

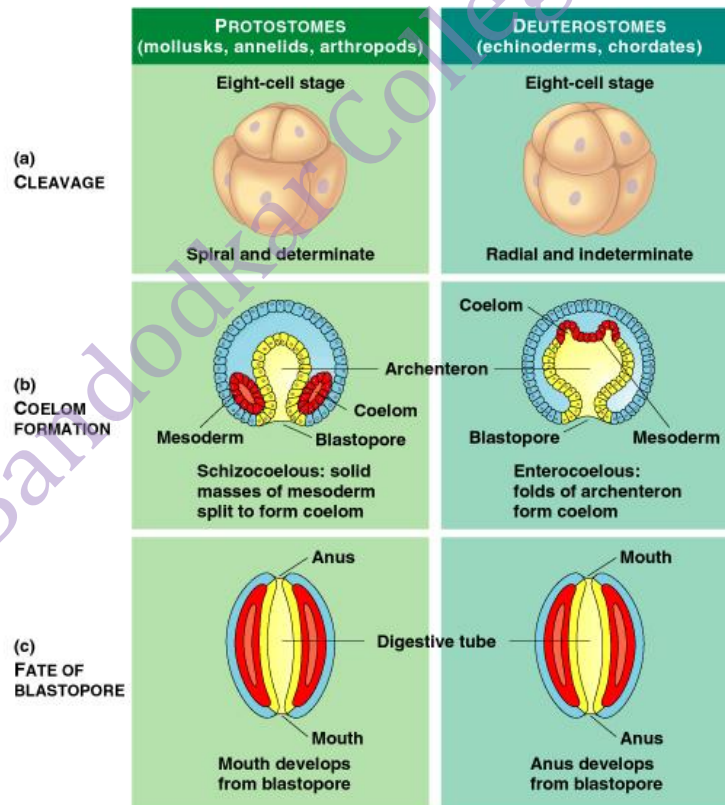
Digestive tube and its evolution

Digestive tube is the part of gut from **pharynx to the anus**. It consists of pharynx, esophagus, stomach, intestine and anus. Function of gut is to perform physical and chemical treatment of food and absorption of digested food. During this very slow process of digestion the food is pushed from anterior to the posterior through peristaltic movements.

Protostomes (Greek: *mouth first*) are a group of animals that includes the flatworms, nematodes, annelids, arthropods and molluscs. Their counterpart, the deuterostomes, includes the echinoderms, hemichordates and chordates.

In **protostomes** the first opening of digestive tube developed in the embryo is the mouth. Thus blastopore develops mouth in protostomes.

Deuterostomes develop the anus first, then the mouth at the other end of the embryo. The blastopore develops into anus.



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As evident that chordates are deuterostomes their anus is developed from blastopore and the mouth develops later and is evolved as compared to protostome thus **digestive system is complete**. The

development of gut is exhibited in gastrulation when stomodeum and proctodeum develop to form mouth and anus respectively.

Pharynx:

Pharynx is a passageway between the mouth and esophagus. The muscle present in the walls of pharynx help in swallowing the food. Pharynx is particularly important in respiration.

In **Protochordates** the digestive tract is very simple. The **pharynx is large** extending about half of body length. It is perforated giving out **several or a few gill** slits helping **filter feeding and respiration**. The **endostyle** in the pharyngeal floor secretes mucus that traps food particles. Found in protochordates and lamprey larvae. Secretes iodinated proteins. Homologous to the iodinated-hormone-secreting **thyroid gland** in adult lampreys and other vertebrates

In **Cyclostomes** the pharynx lies ventral to the esophagus and ends blindly and is entirely concerned with respiration having 7 pairs of gills. At the entrance of pharynx is a valve like velum.

In **Fishes** the numbers of gills then reduce (5 or 4 pairs) with occasional development of teeth.

In **higher vertebrates** (amphibians, reptiles, birds and mammals) pharynx highly develop is connected to lungs.

Esophagus:

The esophagus is a muscular tube that moves boluses from the pharynx to the stomach. There are two muscle layers in the esophagus: circular and longitudinal. The mucus membrane lining the esophagus is of the stratified squamous type of epithelium. The esophagus is the portion of the gut immediately following the pharynx and joins stomach at its other end. **Primitive chordates** almost lack esophagus.

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

The esophagus in **amphibians** is extremely short and is ciliated which carries food to stomach. Secretary cells in the esophagus have a digestive function.

In **reptiles** the esophagus is longer than in lower forms. Longitudinal folds enable to swallow large objects e.g. snakes. Marine turtles have inner lining of esophagus cornified papillae which point posteriorly. In birds also the inner line of esophagus is cornified.

Esophagus of **birds** has a dilated as sac like crop. The crop stores the swallowed food before it is sent to the stomach. It helps birds to eat food faster and store and also compete with other birds in case of limited food. There are crop glands in pigeons which secrete nutritious cheesy material called pigeon

milk. This is regurgitated to feed the young ones. The activity of crop glands is controlled by prolactin of pituitary gland.

In mammals there is a clear distinction between esophagus and stomach. Length of esophagus varies with length of neck.

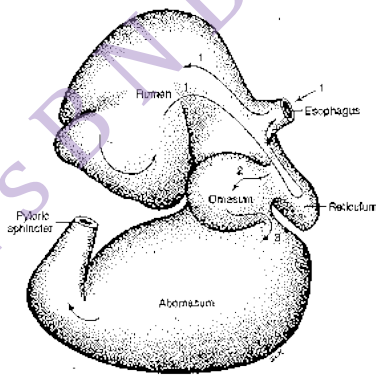
Stomach:

The stomach is a dilated thick walled sac which is highly glandular. The portion having the **gastric glands** is known as true stomach. Its digestive function is secondary acquisition. Shape of the stomach depends on the shape of the body. In snake it elongates like tube, in most animals it is '**U**' or '**J**' shaped.

In **cyclostomes** stomach is weakly developed; similar to esophagus. In **Fish** a considerable variety of stomach is observed. Some are simple straight tubes without any digestive function, as in Dipnoy, chimaeras and number of teleosts. In **amphibians & reptiles** an increasing specialization of stomach occurs (more differentiated from the esophagus). Amphibians have wide cardiac whereas fundus and pylorus are small and narrow. All amphibian stomachs have digestive function. Snakes and lizards have long spindle shaped stomach. Esophagus is distinctly separated from stomach. Crocodiles have stomach modified into gizzardlike muscular regions. **Birds** –Proventriculus (glandular stomach) and ventriculus (muscular stomach, or **gizzard due to lack of teeth**). The gizzard has a horny layer to facilitate grinding of food grains. Mammals - well-developed stomach; **ruminants** have multichambered stomachs:

In mammals, the caudal end of the esophagus is closed off by the **cardiac sphincter**. This structure allows for the passage of food from the esophagus to the stomach. When the bolus reaches the stomach, the first portion of the stomach is the **cardiac portion** of the stomach. In this region, mucus is secreted. The next region of the stomach is the **fundus**. This portion of the stomach secretes digestive enzymes that are responsible for the chemical breakdown of the ingested food. The last portion of the stomach is the **pyloric region** of the stomach. It, like the cardiac region, secretes mucus. Food is then passed through the pyloric sphincter into the duodenum. Other specializations in the stomach are apparent in mammals with other types of diets.

Reticulo-rumen (reticulum and rumen)



Reticulum and rumen are often discussed together since each compartment is separated by a low partition. Eighty percent of the capacity of the stomach is related to the reticulo-rumen. The contents of the reticulum and rumen intermix freely. The rumen is the main fermentation vat where billions of microorganisms attack and break down the relatively indigestible feed components of the ruminant's diet.

Omasum

After fermentation in the reticulum and rumen, food passes to the

omasum. The omasum acts as a filter pump to sort liquid and fine food particles. Coarse fibre particles are not allowed to enter the omasum. Also, the omasum may be the site for absorption of water, minerals and nitrogen.

Abomasum

The abomasum is the true stomach and the only site on the digestive tract that produces gastric juices (HCl and the enzymes, pepsin and rennin). Ingesta only remains here for 1 to 2 hours.

Intestine:

The **intestine** is located between the stomach & the cloaca or anus & is an important site for digestion & absorption. Here the acidic chyme from the stomach is mixed with alkaline bile from liver, pancreatic juice from pancreas and the digestive secretions of number of small glands in the wall of the intestine itself. Vertebrate intestines are differentiated to varying degrees into small & large intestines. The length of the intestine depends on the feeding habit of animal. It is relatively short in carnivorous forms and long in herbivores.

Cyclostomes:

In **cyclostomes** intestine is straight. At its posterior end it enlarges slightly to form a rectum which terminates in anus. This opens into the anterior end of cloacal depression. A longitudinal fold, the Typhlosole takes a spiral course, projects into the cavity of intestine.

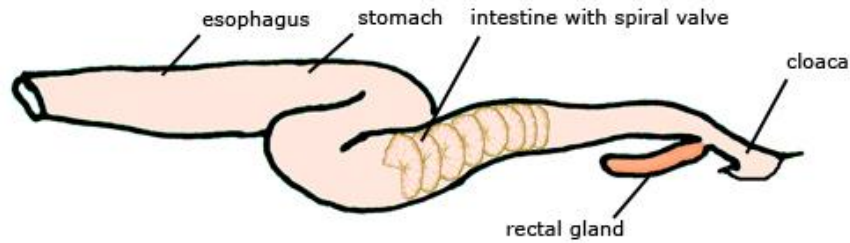
Lamprey Digestive tract



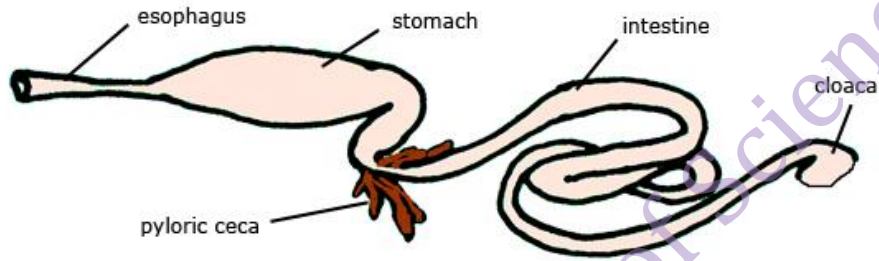
Fishes:

In **Elasmobranches** small intestine is shorter than the stomach. It is wide, straight. Large intestine contains a well developed spiral or scroll valve. In large intestine, a spiral/scroll valve is also found in chimaeras, Dipnoi, *Latimeria*, *Chondrostei* and others. A long rectal gland connects to the intestine by means of a duct at the distal end which throws excess salt (NaCl) from blood to intestine. In Dipnoi cloacal caeca are present. Many fishes have pyloric caecae. Mackerel may have as many as 200 pyloric caecae.

Shark digestive system



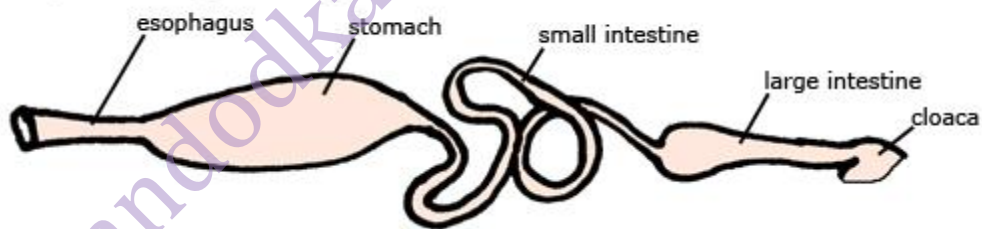
Teleost Digestive System



Amphibians:

In **caecilians** the intestine is not differentiated into small and large regions. In salamander intestine is highly coiled structure. The large intestine is short in anurans and opens into cloaca. A ventral diverticulum of amphibians gives rise to urinary bladder. There is an iliocolic valve present between small and large intestine. Villi are seen in most of amphibians.

Amphibian digestive system

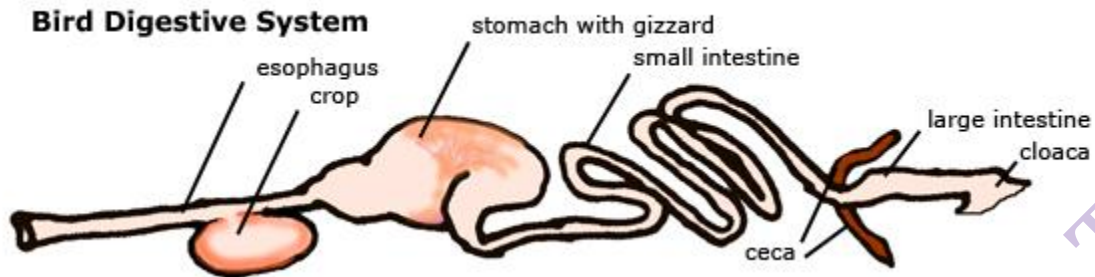


Reptilians:

In **reptilians** small intestine is narrow, elongated and coiled. Large intestine is wide and straight and opens into cloaca. Iliocolic valve is present in addition to colic caecum. Reptiles are the first vertebrates to have true colic caeca.

Birds:

Birds have very long small intestine. Large intestine is wide, short and terminates in cloaca. A colic caeca are lacking in woodpeckers, parrots and others.



Mammals:

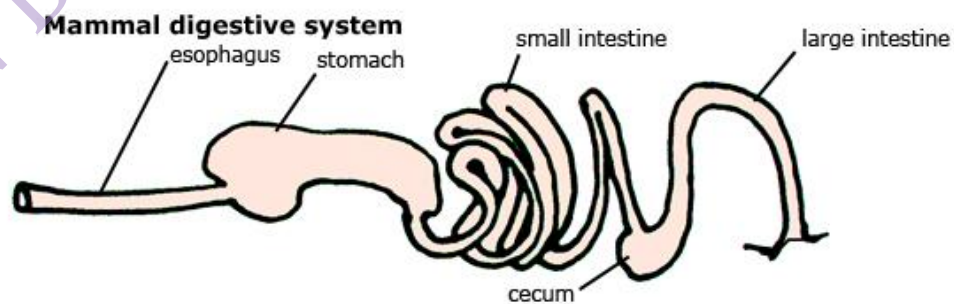
In mammals, the small intestines are the longest part of the alimentary canal (average in man is 22 ½ ft) and the site of most enzymatic digestion and virtually all absorption of nutrients. The small intestine runs from the pyloric sphincter through three subdivisions. The subdivisions include:

- The Duodenum
- The Jejunum
- The Ilium

Because of its carnivorous diet, the cat has evolved a relatively short small intestine and a reduced caecum. The caecum contains bacteria that break down plant material. In mammals, the caecum varies considerably in size, depending on the animal's diet. The epithelium of small intestine has numerous villi. In addition great numbers of glands secreting hormones like **secretin**, **pancreozymin** and **cholecystokinin** and digestive enzymes are present.

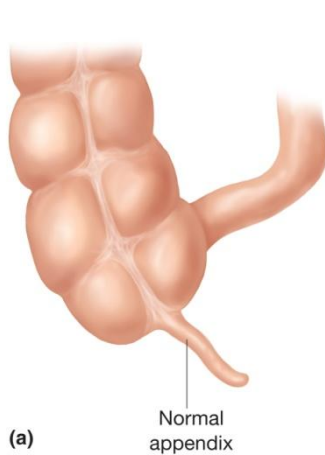
The large intestine (colon) is quite short and straight. It includes:

- Ascending colon
- Transverse colon
- Descending colon



For mammals and other tetrapods, the entire **large intestine** is an important instrument in the conservation of water. Another function of the large intestine is to consolidate the feces. At the

junction of ileum and colon iliocolic valve is present and also a single colic caecum. Colic caecum is big in marsupials, herbivores and some rodents sometimes exceeding the length of body. It is small in bats, carnivores, and whales. The caecum provides extra storage for colon and harbors bacteria. In man its distal end is degenerated called as appendix. The appendix is also found in monkeys, civets and few rodents. The rectum temporarily stores the feces until it is released through the anus. Amongst mammals only monotremes and PIKA (lagomorphs) possess cloaca.



Pika (Lagomorph)

Specializations in digestive duct parts

Stomach

1. In mammals, the caudal end of the esophagus is closed off by the cardiac sphincter. This structure allows for the passage of food from the esophagus to the stomach. When the bolus reaches the stomach, the first portion of the stomach is the **cardiac portion** of the stomach.
2. In this region, mucus is secreted. The next region of the stomach is the **fundus**. This portion of the stomach secretes digestive enzymes that are responsible for the chemical breakdown of the ingested food.
3. The last portion of the stomach is the **pyloric region** of the stomach. It, like the cardiac region, secretes mucus. Food is then passed through the pyloric sphincter into the duodenum. Other specializations in the stomach are apparent in mammals with other types of diets.

Caeca

It is blind diverticula that serve to increase the surface area of the vertebrate digestive tract. In reptiles and higher vertebrates a diverticulum develops, the colic caecum, at the junction of small intestine and the large intestine.

1. **Fishes** pyloric & duodenal caecae are common in teleosts; these are primary areas for digestion and absorption (not fermentation chambers)
2. In **tortoise** caecum is present as a slight projection at the junction of the small and large intestine. It is hardly more than a slight enlargement in the turtles.
3. In **birds** there are two colic caecae. The caecae vary in length and may sometimes be bigger than the hind gut. Occasionally they open ventrally close together and sometimes the two openings fuse to a single one. In some birds the caecae may shift from lateral to ventral position. In some birds there is only one caecum, and a few are devoid of caecae altogether.
4. Caecum varies in length in different **mammals**. It is highly developed in herbivorous mammals. In rabbit caecum is a blind sac present at the junction of small and large intestine which terminate in a narrow 5-6 inch long **vermiform appendix**. The caecum is about 1½ foot in length in rabbit and has a series of pouch-like dilations. There is an **ileo-caecal valve** present between the caecum and ileum. The content of ileum is passed through caecum before passing into the colon. In blood sucking bats the pyloric region is drawn out into a deep elastic pouch or caecum which is filled with blood.

Cloaca in Vertebrates

Cloaca is a large chamber into which large intestine, urinary and genital passages open. In cyclostomes, Holocephali and in most teleosts, the intestine, open to exterior directly through anus. In all other fishes and amphibia the large intestine opens into a cloaca. An outgrowth of the ventral wall of cloaca in amphibia gives rise to the urinary bladder and represents the **allantois** of higher vertebrates. The cloaca divides into three parts: a) the **coprodaeum**, b) **urodaeum** and c) **proctodaeum**. The urodaeum receives the urinary and genital ducts and is the shortest part of the cloaca.

1. The large intestine of **reptiles** is considerably swollen and opens into a cloaca. In many reptiles a small blind caecum present at the anterior portion of the large intestine opens in the cloaca.
2. In **birds** a straight large intestine opens into a cloaca. An unpaired outgrowth arises from the proctodaeum of the cloaca called as bursa Fabricii. It is peculiar in birds only. Basically it develops from ectodermal portion of cloaca during development.
3. Among **mammals** only Monotremes possess a distinct cloaca. In marsupials, some rodents and insectivores the anal and urogenital apertures are surrounded by common sphincter. In all other mammals these openings are completely separate.

Digestive Glands:

There are two important digestive glands in vertebrates namely a) Liver and b) Pancreas. These play important role in digestion.

1. **Liver** produces bile which is stored in the gall bladder (cyclostomes, most birds, and some mammals, including cervids (deers), have no gall bladder)
2. **Bile** aids in digestion by emulsifying fats (breaking fats down into tiny particles that permits more efficient digestion by enzymes)
3. **Pancreas** secretes pancreatic juice (bicarbonate solution to neutralize acids coming from the stomach plus enzymes to help digest carbohydrates, fats, and proteins) into the intestine

Liver

The liver is the largest gland of the body present in **craniates**. It develops from endodermal epithelium forming a primitive tube like diverticulum at the junction of stomach and intestine. The distal part of this diverticulum divides again and again forming the glandular part of liver. The proximal portion gives rise to bile duct. The main function of liver is to produce bile, storage of glycogen and formation of urea and uric acid.

1. **Acraniates** like Amphioxus liver is a simple sac like diverticulum, lying just behind the pharynx. The ammocoete larva of Petromyzon posses a well developed liver with a gall bladder which secondarily is lost in adulthood.
2. The liver is generally larger in carnivorous fishes like **sharks**. In **elasmobranchs** liver is very large and pale yellow in color due to fat. They also have large gall bladder as compared to teleosts. In **teleosts** liver is simple and three lobbed.
3. In **anurans** the liver is considerably large and divided into several lobes, while in **urodeles** it is simple and undivided some cases (divided in others).
4. In **reptiles** the two distinct liver lobes are found. Liver lobes may be completely separate (Chelonia) or connected anteriorly (crocodiles). Gall bladder is always present. In Uromastix the posterior part of liver surrounds the venna cava to form a processus vennae cavae.
5. The **birds** have a large and compact liver usually consisting of two or three lobes. Gall bladder and processus vennae cavae are absent.
6. **Mammalian** liver is large and divided variedly. In monotremes it is four lobbed; which subdivide in marsupials; whereas in rabbits it is large and five lobbed. The large gall bladder lies between the left and right central lobes.

Pancreas

Pancreas is the second largest gland in vertebrates. It secrets important digestive enzymes (ferments) such as trypsin, steapsin and amylopsin (digesting carbohydrates and proteins). The pancreas arise from the anterior part of midgut in form of several sac-like outgrowths near

liver. The distal parts of these rudiments develop into gland proper and the proximal part develop into the duct.

1. In **cyclostomes** (Petromyzon) pancreas derived from endodermal epithelium of posterior foregut. It arise as islands of cells. In Myxine and Bdellostoma pancreas lies round the bile duct.
2. Pancreas is well developed in **elasmobranchs** while it is defused in teleosts.
3. Pancreas is compact gland lying between the stomach and duodenum in **amphibians**.
4. In **reptiles** pancreas is much like amphibians but open into duodenum by three opening.
5. In **birds** also it is similar in origin and structure and mostly open by a single opening.
6. In **mammals** pancreas is compact or diffused to a varying degree. In many mammals two ducts persist one ventrally called main pancreatic duct and a dorsal called as accessory duct. In most mammals pancreatic ducts open into the anterior duodenum.

Reference Books:

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2. Vertebrate Body by Romer
3. Chordate Zoology by E. L. Jordan and P. S. Verma
4. A Manual of Zoology Part II Chordata by M. Ekambarnatha Ayyar