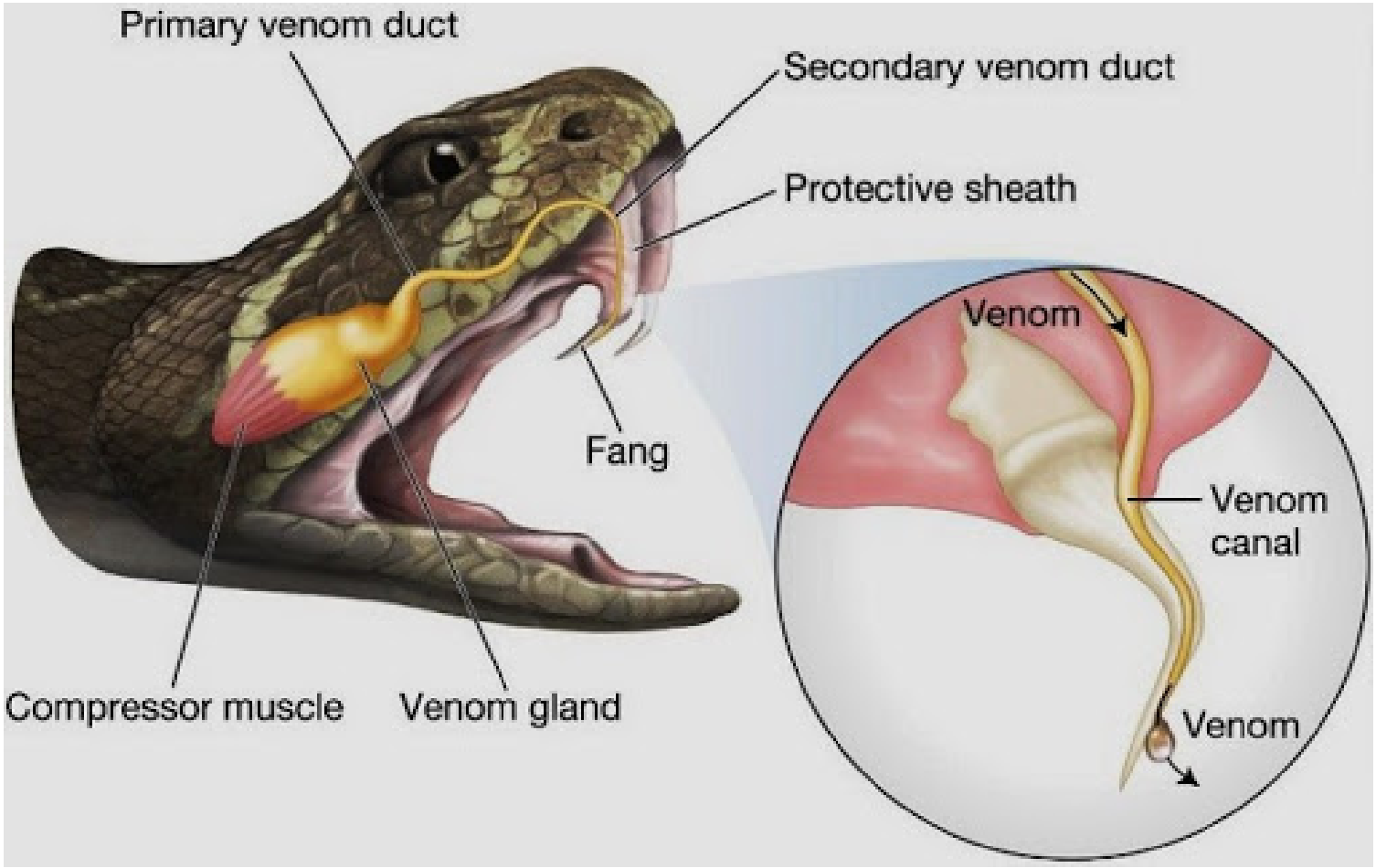
(d)

(e) An immature Allen's humming bird (*Selasphorus sasin*) at a flower feeding

Tongues. (*a*) Rasping tongue and mouth of a lamprey. (*b*) Fish tongue. (*c*) Tongue of a chameleon catching an insect. A chameleon can launch its tongue at an unsuspected insect at speeds of 25 body lengths per second. (*d*) The tongue of a woodpecker extracts insects from the bark of a tree.

3. Oral Glands

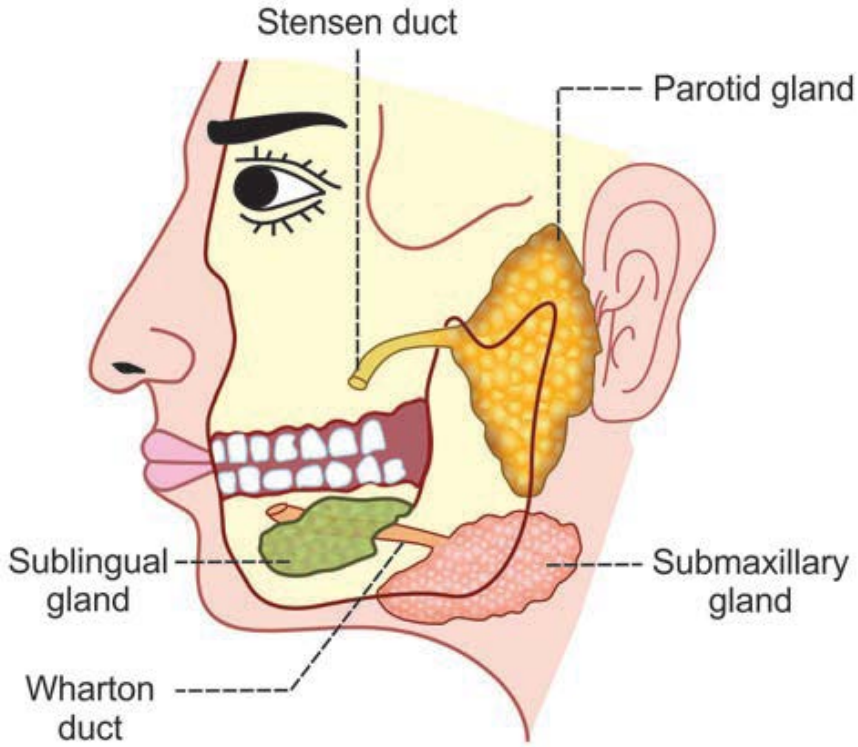
- In vertebrates, a great variety of oral glands are found that secrete a variety of substances such as saliva, poison (lizards, snakes and mammals) and anticoagulant (vampire bats).
- Salivary gland is absent in fishes and amphibians.
- A few mucus secreting salivary glands are present in the buccal cavity of reptiles such as Uromastix (Spiny-tailed lizard).
- In snakes the labial glands are present in a row in the upper and lower jaws. The posterior labial glands of the upper jaw is modified as the poison gland in the poisonous snakes.
- Buccal glands of birds such as pigeon probably secrete **mucus** but they are not salivary glands.
- Buccal gland of vampire bats produce anticoagulant.
- In mammals salivary glands of different kinds found which open into buccal cavity by separate ducts. They secrete saliva containing an enzyme Ptyalin.



Poison gland in the poisonous snakes

Salivary Glands of human

- Salivary glands are compound alveolar glands that secrete saliva.
- In the buccal cavity of humans, three pairs of salivary glands are present, viz., parotid, sublingual and submaxillary.
- Parotid gland is the largest and its duct is called the duct of Stenson.
- Sublingual is the smallest gland and its duct is called the duct of Rivinus.
- Submaxillary/submandibular is moderate and its duct is called the duct of Wharton.



Major salivary glands

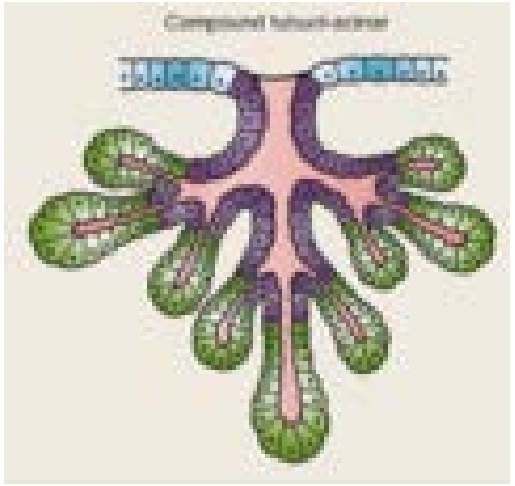
Functions of Saliva

(a) It keeps the mouth moist.

(b) It softens food and helps in swallowing.

(c) It helps in speech.

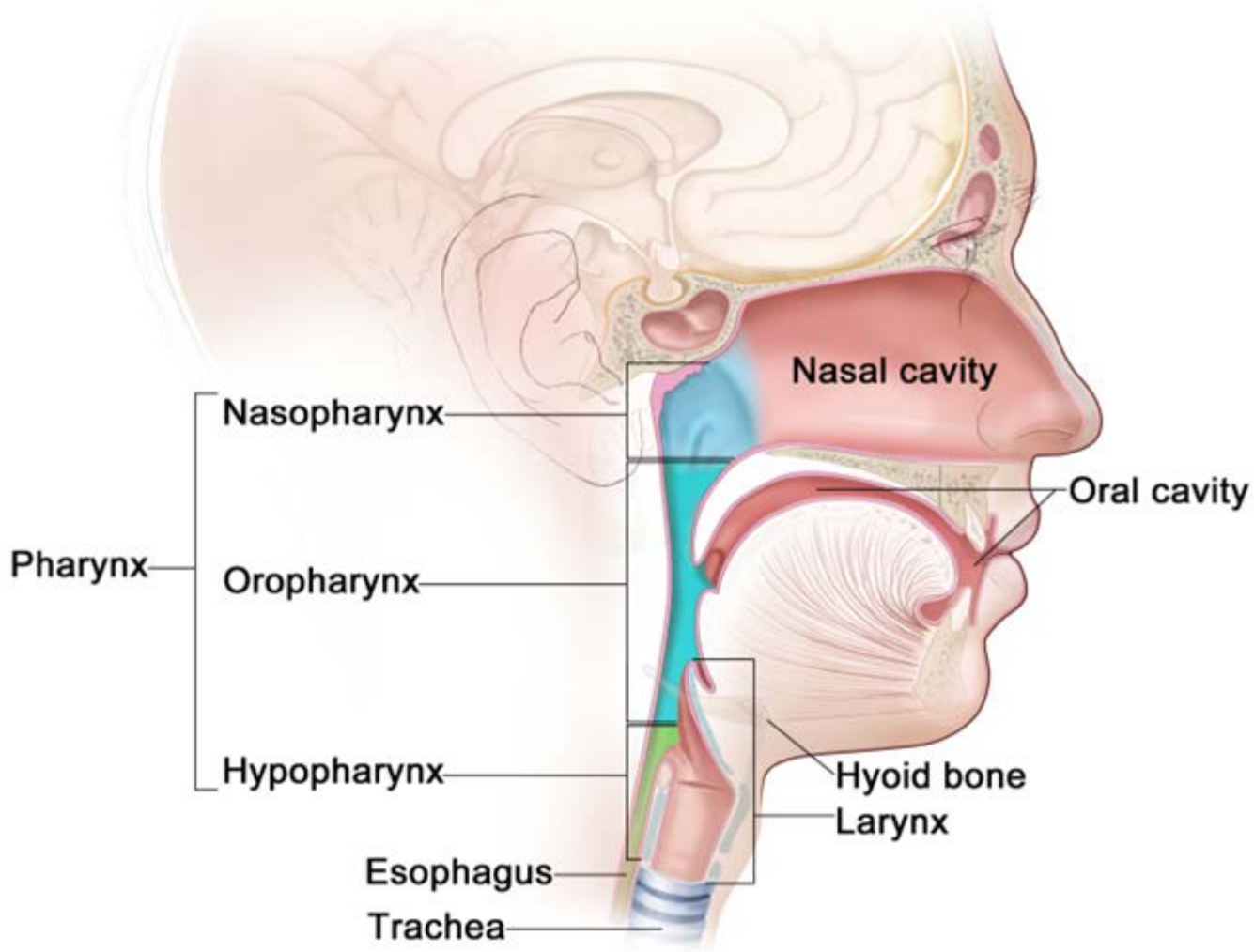
(d) Saliva contains amylase which digests starch.



II. Pharynx

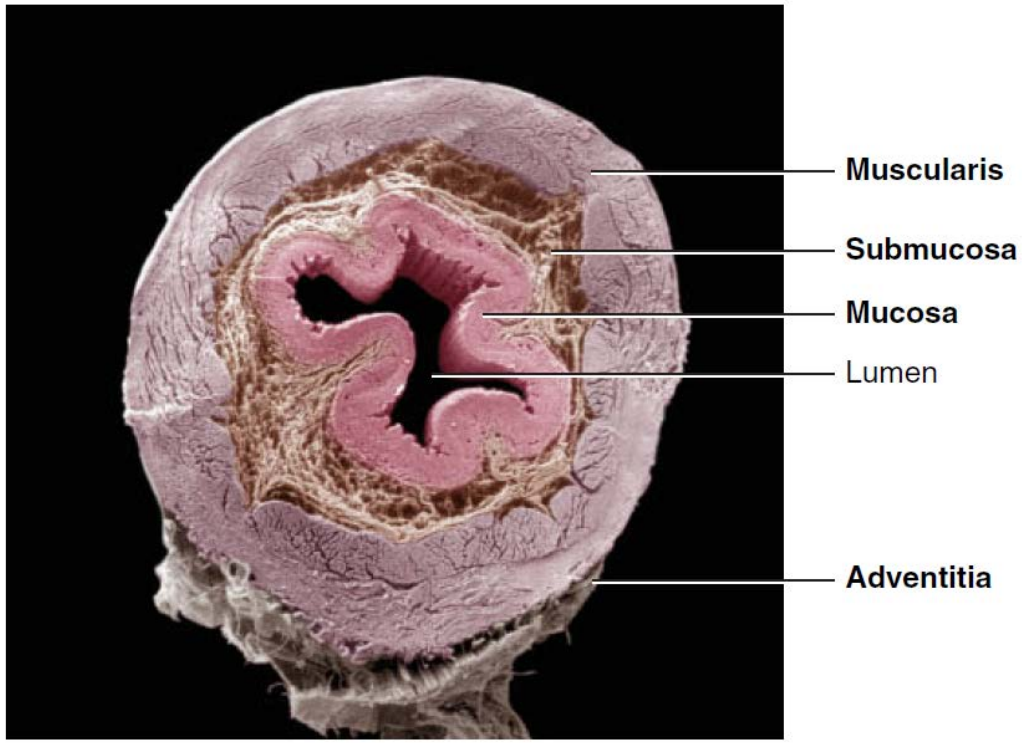
- It is the region of foregut between the oral cavity and the oesophagus.
- It is separated from the buccal cavity by fauces.
- The pharynx is lined with the endoderm.
- It is divided into three parts, viz., nasopharynx, oropharynx and laryngopharynx . Nasopharynx is the upper part located behind the uvula.
- Nasopharynx bears the opening of internal nares on the roof and the opening of Eustachian tubes on the sides.
- Oropharynx is the middle part located behind the buccal cavity.
- Oropharynx provides common passage for food and air.
- Laryngopharynx is the lower part located posterior to the tongue.
- Laryngopharynx contains two openings, viz., glottis and gullet leading into the trachea and oesophagus, respectively.
- Glottis is guarded by a cartilaginous valve called epiglottis, used at the time of swallowing of food.
- In fishes, the pharynx is the respiratory organ.
- In tetrapods, the pharynx is the cross road between food and respiratory passage.
- In tetrapods, it is the site of openings of auditory (Eustachian) tube.

Anatomy of the Pharynx

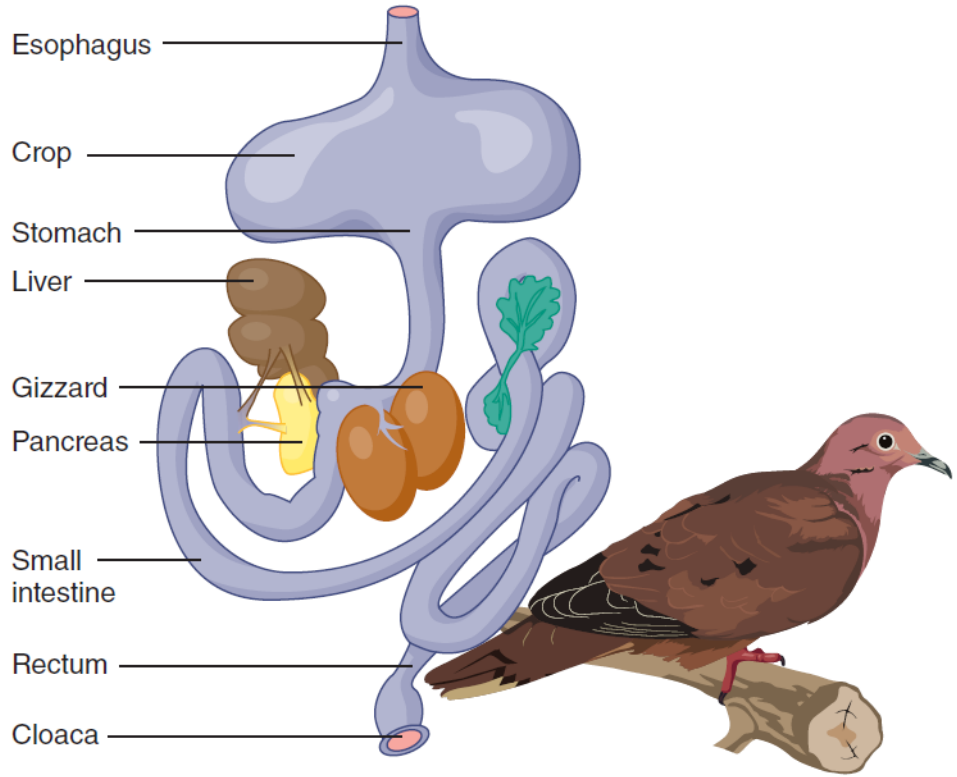


lll. Oesophagus

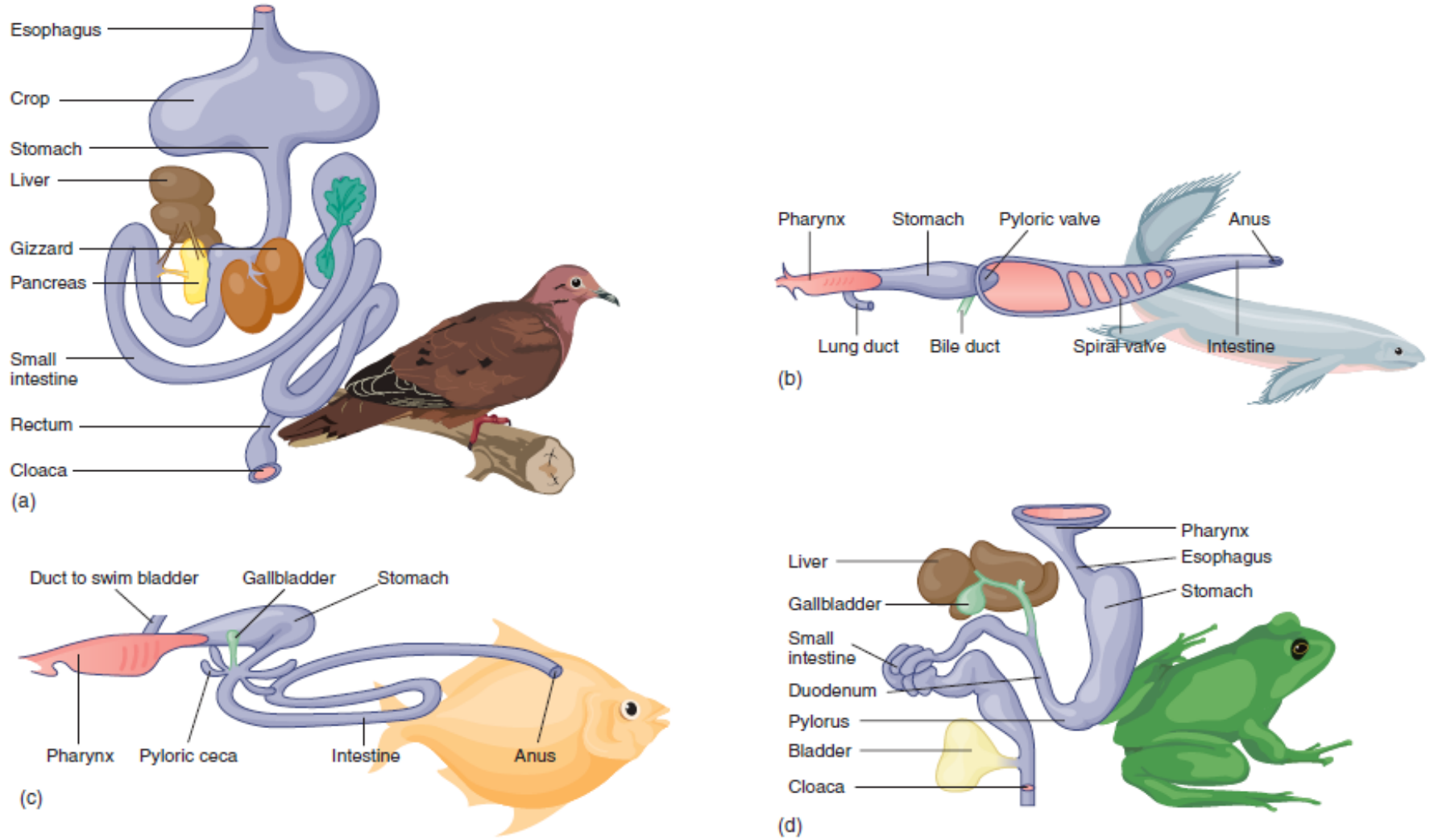
- The oesophagus is a distensible muscular tube connecting the pharynx and the stomach.
- It is a tube, about 25 cm long, which connects the pharynx with the stomach in human.
- It descends from gullet and is parallel to the trachea.
- It does not take part in digestion.
- The oesophagus is very short in neckless vertebrates (fishes and amphibians).
- Sharks and *Latimeria* have a large oesophagus.
- The oesophagus is long in *Polypterus.*
- In amniotes, the oesophagus is fairly long, reaching to the maximum in birds and giraffes.
- In birds, the oesophagus contains a distensible sac called **crop**, which acts as a temporary site of food storage.
- In human, at each end of the esophagus, the muscularis becomes slightly more prominent and forms two sphincters—the **upper esophageal sphincter (UES),** which consists of skeletal muscle, and the **lower esophageal** (*cardiac*) **sphincter (LES)**, which consists of smooth muscle and is near the heart.
- In human, the esophagus secretes mucus by **cardiac glands** and transports food into the stomach. It does not produce digestive enzymes, and it does not carry on absorption.



Section of esophagus

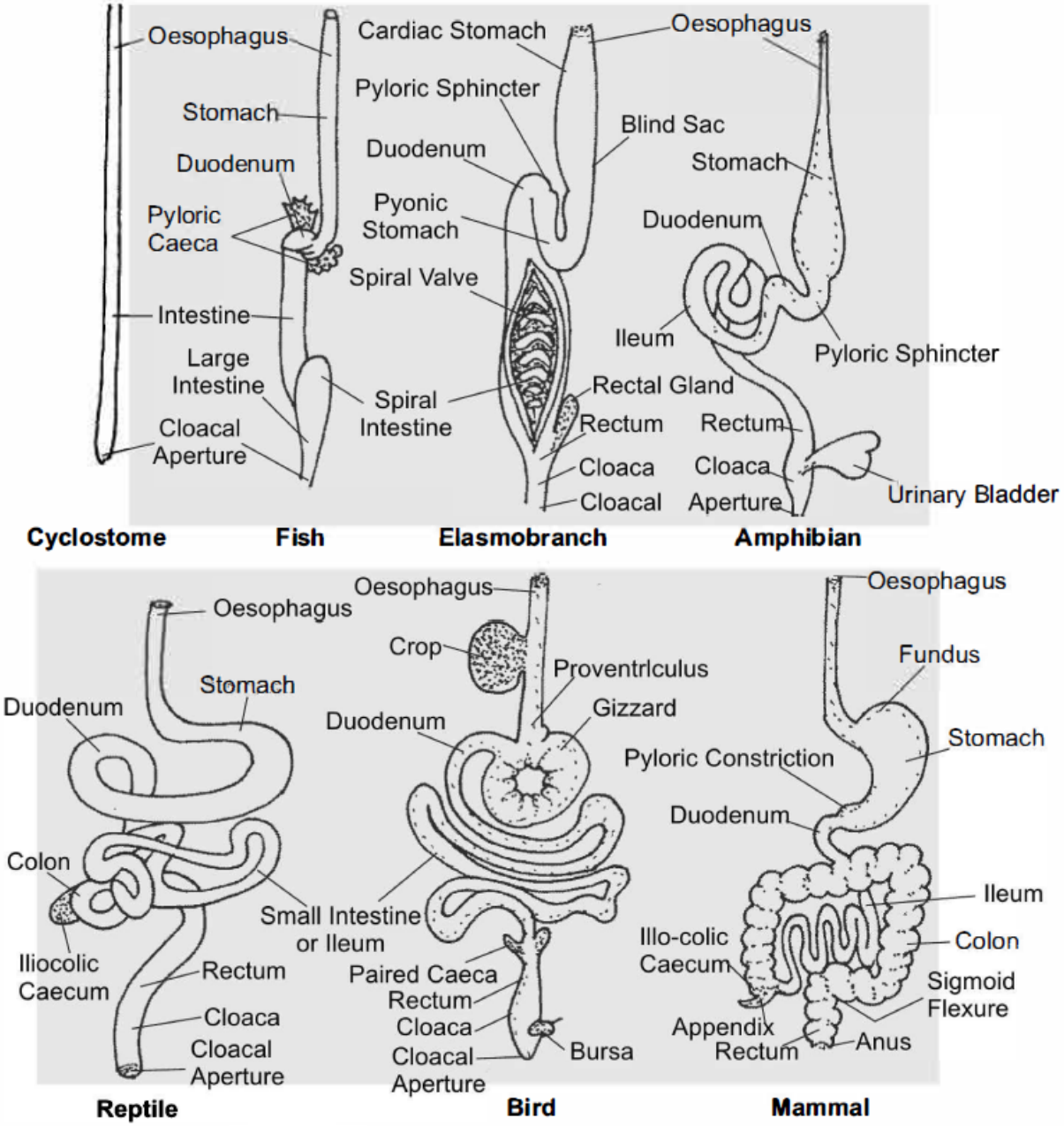


IV. Stomach

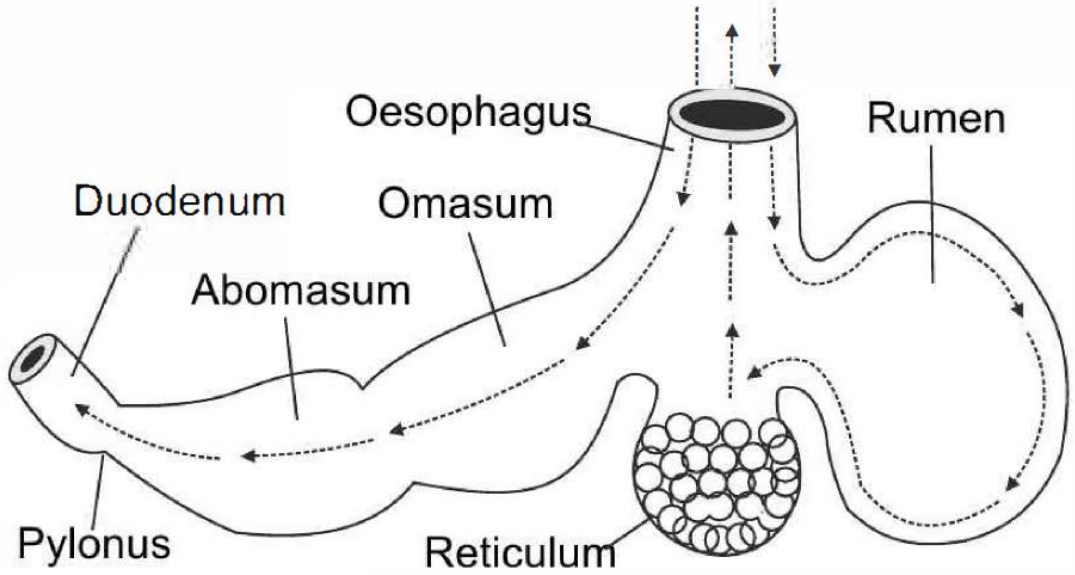


Arrangement of Stomachs and Intestines in a Variety of Vertebrates. (*a*) Pigeon. (*b*) Lungfish. (*c*) Teleost fish. (*d*) Frog.

- The stomach is a muscular chamber at the end of the oesophagus and a pouch-like organ located in the upper left part of the abdominal cavity.
- Oesophagus opens into it and a cardiac sphincter guards the opening.
- It serves as storage and macerating site for ingested food and secretes digestive enzymes.
- The shape of the stomach varies from animal to animal and even in the same animal, depending upon whether the stomach is full or empty.
- Stomach is lacking in cyclostomes, chimeras, lung fishes and some teleosts.
- In embryos of vertebrates, the stomach is a straight tube-like structure.
- In certain fishes, long-bodied amphibians, lizards and snakes, the stomach is cigar-shaped.
- In most fishes, the stomach is I-shaped.
- In some deep fishes, the stomach is so distensible, so that it can hold prey larger than themselves.
- In amphibians, the stomach is long and lacks fundus.
- The stomach of *Uromastix* is U-shaped, having thick muscular walls and the gastric glands found in the mucous lining of stomach.
- In birds, the stomach is short and has no storage capacity. The stomach has a small glandular region called proventriculus and a distal muscular region called gizzard. The gizzard helps in grinding the food.



Digestive tracts of different vertebrates



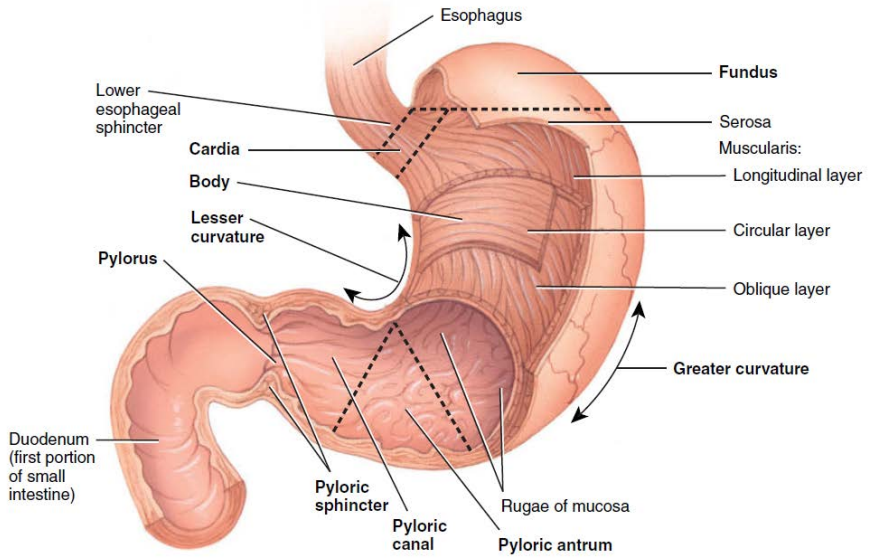
Stomach of a ruminant

- Mammals have a well-developed stomach.
- It is divided into four parts, viz., cardiac, fundus, body and pylorus.
- Cardiac is the upper part of the stomach.
- Fundus is the thickest part situated left to the cardiac part.
- Body is the main part of the stomach and is situated in the middle part.
- Pylorus is the lower part which opens into the duodenum.
- The inner wall of the stomach contains **gastric glands** in which the following three types of secretary cells are found:

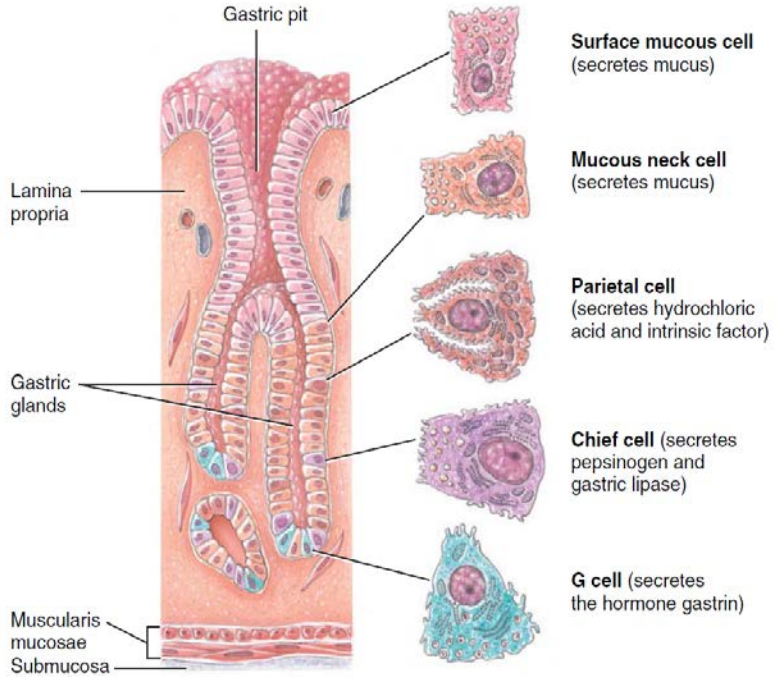
    (a) Chief cell - Pepsinogen and prorennin

    (b) Oxyntic cell - HCl

    (c) Mucus cell - Mucus



Anterior view of regions of stomach

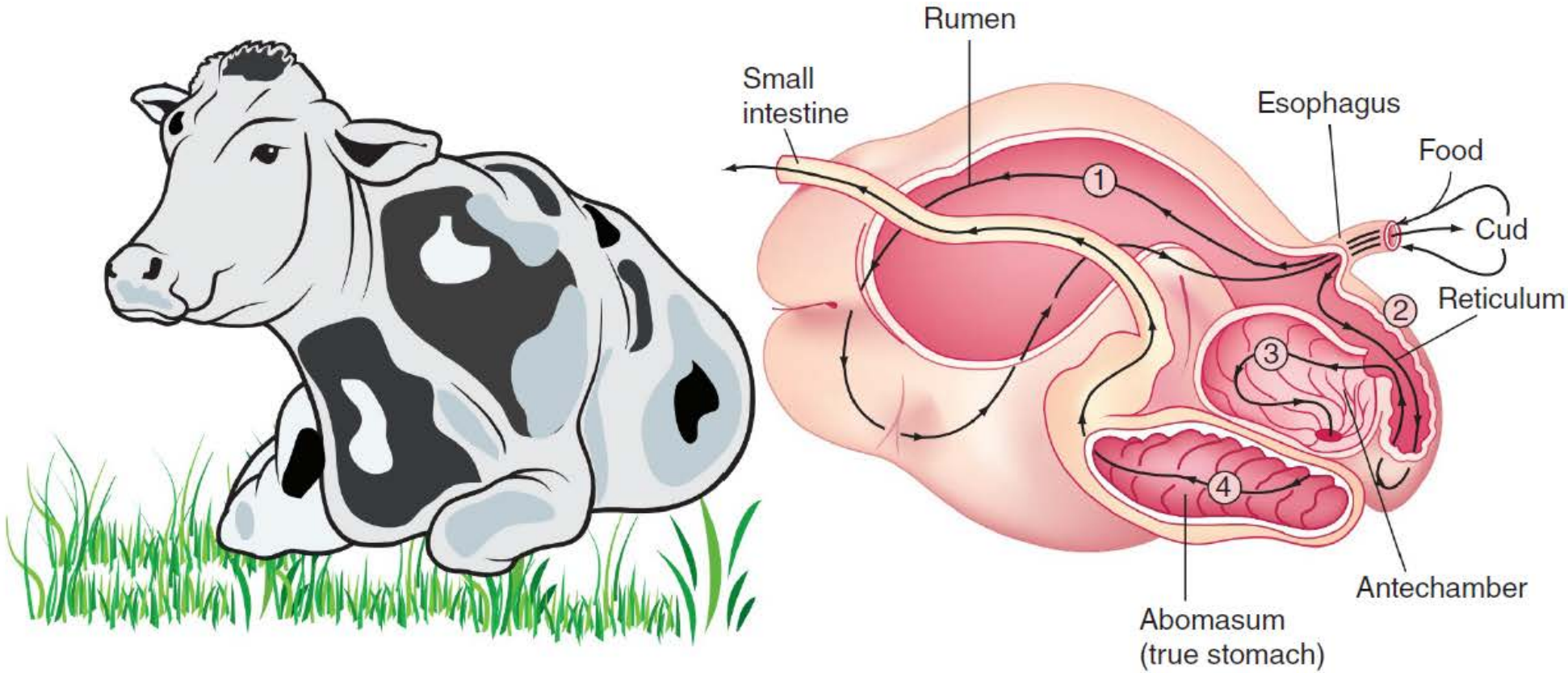


Sectional view of the stomach mucosa showing gastric glands and cell types

- In monotremes (egg laying mammal), the stomach is in the form of a sac-like structure and is without any gastric glands.
- In ruminants, the stomach has four chambers, viz., the rumen, reticulum, omasum and abomasum.
- The rumen is a large chamber while the reticulum is a small accessory chamber having a crisscross ridge on its inner surface. In the rumen and reticulum, food is reduced to pulp.
- In the omasum, food is again triturated (grind to a fine powder). Abomasum is the true stomach in ruminants where enzymatic activity operates.
- In camels, the omasum is absent.

Functions of Stomach

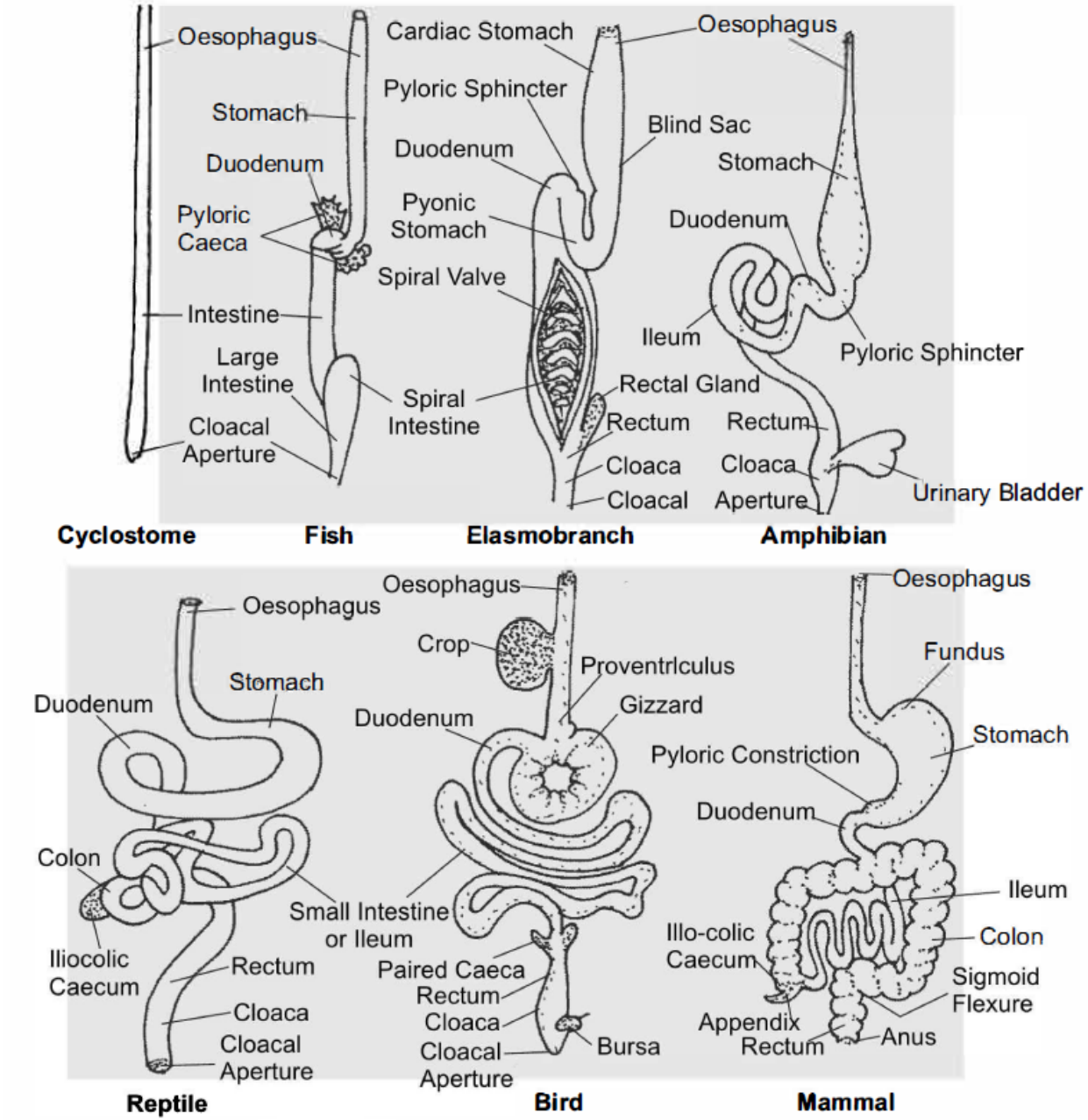
- Gastric glands of stomach secrete gastric juice which takes part in the digestion of food in acidic medium.
- Stomach stores food for four hours.
- Stomach helps in churning and mixing of food with gastric juices.



Ruminant Mammal. Four-chambered stomach of a cow, where symbiotic microorganisms digest cellulose. Grass eaten by a ruminant enters the rumen (1) where it is partially digested. Before moving into a second chamber, the reticulum (2), the food may be regurgitated and rechewed (the cud). The food is then transported to the posterior two chambers, the antechamber (3) and abomasum (4). Only the abomasum secretes gastric juice.

V. Intestine

- The intestine is located between the stomach and the cloaca or anus.
- It is an important site for digestion and absorption.
- The intestines of vertebrates are differentiated to varying degrees into small and large intestines.
- The intestine is relatively straight and short and not differentiated into large and small intestine in cartilaginous and primitive bony fishes (lung fish and sturgeon). However, the intestines of cartilaginous fishes have a **spiral valve**. Caecum is lacking. Distal end of the intestine forms a short, narrow rectum which opens into **cloaca**. Rectum receives a tubular **rectal gland** of unknown function.
- In amphibians, the intestine is differentiated into a coiled small intestine and a short straight large intestine. Duodenum is a straight tube, forms “U” with stomach, and receives hepato-pancreatic duct. True villi in the ileum is absent. Caecum and rectal gland is lacking. It contains urinogenital apertures and **bursa Fabrici.**
- In reptiles and birds, the intestine is differentiated into a coiled small intestine and a relatively short large intestine that empties into cloaca. Bursa Fabrici is well observed in birds but it is not found in reptiles.
- In mammals, the small intestine is long and coiled and differentiated into duodenum, jejunum and ileum. The large intestine is often long (but not as long as the small intestine). A caecum is often present at the junction of the small and large intestine in herbivorous forms.
- In many bony fishes and mammals (except monotremes), the urinogenital and anal openings are separate.
- Vermiform appendix is absent in Fishes, amphibians, reptiles and birds but present in mammals.



Digestive tracts of different vertebrates

Intestine in Humans

Small Intestine

- It is a 6-7 metres long and narrow tube.
- It is divided into three parts, viz., duodenum, jejunum and ileum.

(a) Duodenum

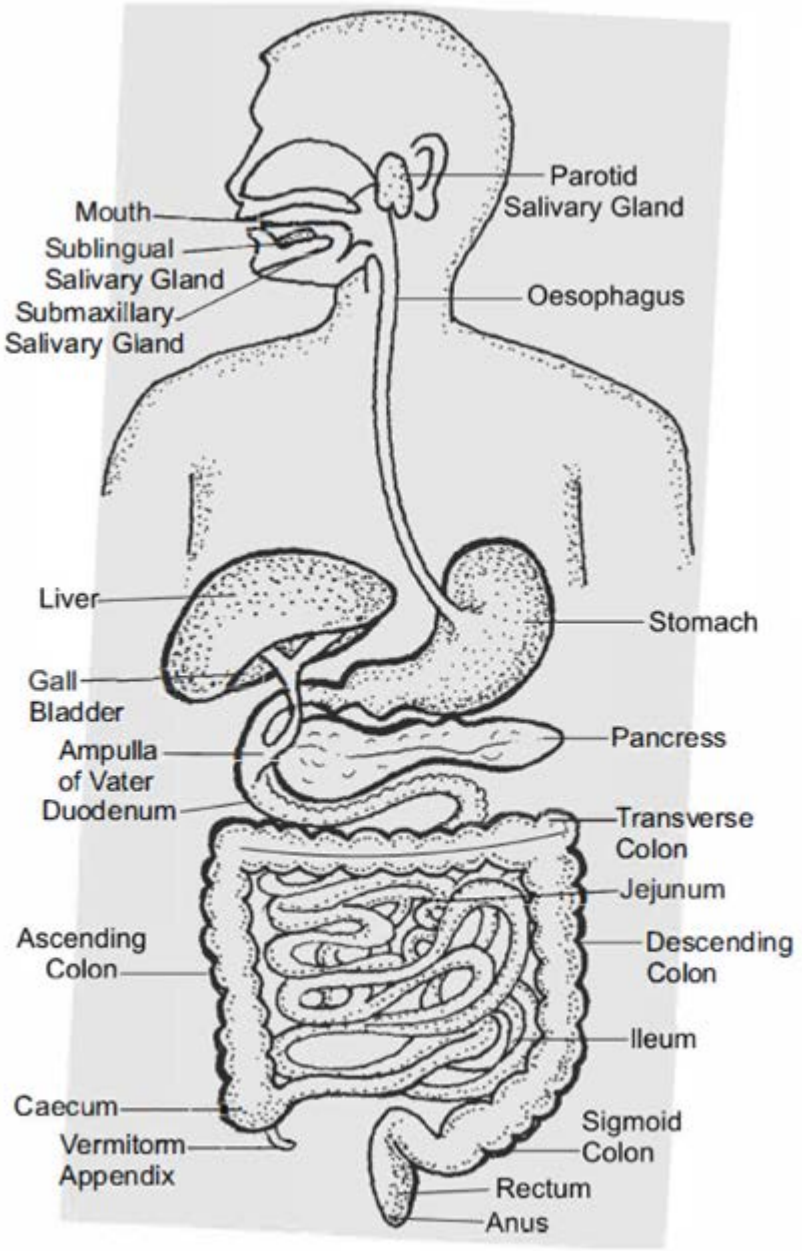
- It is the upper part of the small intestine.
- It receives bile and pancreatic juice from the hepato-pancreatic duct.
- The opening is guarded by the sphincter of oddi.

(b) Jejunum

- It is the middle part of the small intestine.
- It is highly coiled and secretes succus entricus.

(c) Ileum

- It is the lower part of the small intestine
- It opens into caecum of the large intestine.
- The opening is guarded by the ileo-caecal valve.
- Its wall contains many Payer's patches.



Alimentary canal of man

Functions of Small Intestine

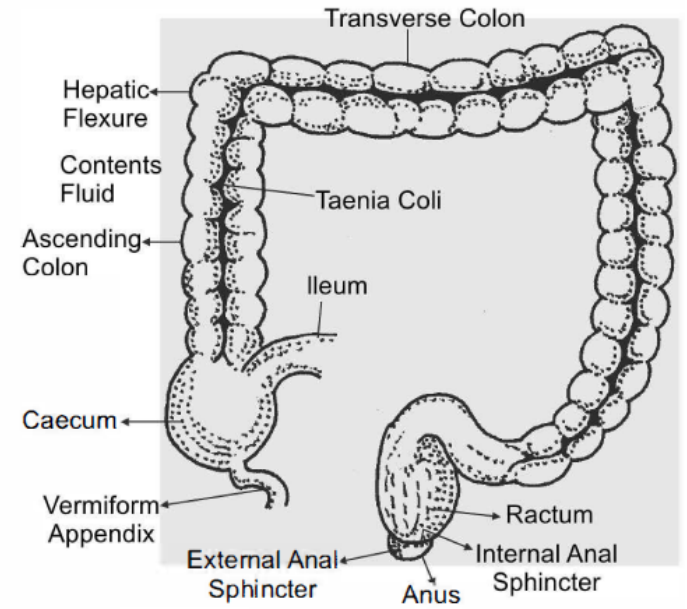
- It helps in the digestion of food in alkaline medium.
- It also absorbs digested food.
- Bruner's gland and Crypts of Lieberkuhn secrete several digestive enzymes.
- Its walls also secrete hormones likes cholecystokinin, enterogastrone, secretin and enterokinin that help in digestion.

Large Intestine

- It is a short and wide tube.
- It is about 1.5 metres long and is divided into three parts, viz., caecum, colon and rectum.

(a) Caecum

- It is the upper part of the large intestine.
- It is a sac-like structure.
- It is distally continued into a thin, hardtube called vermiform appendix.
- Vermiform appendix is a vestigial organ Caecum of the large intestine.



Parts of the large intestine

(b) Colon

- It is the middle and longest part of the large intestine.
- It is divided into four parts, viz., ascending colon, transverse colon, descending colon and sigmoid colon.
- Colon has internal folds of longitudinal muscle called taeniae coli .
- The wall has many external folds called haustra.

(c) Rectum

- Sigmoid colon opens into the rectum.
- It temporally stores fecal material.

Functions of Large Intestine

- It absorbs water and electrolytes.
- It stores fecal material.
- It harbours symbiotic bacteria synthesising vital vitamins.

Anal Canal

- It is the last part of the alimentary canal.
- It connects the rectum with the anus.
- It is about 3 cm long.
- It opens outside by the anus, containing the anal sphincter.
- It helps in the removal of fecal material.

VI. Glands Associated with the Digestive System

Liver

- It is the largest exocrine gland of the body.
- In fishes it is bilobed and yellowish gland. In amphibians liver is 3-lobed and reddish brown gland. In reptiles such as *Uromastix* liver is large, bilobed and dark red in color. In birds it is bilobed and dark red in color. In mammals such as rabbit it is large, red colored, 5-lobed namely- right and left lobe lateral, caudate and Spigelian lobe.
- In humans liver weighs about 1.5 kg and is 15 to 22 cm in dimension.
- It is located in the right upper part of the abdominal cavity and just below the diaphragm.
- It is divided into two main lobes, viz., a large right lobe and a small left lobe.
- The right lobe is further divided into the right lobe proper, quadrate lobe and caudate lobe.

Histological Structure

- Histologically, each lobe is made up of polyhedral lobules.
- Lobules are separated from one another by a connective tissue called Glisson's capsule.
- Glisson's capasule contains hepatic portal vein, hepatic artery and bile duct.
- Each lobule is composed of hepatic cells arranged radially around the central vein forming hepatic cords.
- The space between two hepatic cords is called hepatic sinusoids.
- Hepatic sinusoid contains a network of hepatic portal vein and hepatic artery that open commonly in the central vein.
- The central vein is connected to the inferior vena cava that opens into the right atrium of the heart.
- Sinusoid also contains tissue macrophages called Kupffer's cells.
- Hepatic cells secrete bile into canaliculi which pass through the hepatic cord.
- Many canaliculi of a lobe unite to form bile ductule.
- Bile ductules of surrounding lobules unite to form bile ducts.

- Bile ducts of different lobes unite to form a common hepatic duct.
- The common hepatic duct opens into the gall bladder through the cystic duct.
- The gall bladder stores and concentrates bile.
- At the junction of the cystic and common hepatic duct, a common bile duct originates and opens into the pancreatic duct forming the hepatopancreatic duct.
- This opening is guarded by a valve known as sphincter of Boyden.

Bile

•Bile is an alkaline fluid.

•It contains bile salts, bile pigment, water, mineral salts, etc.

•Bile performs the following functions:

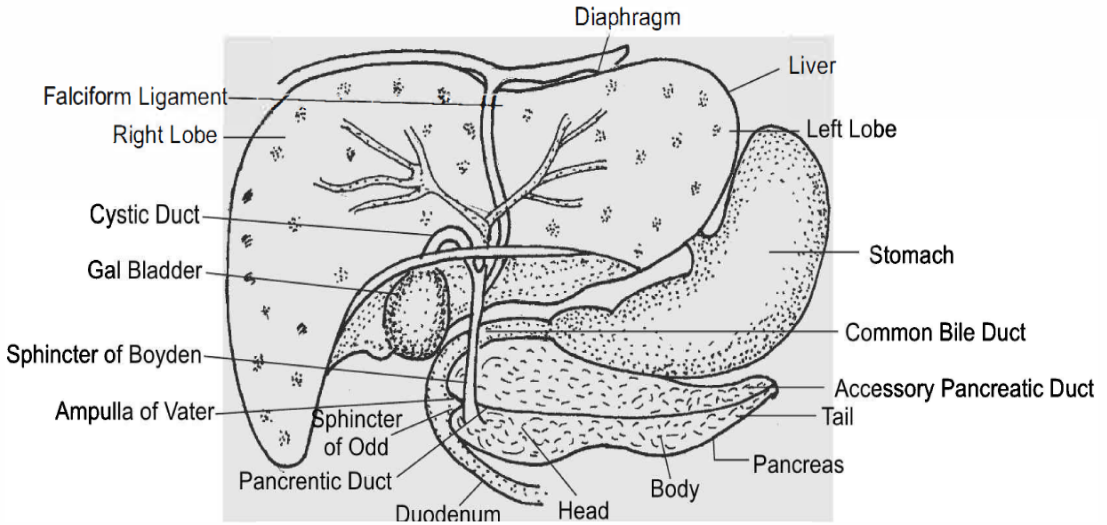
(a) It is an antiseptic fluid.

(b) It is an alkaline fluid that stops the action of gastric juices

(c) It emulsifies fats.

(d) It provides a medium for the excretion of bilirubin.

(e) It helps in absorption of fat-soluble vitamins and fats.



Liver, pancreas, stomach and hepatopancreatic duct

Functions of Liver

- It secretes bile.
- It stores glucose in the form of glycogen.
- It causes deamination of excess amino acids forming ammonia which is converted into urea through Hanslet Krebs's cycle in the liver.
- It synthesises fibrinogen and prothrombin that help in blood coagulation.
- It stores vitamins A and D.
- It produces anticoagulant heparin.
- It is the centre of production of RBCs in the embryo.
- It converts glycogen into glucose.
- It converts excess carbohydrates into fats.

Gall Bladder

- It is a pea-shaped sac-like structure associated with the liver.
- It is about 10 cm long and 3 cm wide.
- It stores about 30 to 50 ml of bile temporarily.