Digestive System
Unit-2 (ZOOA-CC4-8-TH)

Comparative Anatomy of Stomach in Vertebrates:

The stomach is basically a dilation of the digestive tract for the temporary storage of food. Only when its lining epithelium contains gastric glans, properly called a **True stomach**. The stomach is a muscular chamber or series of chambers between the oesophagus and small intestine that serve as a receiving site for recently ingested food, secrets digestive enzymes and lubricatory mucus, mixed with digestive juice. The digestive function of the stomach is apparently a secondary acquisition. The shape of the stomach is related to the shape of the body. In such elongated creatures such as snake, it extends longitudinally, but in those with wider bodies it occupies a more transverse position. The end of the stomach, which connects to the oesophagous, is the cardiac end. The main portion is called the body. The pyloric end connects to the intestine and terminates at the pylorus or pyloric valve. This consists of a fold of the lining mucus membrane surrounded by a thick, involuntary sphincter muscle which regulates the passage of the contents of the stomach into the intestine.

The stomach is straight when it first differentiates in embryos and remains straight throughout life in some lower vertebrates. Most often flexures develop, producing J-shaped or U-shaped stomach. As a result, the stomach may exhibit a concave border or lesser curvature and a convex border or greater curvature. The lesser curvature is actually ventral and greater curvature is dorsal. The expansion at the cardiac end of the stomach, formed by the greater curvature, is the sac like fundus, which contains gastric glands. Fundic glands are composed of four functionally cell types:

a) Mucous cells: secretes soluble mucus.

b) Chief cells: known as zymogen or peptic cells, secrete pepsinogen. On contact with the acid of the gastric juice, the pepsinogen is converted to pepsin, a proteolytic enzyme.

c) Parietal (oxyntic) cells: secrete hydrochloric acid and intrinsic factor. Intrinsic factor, a glycoprotein that is essential for the absorption of vitamin B12.

d) Enteroendocrine cells: secrete gastrointestinal polypeptide hormone gastrin, is the principal effective agent for stimulating the secretion of HCl.

Regions or topography of a stomach:

• The stomach is straight when it differentiates in embryos and remains straight throughout life in some basal vertebrates.

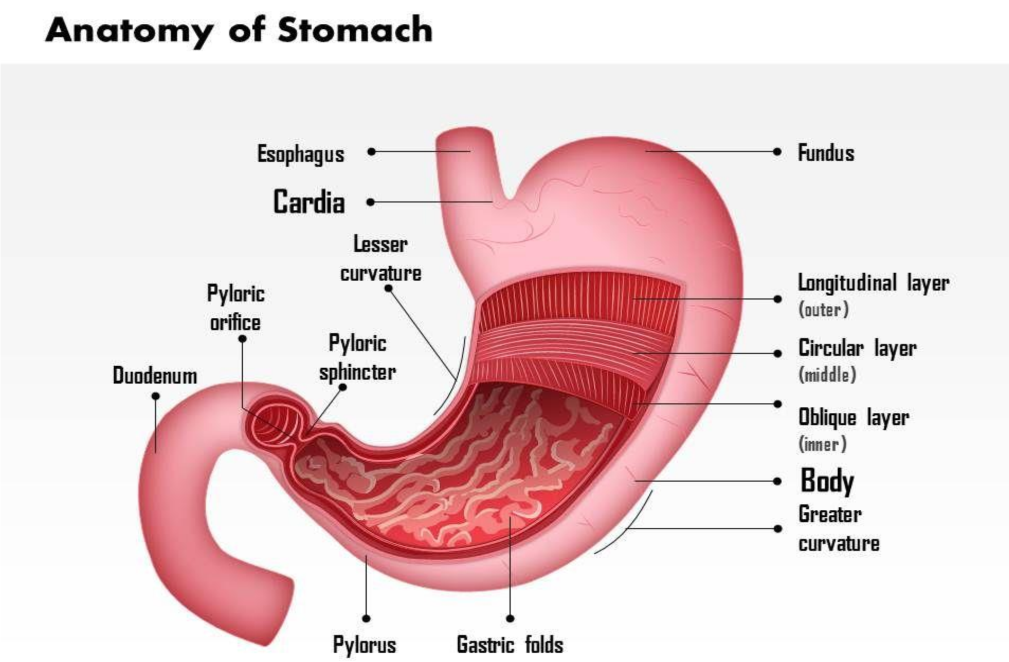
• Flexures develop in course of evolution producing J shaped or U shaped stomachs in other vertebrates.

• The stomachs exhibit a concave border or lesser curvature and a convex border or greater curvature.

• Not only do most stomachs exhibit a flexure but in mammals they undergo a torsion along with their part of dorsal mesentery, twisting in such a manner that stomach and mesentery lie crosswise in the trunk.

• When there is more than one chamber in a stomach, then the first chamber serves the purpose of temporary holding the recently ingested food. Its epithelium is similar to that of oesophagus and have many mucous glands.

• The end of the stomach that lies connected to the oesophagus is the cardiac end whereas the stomach terminates at the pylorus which is the opening of the stomach to the duodenum. The opening is surrounded by a ring of smooth muscle the pyloric sphincter.



Histology of stomach:

• On the basis of mucosal histology, two regions of the stomach can be distinguished.

• The stomach's glandular epithelium is characterized by the presence of gastric glands. These are branched, tubular glands, several of which empty into the bases of surface indentations, or gastric pits.

• There are three divisions of the stomach—cardia, fundus, and pylorus—based on the relative position and type of gastric gland.

• The cardia is a very narrow region found only in mammals, and it marks the transition between the esophagus and the stomach. Its gastric glands, termed cardiac glands, are composed predominantly of mucus-secreting cells.

• The fundus is usually the largest region of the stomach and contains its most important gastric glands, the fundic glands.

• Mucous cells are present in fundic glands, but these glands in mammals are distinguished by their abundance of parietal cells, the source of hydrochloric acid, and chief cells, the presumed source of several proteolytic enzymes.

• Other vertebrates possess instead oxyntopeptic cells that produce bothHCl and pepsinogen. Upon release into the stomach's lumen, pepsinogen is cleaved by HCl to produce pepsin, an active proteolytic enzyme.

• Before emptying into the intestine, the stomach usually narrows into a pylorus, whose mucosal walls hold distinct gastric glands called pyloric glands. The pyloric glands are predominantly composed of mucous cells whose secretions help to neutralize the acidic chyme as it moves next into the intestine. Thus, most of the chemical and mechanical processes of gastric digestion occur in the fundus.

• The cardia (when present) and pylorus add mucus.

Smooth muscle bands in their walls act as sphincters to prevent the retrograde transfer of food.

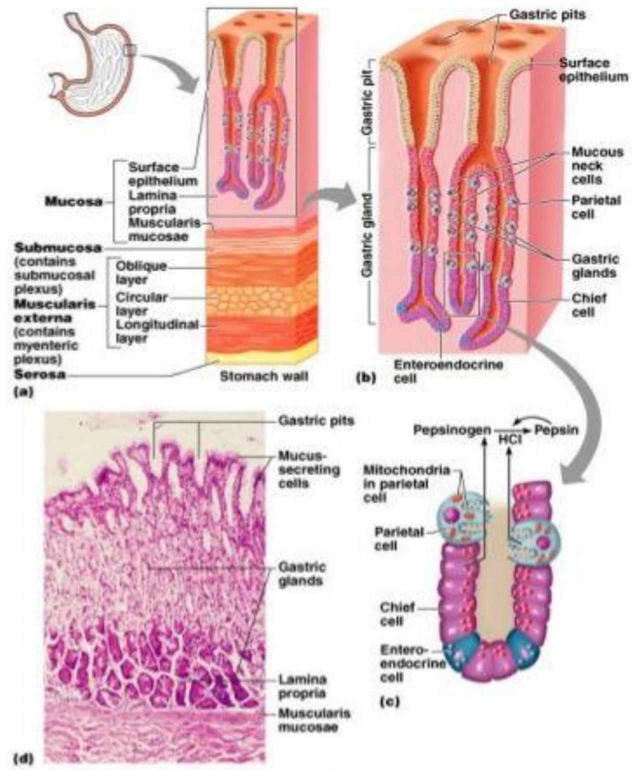
• In addition to a region of glandular epithelium, the stomach of some vertebrates also has a second region characterized by nonglandular epithelium, devoid of gastric glands.

• As in some herbivores, the nonglandular region may develop from the base of the esophagus. In other species, such as rodents, loss of gastric glands in the mucosa leaves a nonglandular epithelial stomach in which smooth muscle contractions knead and mix digesta.

• This nonglandular epithelium in rodents also can be keratinized, perhaps as a result of mechanical abrasion from rough foods such as seeds, grasses, and insect chitinous exoskeletons. Chemical insult from digestive enzymes added in the mouth may also cause a keratinized nonglandular epithelium.

Histology of stomach

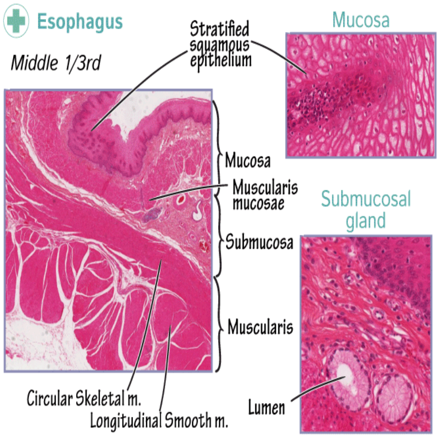
- Simple columnar epithelium: secrete bicarbonate-buffered mucus
- Gastric pits opening into gastric glands
  - Mucus neck cells
  - *Parietal cells*
    - ***HCL***
    - ***Intrinsic factor*** (for B12 absorption)
  - *Chief cells*
    - ***Pepsinogen*** (activated to pepsin with HCL)
    - Stimulated by ***gastrin***: a stomach hormone



ESOPHAGUS & STOMACH

Esophagus

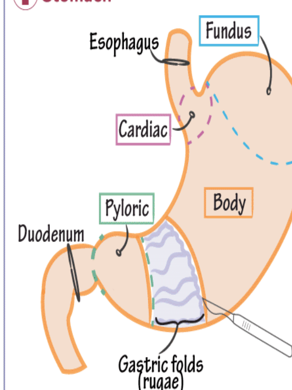
Middle 1/3rd

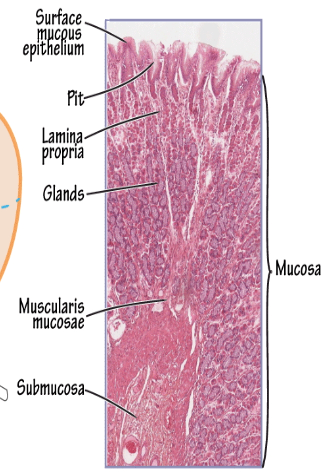


Functional Anatomy

- ✓ Mucosa = Stratified squamous epithelium
  - Provides protection from abrasive foods & liquids.
- ✓ Submucosal and mucosal glands
  - Secrete protective/lubricating mucous.
- ✓ Muscularis
  - Upper 1/3rd = Skeletal mm. in both layers
  - Middle 1/3rd = Skeletal mm. in circular; Smooth mm. in longituidnal
  - Lower 1/3rd = Smooth mm. in both layers

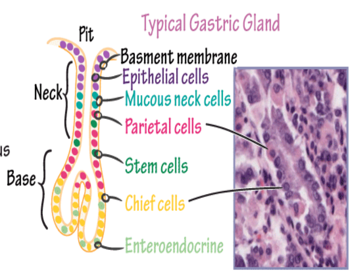
Stomach





Mucosal Glands

- ✓ Cardiac & Pyloric glands
  - Primarily mucus-secreting
  - Cardiac glands have coiled end
  - Pyloric glands are highly branched
- ✓ Gastric (fundus & body) glands
  - Epithelial cells secrete surface mucus
  - Mucus neck cells secrete mucus
  - Parietal cells secrete HCL
  - Stem cells
  - Chief cells secrete Pepsinogen
  - Enteroendocrine cells



<u>Comparative Anatomy</u>:

Agnathans (Cyclostomes, jawless vertebrates):

Agnathans or Cyclostomes have no definitive stomach. The stomach is poorly developed and consists of little more than an almost gradual enlargement at the posterior end of the oesophagous.

I. There is no definite stomach

II. Digestive tract is one long tube from mouth to vent exhibiting no gross differentiation of oesophagus, stomach and intestine

III. The epithelium of the digestive tract is a single layer of cells including mucus secreting goblet cells and flask shaped cells secreting proteolytic enzymes.

IV. The base of each cell is in contact with the underlying vascularised layer of the mucosa from which they receive nourishment.

Fishes:

Stomach is not demarcated externally from the oesophagous but can be distinguished by differences in the mucosal folds which are thin in oesophagous and become thicker and wavy in outline in the stomach. All the fishes do not possess a true stomach and is absent in a number of species. A considerable variety of stomach shapes may be observed.

I. The stomachs of fishes display a wide variety of shapes and the epithelium is sometimes ciliated.

II. The gar stomach is often straight.

III. Sharks exhibit the more common J-shaped stomach i.e. the pyloric end is smaller than the cardiac portion.

IV. The entire stomach of some teleosts is one large caecum.

V. Chimeras and lungfishes have no definitive stomach or have only that is poorly differentiated and lacks digestive glands.

VI. In some teleosts the loop becomes fused at its inner end in such a way that a bag shaped pouch is formed with the entrance and exit brought close to each other at one side.

Amphibians:

All amphibians stomach have a digestive function. Highest differentiation in stomach takes place among anurans. The stomach lies on the left side in the body cavity attached to the dorsal body wall by a mesentry called mesogaster. In frogs the cardiac end of the stomach is wide, there is no fundus and the pyloric end is short and narrow. Pyloric stomach is provided with gastric gland. The stomach is not distinguishable grossly form the oesophagous.

I. In salamanders the stomach is a straight spindle shaped tube.

II. In toads and frogs, the stomach is not distinguishable grossly from the oesophagus. Both of the regions are capable of enormous distension.

III. In some urodels like Necturas, has a spindle shaped long stomach. The cardiac and pyloric part has no well demarcation.

Reptiles:

No striking deviations are to be observed in the stomachs of reptiles. Snakes and lizards have long, spindle-shaped stomachs in correlation with their elongated and narrow body shape. There is a clear-cut line of demarcation between stomach and oesophagous. In turtles and tortoises due to peculiar body shape, the stomach is tubular but greatly curved into 'U' shaped structure. Crocodiles have the most specialized gastric organs. Part of the stomach is modified into a gizzard like muscular region. Organ endowed with an specially thick muscular that grinds food. The thin walled glandular region of the stomach lies in front of the gizzard where gastric juices are added.

I. The shape of the stomachs of lizards and turtles are shown in the following figure.

II. Crocodiles have a highly developed stomach, having two parts- proventriculus and gizzard.

III. The proventriculus secretes the digestive enzymes and the gizzad lined with a horny membrane simply grinds and makes a mash of food mixed with gastric secretions.

Birds:

In accordance with the lack of teeth and the type of food eaten by birds, the stomach has been modified greatly for trituration. It has become differentiated into two regions: **Proventriculus**, which continuous with the oesophagous, has a glandular lining which secrets gastric juices; **Gizzard**, much modified and muscular organ, which represents the pyloric portion of the stomach. The glandular cells lining the gizzard secrete a tough, horny layer which in some case bears bumps or tubercles on its surface. These aid in the grinding process. The gizzard is best developed in grain eating birds. It is less developed in insect eating birds. Gizzard is absent in necter eating bird.

I. The stomach in birds have two parts- proventriculus and gizzard.

II. The proventriculus secretes the digestive enzymes and the gizzad lined with a horny membrane simply grinds and makes a mash of food mixed with gastric secretions.

III. The gizzard is best developed in grain eating birds and less developed in carnivorous birds.

Mammals:

Many modifications exist in the transversely arranged stomachs of mammals. In monotremes, true stomach absent, epithelial lining lacks gastric glands, presence of pouch like structure which serves merely for the storage of food. In platypus (*Ornithorhynchus*), stomach sis very simple, blind pouch like organ, has no clear distinction of parts. Hindgut fermenters, members of Order-Perissodactyla (horse, ass, zebra, rhinoceros, tapirs) and elephants are the monogastric (= caecalid = hindgut) fermenters, have a simple stomach and an enormous caecum, a closed end sac at the junction of small and large intestines.

I. In Monotremes, the lining epithelium lacks gland and the stomach mainly serves for the storage purpose. It is therefore ***not considered as a true stomach***.

II. The stomachs of Whales (cetaceans) and Hippopotamus are divided into several compartments.

III. In the porpoise (toothed whales) the stomach is divided into 3 compartments- cardiac, middle and pyloric compartments. **Cardiac compartment** is a spacious chamber having smooth and thick mucous membrane. The **Middle chamber** is smaller in size having a glandular mucous membrane having a number of complex folds. **Pyloric portion** is long and narrow and is further divided in to a small anterior bulbous portion and a long and narrow posterior portion.

Human Stomach:

I. The region of stomach at the base of the oesophagus is the cardiac portion.

II. Lateral to the cardiac portion is the fundus characterised by an array of gastric glands.

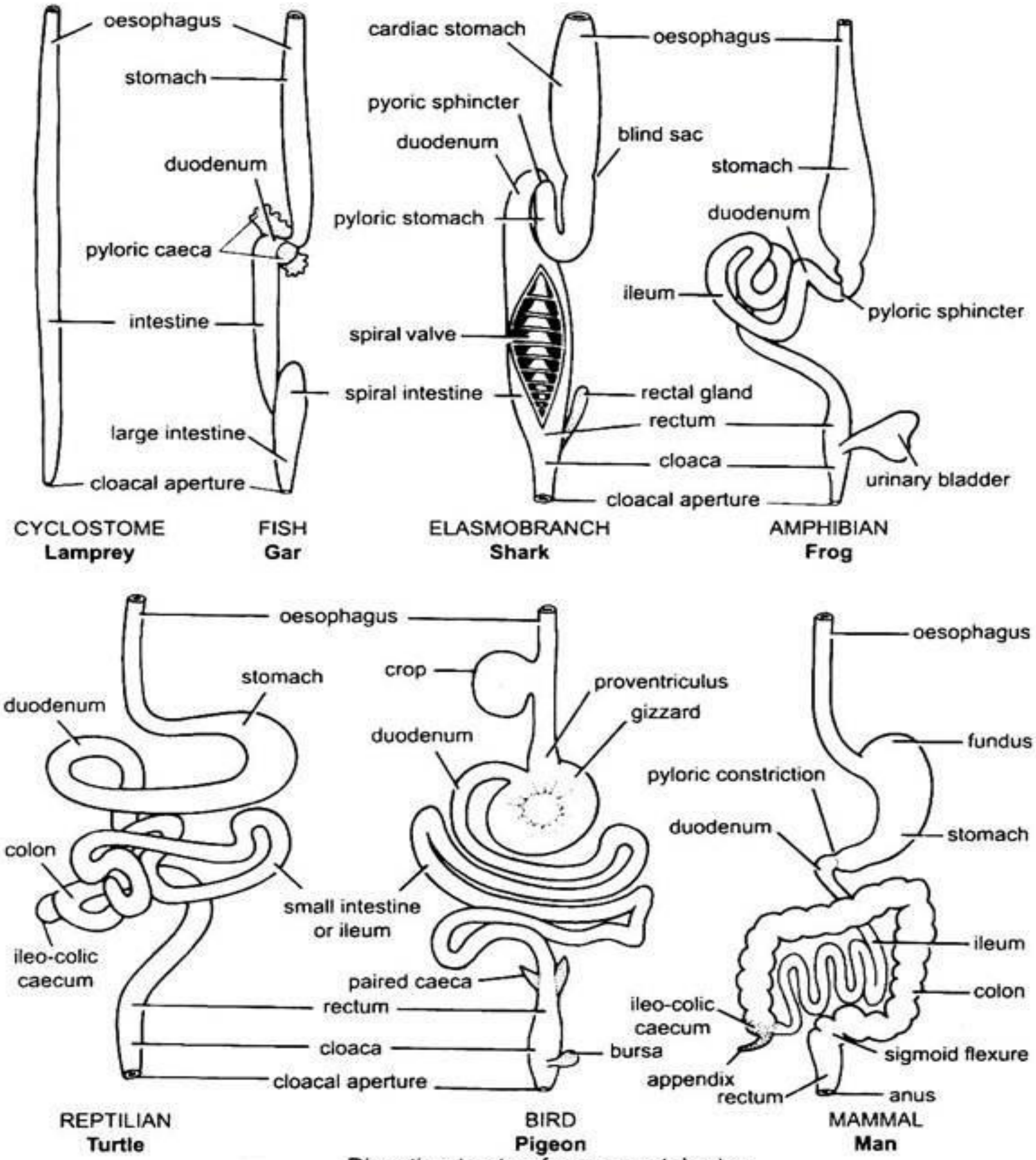
III. The region between the lesser and greater curvature is the body of the stomach and the region preceding is the pyloric portion.

IV. The cardiac and the pyloric portion of the stomach can be distinguished from other regions on the basis of eth histology of their glands.

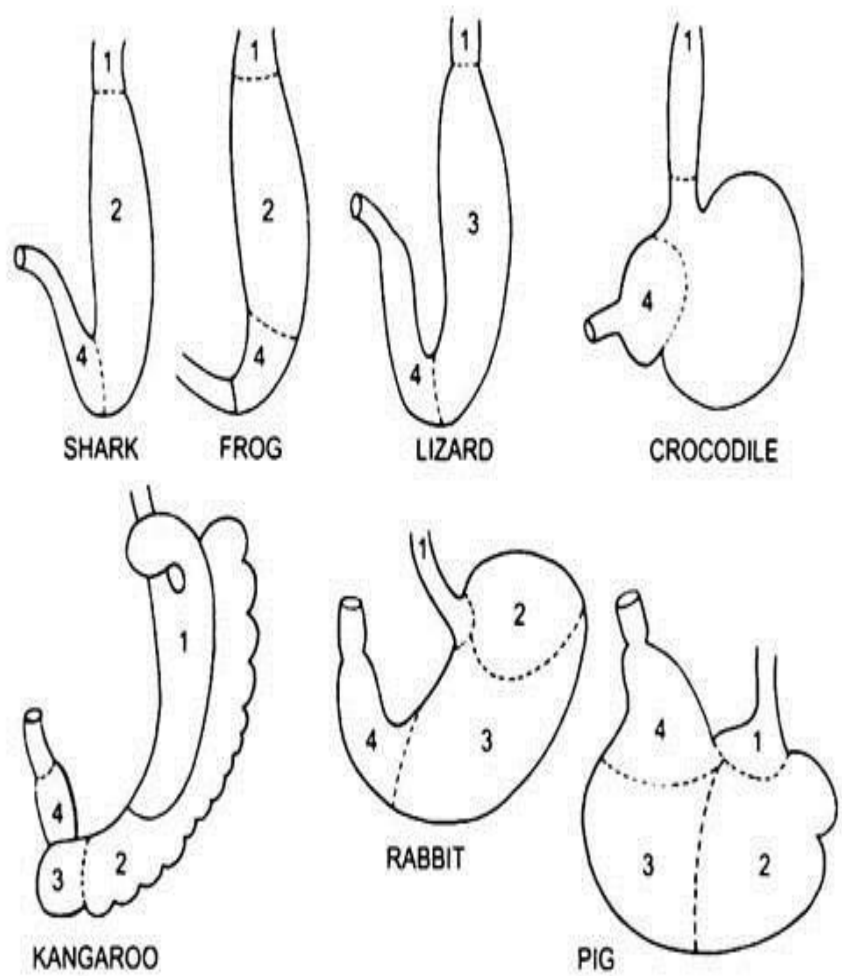
V. None of the regions have zymogenic cells.

VI. The mucosa in the cardiac region resembles that of eth lower end of oesophagus, the glands being compound tubular with many goblet cells. A few parietal cells are also present.

VII. Pyloric glands are simple branched tubular glands extended deeper into the mucosa. They have many goblet cells and relatively few parietal cells. Between the fundus and the pyloric region, the mucosa exhibits typical gastric glands.



Digestive tracts of some vertebrates.



Stomachs of some vertebrates showing different glandular regions. 1–oesophagus; 2–cardiac region; 3–fundic region; 4–pyloric region.

Dentition in Mammals:

Teeth and Dentition - The hard and usually pointed structures connected to the jaw bones in the buccal cavity of vertebrates are known as teeth. The structure, kind, number and arrangement of teeth are collectively called dentition. Although teeth are found among fishes, amphibians and reptiles and are also known to have been present in ancestral birds, but they are most highly specialised in mammals. Teeth are as a rule present in the foetal as well as adult conditions of mammals. In all such cases they are never found on the palatal bones but are present on the premaxillae, maxillae and mandibles and are, unlike those in most lower vertebrates, differentiated in form and function.

Origin and Structure of Teeth in Mammals - Teeth have evolved from denticles which are released from armour near the margins of the mouth as ossification in the integument. A typical mammalian tooth can be distinguished mainly into two regions — crown and root. The crown is the exposed part of the tooth and situated above the root and in the old age it is generally subject to wear. The root is the hidden part in the gum which is anchored in the socket or alveolus of the jaw bone. The tooth encloses a pulp cavity that contains blood vessels, nerves, and connective tissue. The junction of crown and root is called neck.

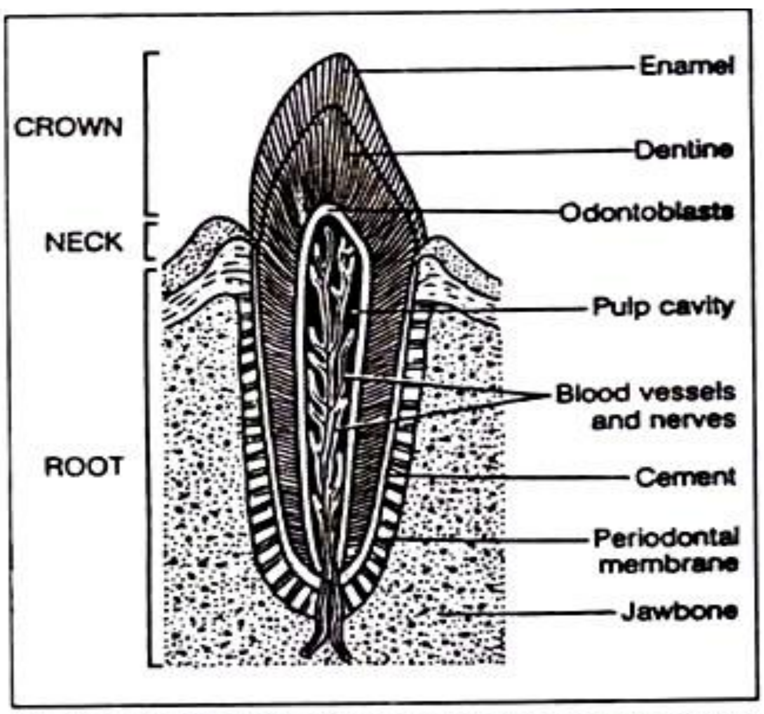


Fig. 10.127 : Structure of a tooth showing its relation with the jaw bone.

There are three kinds of tissues in a typical tooth. They are enamel, dentine and cement. Unworn crown is covered by a thin, very hard, glistening layer, called enamel. It is the hardest and heaviest tissue of the vertebrates and is composed of crystals of hydroxyapatite [$3(Ca_3PO_4)_2$. $Ca(OH)_2$). It is ectodermal in origin and totally acellular. Below enamel, a hard dermal bony substance layer is found, called dentine. It is harder than bone but softer than enamel. The ivory is a specialised dentine and hard creamy-white substance, found in elephant, hippopotamus, walrus and narwhals tusks. The human dentine is composed of mainly calcium phosphate and fluoride 66.72%, organic matter 28.01% and calcium carbonate.The root of tooth is covered by a thin layer of cement (cementum or Crusta petrosa) and a vascular periodentai membrane of strong connective tissue fibres (Sharpey's fibres). Cement is a nonvascular bone and usually acellular. It is softer than dentine and is rich in collagenous fibres. It wears rapidly when exposed. The pulp cavity is lined by a layer of bone cells, called odontoblasts. Both dentine and cement are mesodermal in origin.

Functions of Teeth:
Teeth play an important role in everyday life of an animal.

The functions of teeth are as follows:
(i) The primary function of teeth is to grasp and hold the prey or food in the mouth cavity (buccal cavity),

(ii) Teeth are modified to serve as a grinding mill for chewing food.

(iii) Teeth may serve as weapons for offence and defence by working as tearing organs.

Significance of Teeth:
(i) Teeth are so characteristic of mammals that their classification is based largely on their dentition. Thus, study of dentition is important for taxonomic work on mammals.

(ii) The number of teeth present gives an idea of the approximate age of the mammal,

(iii) Study of dentition has helped in deciding the pedigree or ancestry of certain mammals.

Toothless Mammals:

Not all mammals possess teeth. In some monotremes, Echidna and in some American ant- eaters, however, they are entirely absent at any time. In some spiny ant-eaters (Tachyglossus) no teeth are found in any stage. A secondary toothless condition occurs in some mammals.

In Platypus (Ornithorhynchus), embryonic teeth are replaced in the adult by horny epidermal plates but no true teeth are present. The true or great ant-eater (Myrmecophaga) also has no teeth. Also the whalebone whale and many edentates lack teeth in the adult condition only. In most of these mammals, teeth make their appearance temporarily in the foetus and are soon absorbed.

In whalebone whales foetal teeth are replaced before or soon after birth by baleen plates for straining the planktonic food. Although other ant-eaters, armadillos and certain other forms possess teeth, they are imperfect structures differing from typical mammalian teeth.

Differentiation (Shape) of Teeth:

Morphologically, teeth can be distinguished into two types such as homodont and heterodont.

1. Homodont Teeth:

In vertebrates other than mammals, all the teeth present are similar in shape and size. They are said to be homodont or isodont. Among mammals only certain cetaceans have homodont dentition, i.e., teeth which are all similar in shape. Further the number of teeth in these homodont mammals varies between 2 and 200. In certain mammals such as toothed whales, dolphins, porpoises and armadillos, teeth become secondarily uniform or homodont.

2. Heterodont Teeth:

Mammalian teeth are characteristically heterodont, i.e., dissimilar in shape, size and functions. The heterodont dentition commonly includes four kinds of teeth such as incisors, canines, premolars and molars. The differentiation depends upon the nature of food eaten and the manner of procuring or securing it.

Attachment of Teeth:
The manner of attachment of teeth at their bases with the jaw bones varies throughout the vertebrates.

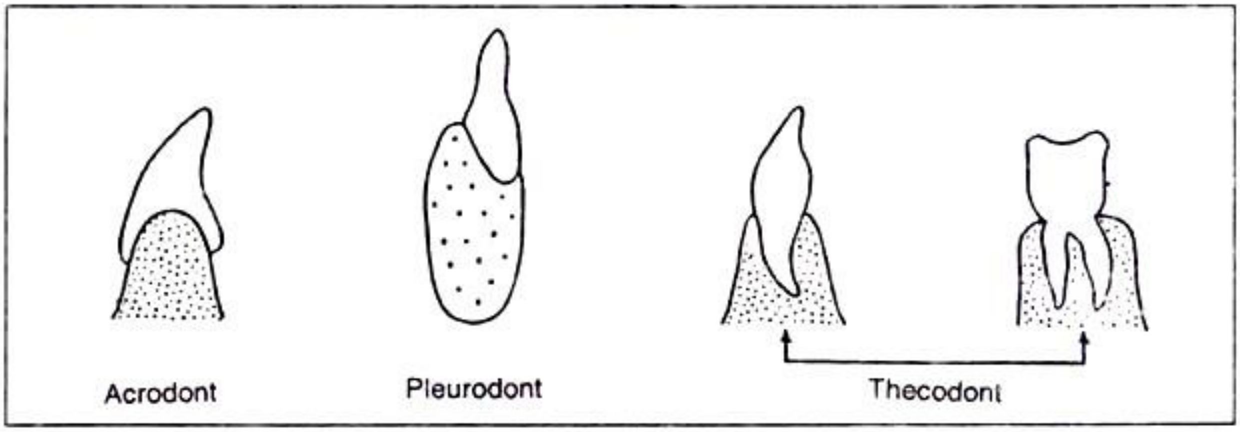
These are of the following three types:

1. Acrodont Type:
This condition occurs in most vertebrates in which teeth are attached on the crest of jaw bone or attached to the free surface or summit of the jaw bone as in shark or frog. Such teeth are apt to break off easily but are replaced.

2. Pleurodont Type:
This condition occurs commonly in urodels and lizards. Teeth are attached to the shelf-like indentations on the inner margin of jaw bone by their bases as well as one side. Acrodont and pleurodont teeth are rootless, so that nerves and blood vessels enter the pulp cavity along lateral side at the base of the tooth.

Thecodont Type:
Thecodont type of teeth is found in some fishes, crocodilians and mostly in mammals. In this type the teeth have roots (one or more) and the roots are embedded in sockets called alveoli or theca of jaw bones, a crown projects above the socket.

In mammals the roots of thecodont teeth are longer, they may be open or closed below. In the open type the pulp cavity has a wide opening or root canal, such teeth continue to grow throughout life by addition of dentition, e.g., incisors of rodents, tusks of elephants. Most teeth are of the closed type in which the opening of the pulp cavity is very small and serves only for passage of blood vessels and nerves, such teeth do not grow after reaching a definite size.



Succession of Teeth:
According to their permanence or replacement (succession), teeth fall into three categories:

1. Polyphyodont,

2. Diphyodont and

3. Monophyodont.

1. Polyphyodont:
In most of the lower vertebrates, the teeth are being constantly replaced an indefinite number of times during life, i.e, successions are numerous and continuous throughout life. Such a condition is known as polyphyodont which is not found in mammals.

2. Diphyodont:
In most mammals, there are only two successions, i.e., teeth develop during life in two successive sets. This condition is known as diphyodont. Teeth of the first set are called deciduous, lacteal or milk teeth. They usually erupt after birth and they are replaced by permanent dentition.

In many mammals such as guinea pigs milk teeth develop and are lost before birth. Milk dentition has no molars included. Later, milk teeth are replaced in the adult by the permanent S which last throughout life. If lost they are not replaced. In cape ant-eaters or aardvarks, milk teeth outnumber the permanent teeth.

3. Monophyodont:

In some mammals such as platypus, marsupials, moles, sirenians, cetaceans (toothless whales), etc., only one set of teeth develops, known as monophyodont condition.