Introduction

Comparative Anatomy, Its Meaning and Purpose of Study

Anatomy is the study of the structure of animals, if the structure is seen by naked eyes this type of anatomy is called **gross anatomy** but when we used microscope to detect the fine structure called **microscopic anatomy (histology)**. The study of similarities and differences in the body structure of different animal groups, or animals is known as **comparative anatomy**. In fact, the study of comparative anatomy is more purposeful than mere study of the location and structure of different organ systems in different animals independently because:

1. Comparative anatomy assists scientists in classifying organisms based on similar characteristics of their anatomical structures.

2. Comparative anatomy has long served as evidence for evolution. Despite their differences, all vertebrates are built according to the same basic plan. Thus, comparative study of various homologous vertebrate structures supports Darwin's theory of **descent with modification**. But this common basic plan inspire that their Creator is One (The God), in addition they share in living on same planet (the Earth) and not as evidence for evolution.

Two major concepts of comparative anatomy:

Homology and analogy (homoplasy)

Homology refers to intrinsic structural similarity while analogy refers to superficial functional similarity.

1. Homologous organs. These organs are similar in different species, they have same anatomical structural parts (basic plan) and embryonic origin, but they are dissimilar in function, for example, the arms of human, forelimbs of cat, flippers of whale, and wings of bat (Fig.1).

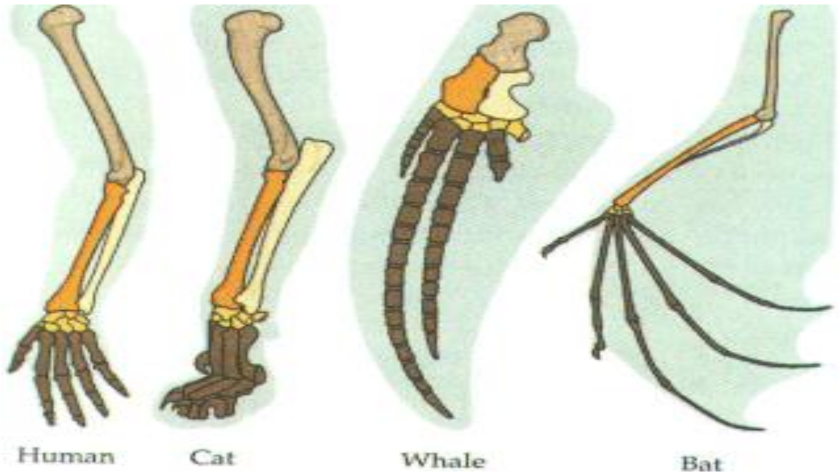


FIGURE 1: Forelimbs of different vertebrates are considered as homologous organs, they have same structures.

2. Analogous organs. These organs show same function, because they evolved in a similar environment, and adapted for similar conditions but they differ in structure and embryonic origin. An example is the antlers of deer are commonly called horns, but really they are not horns but extensions of dermal bone lack any hornified covering. They usually serve the same purpose as the horns do (Fig. 2).

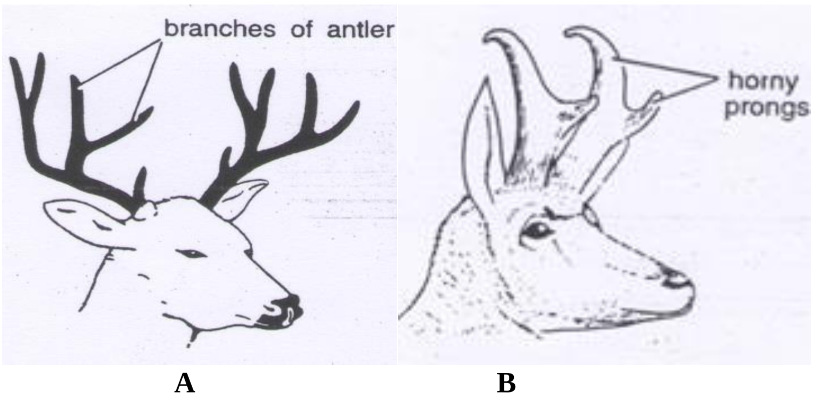


FIGURE 2: A- Antler of male deer, B- Pronghorn of American pronghorned antelope.

Seven selected chordates studied in comparative anatomy

During this study **seven** chordates have been selected. Each selected chordate represents its group to compare between their various analogue body organs and systems to reveal the similarities and differences between them. Taking in consideration that these selected animals are arranged according to the evolutionary scale as following:

1. Lancelet, amphioxus *Branchiostoma lanceolatus*, representing the primitive chordates (protochordates).

2. Lamprey, *Petromyzon fluviatilis*, represents two living agnathan classes: Myxini and Cephalaspidomrphi.

3. Dogfish, *Scyliorhinus canicula*, represents the two living fish classes: Chondrichthyes and Osteichthyes.

4. Frog, *Bufo viridis*, represents Class Amphibia.

5. House lizard, *Gecko gecko*, represents Class Reptilia.

6. Common or rock pigeon, *Columba livia*, represents Class Aves.

7. Rabbit *Oryctolagous cuniculus*, represents Class Mammalia, in addition to human *Homo sapiens* a typical mammal.

Human Body Systems

Organs of the human body are commonly grouped into systems. Each body system includes organs and structures that serve a common purpose. The systems are highly interdependent, working together to sustain life and enable interaction with the surrounding environment.

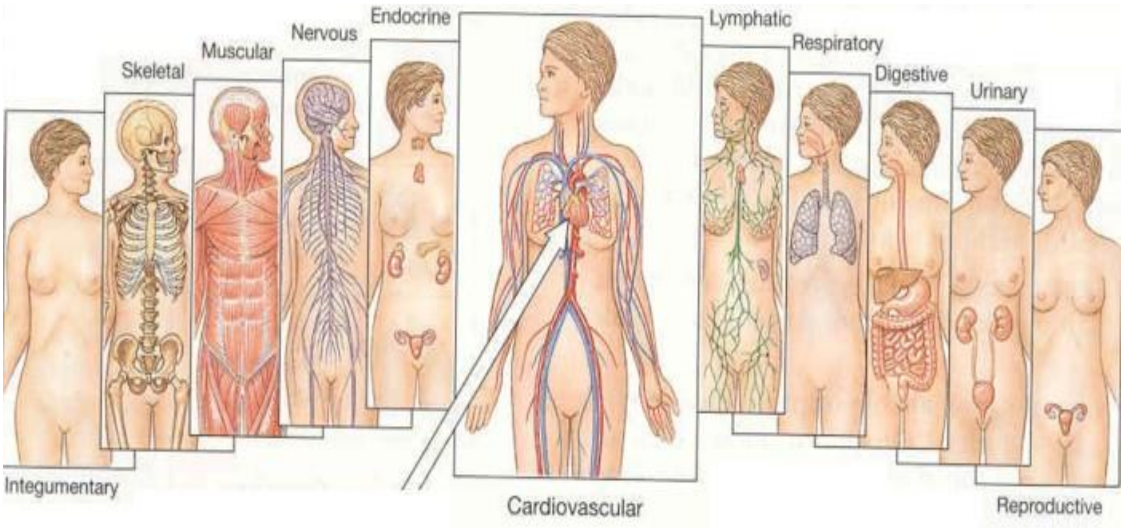


FIGURE 3: Organ systems of human body.

1. Integumentary system. This system consists of skin and structures derived from it such as; nails hairs, sweat glands and other glands that are derived from the skin. Hair and its modifications like spines, quills, bristles, wool and fur; feathers, and horny scales; nails, claws and hooves, all these structures are derived from epidermis of skin and considered as epidermal exoskeleton, where skin consists of two layers, inner one is dermis and outer one is epidermis. The structures which are derived from dermis are collectively form dermal exoskeleton, like fishes' scales and turtle shield. Skin helps to protect fragile underlying tissues and organs and acts as a barrier against infection and trauma. It is an important sensory organ where contains nerves that allow the body to receives stimuli such as touch, temperature and pain. It also plays a role in body temperature regulation and synthesizes vitamin D from sun exposure. Skin is the largest body organ.

2. Muscular system. Responsible for voluntary and involuntary movement of body parts and organs. It comprises large skeletal muscles that enable us to move, as well as cardiac muscles of the heart for its contraction and relaxation and smooth muscles of internal organs.

3. Endoskeletal system. This system includes: bones, cartilages, tendons and ligaments. Provides framework for muscles to attach, making movement possible. Bones provide rigidity and strength that support the body and allow movement and mobility. Houses bone marrow and stores minerals. Bones also serve as a protective shield for internal fragile organs.

4. Digestive system. It consists of three main divisions and each in turn has its subdivisions: buccopharyngeal cavity (mouth, pharynx, tongue, teeth, palate); digestive tract (esophagus, stomach, intestine, and anus); and digestive glands (salivary glands, liver, and pancreas) that secrete digestive juices into digestive tract. Mechanical and enzymatical roles of this system are: breaks down food into small molecules; nutrient absorption to enter circulation to reach all body's cells; eliminates toxic waste from the body.

5. Respiratory system. It works together with the cardiovascular system to provide oxygen to all body parts and to remove carbon dioxide from the blood. External respiration, or breathing, is the movement of air into and out of the lungs through the airways. Inspiration (breathing in) pulls air into the lungs and allows the oxygen in the air to move into the tiny blood vessels (capillaries) found in the lungs. At the same time, carbon dioxide moves out of the blood vessels in the lung and into the air in the lungs, through a process of expiration (exhalation) this carbon dioxide-rich air moves out of the lungs.

Internal respiration is the exchange of oxygen and carbon dioxide that takes place between the blood and metabolizing cells throughout the body. Respiratory system comprises of: Mouth, nose, nostrils, sinuses, pharynx, cilia, trachea, larynx, diaphragm, lungs, trachea, bronchi, bronchioles and alveoli.

7. Urinary system. Blood filtration and cleaning takes place in this system through its primary organs, the kidneys which are called blood filters. Urinary system filters and removes extra water, salts, and waste produced by the body from the blood and produces urine which can then be excreted outside the body. This main excretory system also helps regulate blood chemistry: blood volume, blood pressure, blood pH, and electrolyte levels. This system comprises of kidneys and their ducts, in addition to urethra and urinary bladder.

8. Reproductive system. It is responsible for sexual functioning and maintains sexual characteristics and passes on genes to next generation to keep the species. It also produces sex hormones such as estrogen and testosterone. The system of each sex consists of gonads (testes in male and ovaries in female) and associated structures (ducts and glands). Ovaries, fallopian tubes, uterus, vagina, testes, ductus (vas) deferens, urethra, penis, and prostate gland are organs of this system.

9. Cardiovascular system. This system supplies oxygen-rich blood to all cells of the body. The left side of the heart contains oxygenated blood that originates from the lungs. This blood is transported throughout the body in large blood vessels called arteries. Arteries branch into arterioles and then into capillaries where oxygen, carbon dioxide, water, and nutrients are exchanged with surrounding tissue. Veins then transport the deoxygenated blood back to the right side of the heart, where it is pumped back to the lungs for reoxygenation and carbon dioxide removal. So the Primary function of this system is**:** Supplies oxygen-rich blood to the body and removes carbon dioxide waste from the bloodstream to prevent toxic accumulation. Cardiovascular system comprises of: heart, blood vessels (arteries, veins, and capillaries), and blood.

10. Lymphatic system. It collects and transports lymph from tissues back into the bloodstream. Lymph is formed from the fluid that moves out of the bloodstream and the body's cells into the tissue. It is rich in nutrients and white blood cells.

Lymph circulates from the tissue back into the bloodstream through lymph channels. At regular points along the way, lymph nodes monitor and filter the lymph, looking for toxins and infections. The lymph channels merge to form bigger lymphatic vessels that join the subclavian veins in the neck.

The largest organ in the lymphatic system is the spleen, which filters the blood and produces lymphocytes (white blood cells that fight infection). Lymphocytes include T cells, B cells, and natural killer (NK) cells. These cells work to identify infective agents such as viruses, bacteria, and fungi. They are able to neutralize them by attacking the infectious agent and triggering the formation of antibodies that assist in destroying the infection. The **Primary function of this system is** filters out lymph fluid to help the body to maintain proper fluid balance and to help maintain the body's immunity function, and includes the organs: Spleen, thymus, tonsils, lymph nodes, and lymphatic vessels.

11. Nervous system. This system comprises brain, spinal cord, and nerves. Considers the control center of the body and with endocrine system, coordinates all organ functions. It controls the body's interaction with its environment by allowing thought, memory, and motion. It also enables the functioning of the senses such as taste, touch, sight, hearing, and smell. These processes occur through messages sent along specialized nerve cells called neurons.

The central nervous system consists of the brain and spinal cord. The peripheral nervous system consists of nerves that lie outside the central nervous system. It sends information to and from the central nervous system. The peripheral nervous system has two parts. The autonomic nervous system controls the involuntary functions of the heart, smooth muscle and many of the glands in the body. The somatic nervous system sends signals from the central nervous system to the skeletal muscles to mediate voluntary movement. Ganglia are nerve clusters that function to relay nerve impulses by connecting the central and peripheral nervous systems.

The primary function of this system is control and regulate conscious and unconscious functioning of the body; allows sensing and interaction with the environment, and its organs are: brain, spinal cord, ganglia, nerves, and sensory organs.

12. Endocrine system. It includes ductless glands (e.g. hypothalamus, pituitary, pineal body, adrenal, thyroid, pancreas, testes and ovaries) that release hormones. Hormones are proteins have very narrow optimum concentrations, so too much or too little can significantly affect the body's functioning. This system works with nervous system in regulating metabolic activities.

13. Sensory system. It comprises the main five sense organs: sense of sight (eyes); sense of hearing (ears); sense of odor or smell (nose); sense of taste (tongue); and sense of touch (skin). These senses receipt the information from the external environment for sending them to the central nervous system for interpretation; hence they considered receptors and windows of brain on the environment.

14. Immune or lymphatic system. It includes lymphatic organs which are: spleen, thymus, lymph nodes, and tonsils. This system returns excess tissue fluid to blood and defends against disease.

CHAPTER ONE
Integumentary System

This system includes the skin and its various derivatives. Skin which is the original part of this system is largest organ in the body. In human this system constitutes about 12- to 15% of total body weight and covers 1.5-2 m^2 of total surface area of the body.

There is an obvious variation not in the structure of the skin of different animal groups but also in the structure of the skin of the developmental stages of same organism and even in the skin of different parts of same body. All these variations are referring to the variations in the skins' environments and the degree of their interaction with them.

Skin is the first line of defense

In addition to the general cover of the body, skin also includes the conjunctiva of eyeballs and external surface of ear drums. It is directly continuous with the mucous lining of mouth, rectum, nostrils, eyelids, and urogenital ducts, so the skin is a defensive organ in front of the entrance of microorganism, and considered as the body's first line of defense against pathogens (bacteria, viruses and other microbes), in addition to many other functions we can conclude them after finishing the study of the system, where all functions of the skin derivatives attribute to the skin.

General structure of integument (skin)

The skin of all chordates is built according with the same basic plan in having two layers, from outer to inner side:

i. Epidermis is buildup of epithelial tissue, which derived from ectoderm. Epidermis of invertebrate chordates resembles that of invertebrates, where composed of single epithelial layer (simple epithelium), whereas epidermis of all vertebrates is a multicellular type of epithelium (stratified squamous epithelium) .

ii. Dermis is thicker than epidermis and it is considered a true skin, which is composed of connective tissue of mesodermal origin.

The tissue, which is directly below the dermis is the **hypodermis**, or subcutaneous layer. It is composed of loosely linked connective tissue and subcutaneous fat (Fig. 1).

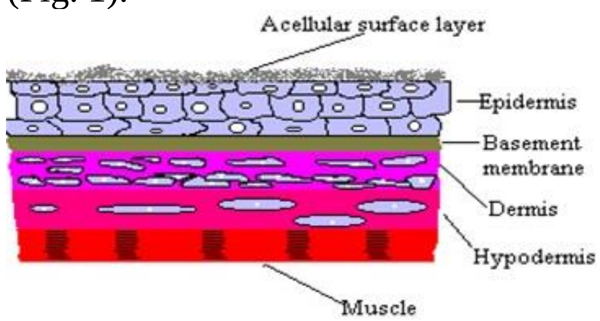


FIGURE 1: **Basic plan or typical layers of chordate skin.**

Epidermis of aquatic and terrestrial vertebrates

Epidermis in aquatic vertebrates and invertebrate chordates is: i. thin; ii. covered by non-cellular cuticle secreted by epidermal cells; and iii. rich in mucous glands and may have other glands, while in land vertebrates, epidermis is: i. thicker; ii. covered by corneal layer and iii. rich in structures such as scales, feathers, hairs, nails, claws, hoofs, horns, etc., mucous glands reduced or absent and other glands present. Most skin derivatives are derived from epidermis.

Thick and thin skin

Epidermis is thick in places that are subjected to much contact, pressure and use, such as palm and sole which is called **thick skin**, and other regions are called **thin skin**. From wisdom epidermis lacks blood vessels where it is sloughed or shed when strongly interact with environment, but it is innervated. Epidermis nourishment takes place through diffusion from underlying dermis, which is vascularized. Epidermis is generally distinguished into three regions.

Three main regions of epidermis

i. Malpighian layer or **Stratum germinativum (innermost region)**. It is the innermost or basal region of epidermis, includes a single row of living short columnar cells. Malpighian layer is separated from the underlying dermis by a basement membrane. These cells frequently undergo mitosis to continually replace the worn out cells of the outer layer of epidermis.

ii. Transitional layer (middle region). As new polygonal cells are formed through the mitotic division of cells of Malpighian layer, these cells gradually approach the surface and occupying a middle region between the innermost and outermost region of epidermis.

iii. The outermost region (outer region). This region is composed of many layers of usually flattened (squamous) cells covered by dead horny, resistant covering or **stratum corneum** on the skin surface. This dead cornified or keratinized layer results from the deposition or accumulation of the tough fibrous **horny protein**, called keratin in the upper flattened cells of the transitional region. Keratin replaces all metabolically active cytoplasm, causing cells death which are eventually shed, without keratin or stratum corneum, the land vertebrates like reptiles, birds and mammals would, like frogs which have very thin corneal layer, be able to survive only in damp places.

Dermis. The dermis is a dense connective tissue layer and is comparatively thicker than epidermis. It is composed of: **1.** The three elements of the connective tissue: a mass of collagen and elastic fibers, cells and matrix. Elastic fibers bring the skin back to its normal shape. Dermis is a part of skin of sheep and cattle that become commercial leather when treated. **2.** The dermis is well supplied with blood vessels, so cuts and burns that penetrate down into the dermis will bleed or cause serious fluid loss. **3.**

Other cells which are present in this connective tissue layer such as macrophages, mast cells and lymphocytes make the skin a first line of defense when the outer epidermal layer is broken and penetrated. **4.** Pigment cells also called **chromatophores** or **melanophores** are mostly located in dermis, although sometimes pigment granules are also found in epidermis. **5.** Numerous skin derivatives as hair follicles, sweat and sebaceous glands are dipping down into the dermis. However, these structures are epidermal in origin. **6.** The dermis may also contain true bony plates or structure of dermal origin.

Main variations in the anatomy of the integument of different groups

Although the fundamental structure of the skin remains similar in all chordates, yet variations occur in different groups or classes involving:

i. Presence or absence of cuticle and specializations of stratum corneum or surface layer of epidermis in terrestrial forms.

ii. Presence or absence of dermal bones.

iii. Relative abundance of glands.

iv. Absence or presence of chromatophores or melanophores and their locations.

Comparative anatomy of the skin

Amphioxus

1. The skin of amphioxus, and other lower chordates (protochordates), reduced to its simplest form like the of invertebrates, where they are invertebrate chordates.
2. The epidermis is thin made of a single layer of tall or columnar epithelial cells.
3. Columnar cells secrete a thin non-cellular cuticle, perforated by minute pores, covered the epidermis.
4. There are numerous unicellular epidermal glandular cells, which secrete mucous. These glands or goblet cells are scattered among the epidermal cells.
5. Amphioxus skin lacks keratin and, thus no scales are present.
6. The dermis is thin and composed of soft vascular and innervated connective tissue, lacking pigment cells (chromatophores) (Fig.2).

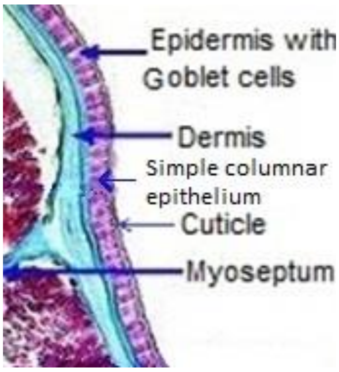


FIGURE 2: Vertical section through Amphioxus skin.

Lamprey

1. The outer cells of the epidermis are active enough to secrete a thin cuticle.
2. Like all other vertebrates, epidermis constructed from stratified epithelium, innervated but not vascularized. No scales.
3. There are numerous unicellular epidermal glands in different forms, such as club-shaped, thread-like and granular mucus glands, scattered among epithelial cells of epidermis (Fig.3).
4. Dermis is thin. Chromatophores are located in dermis.

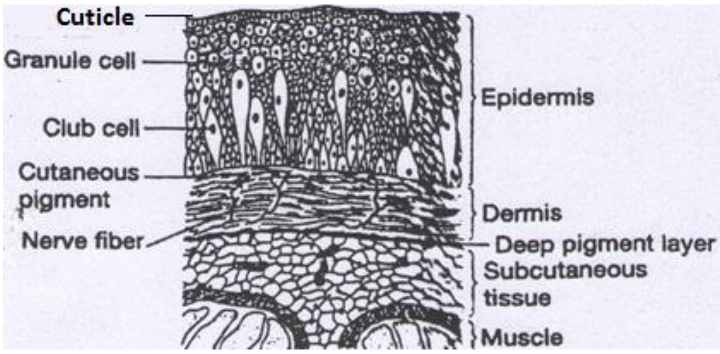


FIGURE 3: V.S. through the skin of lamprey.

Fishes

1. The epidermis is several-layered but simple, thin and without a typical stratum corneum as an adaptation to life in water, hence there are no epidermal scales.
2. Epidermis is quite rich in unicellular mucous glands, or goblet cells, secreting mucus which reduces friction between body surface and water and protects skin from bacterial or fungal infections.
3. Dermis is typical, but all the connective tissue fibers run parallel to the surface.
4. A peculiarity or distinguishing characteristic is the presence of, at least, five types of **dermal scales** projecting above the surface. Of these cartilaginous fishes (elasmobranchs) have placoid scales (Fig.4), other four types present in living bony fishes and extinct bony fishes.
5. Brilliance of coloration are great in fishes than in any other group of chordates. This is because of pigment cells called chromatophores, which are found in the dermis and on scales.

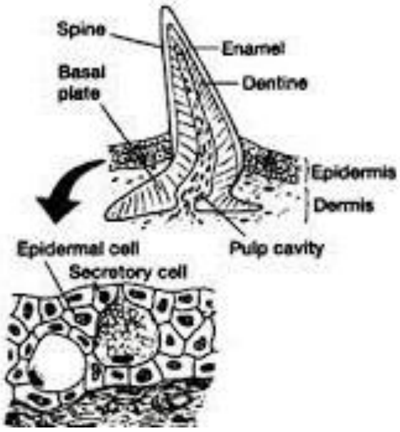


FIGURE 4: Vertical sections (V.S.) of shark skin.

Amphibia

Typical amphibian skin is shown through frog. It is thin and less intimately (frimly) attached to the underlying muscles due to numerous large subcutaneous lymph spaces beneath dermis.

1. Amphibians are the first vertebrates to have a dead stratum corneum. A dead corneal layer is an adaptation to terrestrial life, protecting the body and preventing excessive loss of moisture.
2. Amphibians have abundant multicellular skin mucous glands, rather than unicellular. Many amphibians have cutaneous poison glands, such as parotid glands of toads where their toxic secretion serve toward off enemies.
3. Remnants of dermal bony scales are found embedded in the skin of some gymnophiona and a few tropical toads.
4. The dermis is relatively thin in amphibians; it is composed of two layers: an outer one, less compact layer, the **stratum spongiosum**, where blood vessels, lymph spaces, glands and nerves are abundant. Since this layer is highly vascularized it performs cutaneous respiration. Inner layer is more compact layer and so called **stratum compactum**, composed of parallel bundles of waved collagen fibers from which a few fiber bundles ascended toward stratum spongiosum, (Fig.5).
5. Chromatophores lie for the most part, between epidermis and dermis.

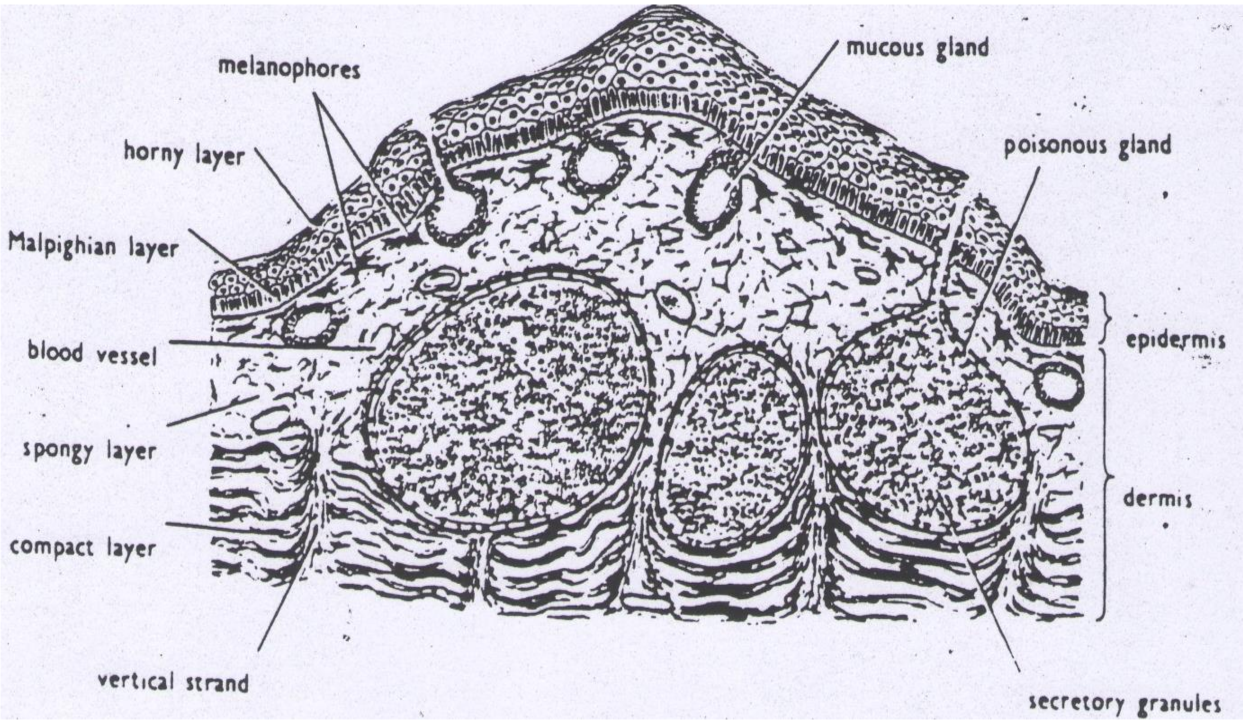


FIGURE 5: V.S. of frog skin.

Reptiles

They are the first true land vertebrates and their integument shows many terrestrial adaptations.

1. Stratum corneum is relatively thicker making the skin dry and prevents any loss of body moisture. It is variously modified to form overlapping

horny epidermal scales covering the body. Stratum corneum is shed periodically in small bits or even in a single piece as in snakes.
2. In addition to horny epidermal structures, reptiles also retain the bony dermal armor of their ancestors, in the form of bony dermal scales, or plates, called osteoderms in the dermis.
3. Reptiles exhibit relatively **few** integumentary glands for: i. sexual attraction scent gland near cloaca in some snakes, ii. femoral glands in the thigh of male lizards, and iii. musk glands of musk-turtles and alligators to release a foul musky odor from scent glands on the edge of its shell possibly to deter (prevent) predation. Reptiles have no mucous glands.
4. The dermis consists of **superficial** and **deep** layers, (Fig.6). In many lizards and some snakes, the superficial layer has an abundance of chromatophores and metachrosis is highly developed. This elaborate color pattern for concealment from predators and preys, or as warning signals. Some lizards such as chameleons have marked capacity to change their body coloration with the help of chromatophores present in dermis. Deep layer of dermis has bundles of skeletal muscles. Leather of high commercial value may be prepared from the skins of certain reptiles.

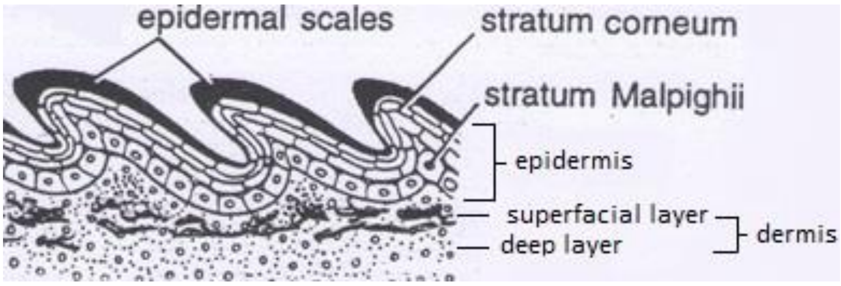


FIGURE 6: V.S. of lizard skin.

Birds

1. Skin is thin and loosely attached to underlying muscles, except in exposed regions to achieve the muscles' maximum freedom movement for flight.
2. Exposed regions of the skin are covered by thick corneal layer, which shed in form of epidermal horny scales.
3. No skin glands occur in birds with exception of uropygial or oil gland on tail, its oily or waxy secretion is coated on feathers and beaks during preening.
4. The dermis is also thin, but muscle fibers are particularly abundant, being used to raise and lower the feathers, (Fig.7).
5. Pigment in the skin of birds is generally confined to the feathers and scales of beaks and other naked region where not covered by feathers.

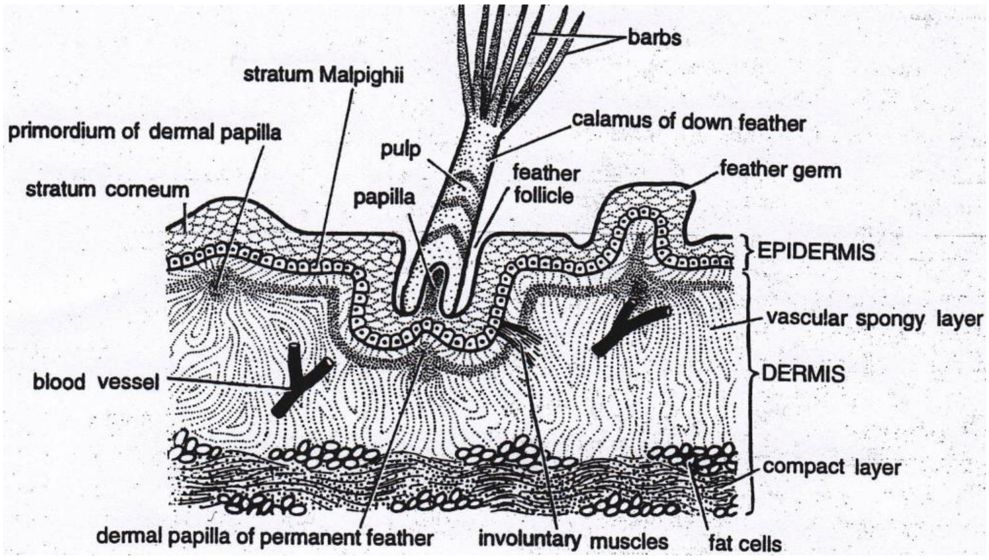


FIGURE 7: Vertical section of bird skin.

Mammals

1. Epidermis, which is thinner than dermis, is covered by stratum corneum containing keratin.
2. The dermis in mammals is best developed. Its connective tissue fibers extending in all directions to strength the dermis, cells are scattered among the fibers.
3. The dermis is divided into a superficial **papillary layer** presents numerous papillae, that fit in the under surface of the epidermis. Touch corpuscles of Meissner and blood capillaries are found in the dermal papillae. The **reticular layer** contains the larger blood vessels, glands, hair follicles and sensory corpuscles. Small bundles of muscle cells, the erector pili muscles, are associated with hair follicle (Fig.8).
4. Mammalian skin has a wide variety of glands which are all multicellular, and derived from epidermal layer, the stratum germinativum but they invade dermis as in case the hair follicle. Based on function there are **five** major types of skin glands: sebaceous, sweat, mammary, lacrimal, and scent. Of these mammary, sebaceous, and sweat glands are found only in mammals. Mucous glands do not occur in the skin of mammals.
5. Skin color is due to the varying concentrations of melanin granules in basal layers of epidermis, or due to pigment containing melanocytes located in dermis just beneath the epidermis. Albinism results from lack pigments, while melanism results from the presence of an excess of black pigments. Hair color is due to varying intensities of brown or black pigment granules between and within the hair cells which secreted by follicular melanocytes.

As a person ages, the texture of their hair can change which is a clear science of aging. Hair become thinner, dry, dull, gray to white in color due to loss its pigment, where pigment cells in our hair follicles gradually die.

Hair changes can also occur due to environmental exposure and physical stress.

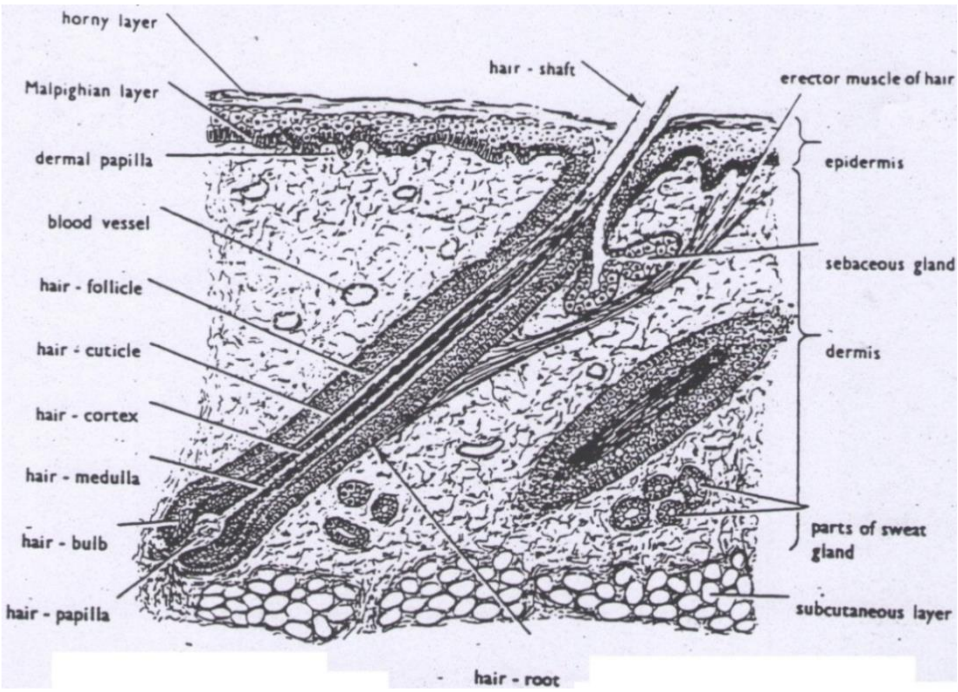


Figure 8: V.S. through the rabbit skin.

Three main groups of skin derivatives

All skin derivatives can briefly have gathered into 3 groups:

1. Skin glands. They are modified epidermal cells.
2. Numerous cornified structures. They are cornified derivatives also formed from skin epidermis, such as: epidermal scales, bills, feathers, claws, nails, hoofs, hair and its modification, horns, horny teeth such as: lamprey teeth, baleen, egg tooth, teeth of frog larvae (tadpoles).
3. Dermal bones. They are derived from the skin dermis called osteoderms, and remain within the integument, such as: dermal scales of fishes, dermal shells and plates, antlers of deer and giraffe horns.

Two body skeleton

Cornified (keratinized) structures and dermal bones within the integument both form the body **exoskeleton**, while all bones which are deep and within the body and joined together to form framework which is body **endoskeleton** attributes to another independent system, the endoskeleton. To distinguish between exoskeleton and endoskeleton follow the following scheme:

Skeleton

Exoskeleton
(Within the integument)
Includes:

Keratinized exoskeleton
(Derived from epidermis)

Dermal bony exoskeleton
(Derived from dermis)

Endoskeleton
(Deep, within the body)
Composed of:

Bone
Cartilage
Notochord

Derivatives of chordates' skin

Study of the comparative anatomy of the skin of various chordates indicates that numerous derivatives or structures are derived from this main body organ (skin). These derivatives are classified to nine groups to be easy to study:

I. Epidermal glands
II. Scales; Dermal bony plates.
III. Epidermal or Horny teeth
IV. Dermal Fin Rays
V. Digital cornification (claws, hoofs, nails)
VI. Beaks or Bills
VII. Feathers
VIII. Horns and Antlers
IX. Hair and its modifications (spines, quills, bristles, fur, wool).

I. Epidermal glands. According to structure, skin glands are of two general types: **unicellular** or **multicellular**, depending upon whether they consist of isolated unicellular glands are scattered, as modified single cells, among other epithelial cells of the skin epidermis. The multicellular skin glands are formed by ingrowths of the stratum germinativum that invade the dermis. Multicellular glands are simple, branched, or compound and tubular or alveolar in shape. They are lined by cuboidal or columnar epithelium.

Major types of integumentary glands

All types of integumentary glands are derived from epidermal layer of skin. They are:

1. Mucous glands.
2. Poison glands.
3. Luminescent glands or Photophores.
4. Femoral glands.
5. Uropygial glands.
6. Sweat glands.
7. Sebaceous glands.
8. Ceruminous or wax producing glands
9. Meibomian glands.
10. Lacrimal glands.
11. Scent glands.
12. Mammary glands.

Comparative anatomy of skin glands

1. Mucous glands. Mucous glands secrete a substance called mucin, which is protein in nature. Mucin together with water forms a slimy, viscid material called mucus. Mucus role in animals' skin includes: **i.** keeps the skin moist; **ii.** lubricates the surface of the body, thus lessening the degree of friction with surrounding water; **iii.** it also slipper enables the animal to escape more readily from enemies; **iv**. protects the body from harmful bacteria and fungi. **v.** The secretions of the unicellular mucous glands in the snout of the amphibian larvae digest the egg capsule and free the embryo.

Unicellular mucous glands are scattered in the skin epidermis of aquatic animals those lack corneal layer. They are usually called goblet cells. The multicellular types are abundant in amphibian skin.

2. Poison glands. Many fishes and amphibians have poison glands. These are modified multicellular skin glands. They are larger, irregular, fewer in number in comparison with multicellular mucous glands (Fig.5). **Parotid glands** near the tympanic membrane of toads are aggregations of poison glands. Secretion of poison glands may be bitter, irritating and even dangerous to predators.

3. Luminescent glands or **Photophores**. Some deep-sea elasmobranchs and teleosts living in almost total darkness have light emitting organs called photophores in the skin. Most frequently these are arranged in longitudinal lines near the ventral surface of the body. Photophores are modified integumentary glands arise in dermis and often of complicated structure. The superficial **mucous cells (lens)** form a magnifying lens. Beneath the lens other cells are the source of light, the **luminous cells (glandular part)**. Luminous cells surrounded by reflector and pigment cell (Fig.9). The reflector is made up of guanine crystals to reflect the light upward. Photophores serve for species and sex recognitions, sometimes as allure, a warning or an aid for concealment by countershading and attract prey.

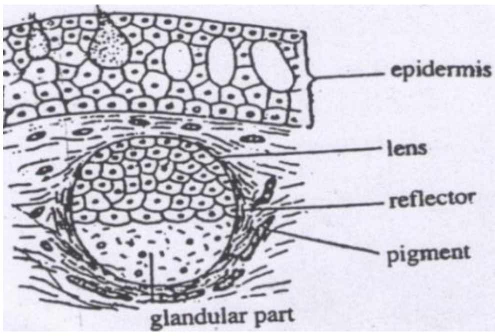


FIGURE 9: V.S. through the luminous organ (photophore) of bony fish.

4. Femoral glands. These are found in the male lizards (e.g. *uromastix*) on the ventral surface of each thigh, in single row of 12-18 femoral pores from knee to cloacal aperture. Their sticky secretion hardens in air to form temporary tiny spines that serve to hold the female during copulation.

5. Uropygial glands. It is one of the few integumentary glands found in birds. This is a simple branched saccular oil gland in form of a prominent swelling on the dorsal side of the body at the base of uropygium, or tail rudiment (Fig.10A). The bird by squeezing out the gland and bringing a quantity of oil on its bill, oils its feather as it preens them making them quite impervious to water (Fig.10B). The uropygial gland is best developed in aquatic birds. Not all birds possess uropygial gland. It is notably absent in paleognaths, parrots, and some varieties of pigeons.

A B

FIGURE 10: A- Oil or uropygial gland at the base of tail rudiment. B- Bird takes oil from its uropygial gland to preen its feathers to be impervious with water.

6. Sweat glands. Sweat glands are abundant in the skin of most mammals. They are coiled tubes embedded deep in dermis, with their long ducts opening on skin surface (Fig.8). Sweat glands are most numerous in regions devoid of hair such as a palm, or where the hairy coat is scant. A little urea and some salts are eliminated dissolved in water to form the sweat produced by these glands. Sweat glands have two important functions: getting rid of metabolic wastes, and helping to maintain a constant body temperature (thermoregulators). Sweating is one of the major mechanisms for cooling the body of many mammals. Horses can sweat up to 30 liters of fluid a day during active exercise, but cats and dogs and most other carnivores have few sweat glands and must cool themselves by panting. Panting expels hot air and brings in cooler air, which then helps moisture in the mouth evaporate quickly to reduce body temperature. Elephants also use their large ears to keep cool by flapping them like a fan. Water buffalos spend most of their day submerged in water, sometimes up to their nostrils, because they do not possess adequate sweat glands to cool themselves. Also birds pant because they are endothermic and lack sweat glands. Scent in the sweat of many animals is used to mark territory or attract the opposite sex.

Sweat glands are absent in certain edentates; and marine forms such as sirenians and cetaceans. The secretion of sweat glands of axillary and pubic region is relatively thick and contains fat droplet as well as pigment granules. Most animals have to find other ways to cool themselves down when they get too hot. For example, pigs and hippopotamuses roll in the mud to cool themselves down. As the water in the mud evaporates from their skin.

7. Sebaceous glands. These are branched alveolar glands distributed over the greater part of the surface of the skin, being notably absent from the palms and soles. With few exceptions the duct of the gland opens into a hair follicle (Fig.8). They may open directly onto skin surface such as the corners of the mouth and lips, tip of the nose, and mammary papillae. The oily secretion of this gland is called sebum (=grease), keep the hair and skin soft and smooth. Sebaceous glands are absent in pangolins and marine mammals (sirenians and cetaceans) which are particularly devoid of hairs.

8. Wax producing glands. They are located in the ear passages of the mammals. Their waxy or greasy secretion called cerumen helps trap insects or dust particles and protect the tympanic membrane.

9. Meibomian glands. They are located in the margins of the upper and lower eyelids of human and mammals. Their long ducts open via a row of minute foramina along the border of the lid just internal to the eyelashes. Meibomian gland cells (meibocytes) produce a constantly a lipid-rich secretion (meibum) that mix with aqueous tears produced by lacrimal glands.

10. Lacrimal glands. They are Paired almond-shaped glands, one for each eye, and of compound tubuloalveolar serous type. Each gland developed as an outgrowth of the upper lateral margin of the conjunctiva. Conjunctiva is a transparent membrane which lines the eyelids and the front of the eye ball. Its ducts open into conjunctiva sac. The lacrimal glands and their tears exist in animals which live on land and in air. Fish do not have lacrimal glands. The secretion of the lacrimal glands is clear salty liquid called tears in form of isotonic saline. Tears as a bathing solution for the eye, nourish, moisten, flush, and protect the conjunctiva and cornea so keep the eyeball surface moist. Enzyme lysozyme is present in tears prevents microbial infection. Tears mix with the **Meibomian** glands secretion (meibum) to form a tear film coating the outer surface of the eye. The secretion of the lacrimal gland flows in the sac and is drained into the nasal cavity (Fig.11). If excessive amount is secreted it is called tears. Blinking helps in the movement of tears to keep the cornea free of irritants like dust.

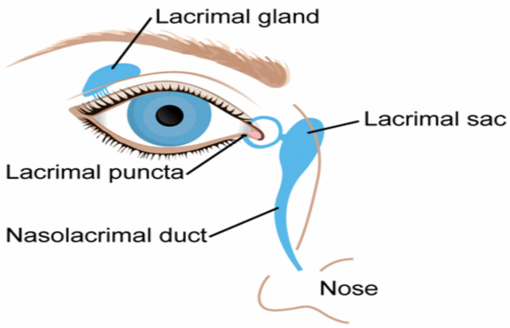


FIGURE 11: Human lacrimal apparatus.

11. Scent glands. The location of scent glands varies greatly. In deer family they are located on the head in the regions of the eyes. Many carnivores have scent glands near the anal opening. Skunk and weasels have saclike scent glands which open into the rectum just inside the anus. Scent glands may be located at the openings of the reproductive organs, as in many rodents; on the face, as in bats; between the hoofs as in pigs; navel on abdomen as in musk deer; and in still other mammals on the arms, legs, and other parts of the body. Their odorous secretions serve to**: i.** attract members of the same species or of the opposite sex. **ii.** In some they serve as lures; **iii.** in others as a defense against enemies; **iv.** in still others, they are used by males in marking out a territory.

12. Mammary glands. Present in both sexes but are rarely active in males. In general, the actively secreting mammary gland is made up of many small masses called lobules. Each lobule consists of large numbers of alveoli composed of secretary cells. The small ducts leading from the alveoli converge to form a large duct. This unites with similar ducts from other lobules, and the common duct or ducts thus formed lead to the outside. The mammary tissue consisting mainly from alveoli, branching ducts and fatty, or adipose, tissue usually surrounds the ducts and alveoli, accumulation of the adipose tissue contributes much to the size of the mammae, in human females, adipose tissue begins to accumulate around the mammary glands at puberty to form **breast** or called **udder** in ruminants and perissodactyles.

In monotremes the mammary glands are of the compound alveolar type and **lack nipple** or **teat**, the glands opening onto a depressed area of the skin, on the mother's belly surrounded by a tuft of hair (Fig.12a). The milk oozes onto the hair. The young grasps tuft of hair and obtain their nourishment by lapping or sucking.

In all other mammals, mammary glands possess nipples or false nipples (teats). A nipple is a raised area from the breast through which the mammary duct or ducts open directly to the outside. The **false nipple** or **teat** is present in horses and cattle and other perissodactyles and artiodactyles. Teat is an outgrowth from the skin of the mammary area. The mammary ducts which carry alveolar secretory units open into a cistern at the base of the teat, and the milk is then carried by the secondary duct to skin surface (Fig.12b). In some mammals a single duct, which carry alveolar secretory units, leads to the surface and opens on the **nipple**, as in rodents, marsupials and insectivores. In others, several ducts may open on the nipple, as in some carnivores and in man, in which as many as 20 separate ducts may present (Fig.12c). Nipples and teats are usually paired, their number being roughly proportional to the number of young delivered at birth. They vary from 1 pair to 11 pairs in certain insectivores.

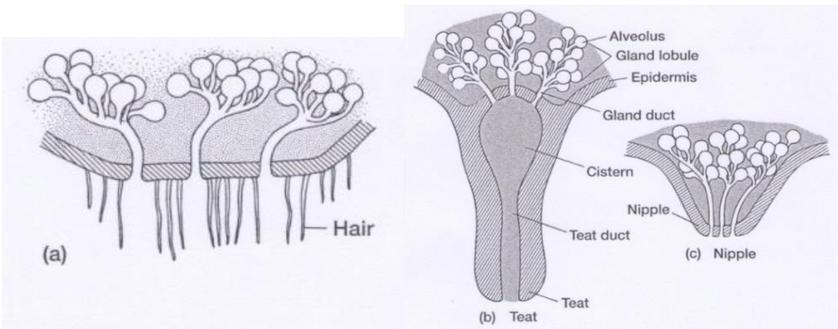


FIGURE 12: Longitudinal sections through the breast of mammals, showing three forms of mammary glands: (a). Mammary glands of monotremes; (b). Mammary glands of perissodactyles and artiodactyles, and (c). Mammary glands of marsupials and most placental mammals except perissodactyles and artiodactyles. The secretory unit of these three types is of compound saccular type.

II. Scales; Dermal bony plates

In many vertebrates the body is covered with scales which give it protection. Scales, regarding their origin, are of two types: epidermal and dermal.

1. Epidermal scales. These are cornified derivatives of the epidermis, found primarily in terrestrial tetrapods. Few examples are to be found in amphibians, but in reptiles, birds and certain mammals they are very well developed. Epidermal scales, with little exception, are usually shed and replaced from time to time.

2. Dermal scales. Dermal scales are bony structures located in the dermis of the skin and are therefore of mesodermal in origin. In contrast to the horny epidermal scales, the bony dermal scales are not shed but increase in size during life by the addition of new bone.

Comparative Anatomy of Scales

Amphioxus. No scales of any kind are present in the skin of amphioxus.

Lampreys and hagfish. Integumentary scales are absent in modern or living agnathans.

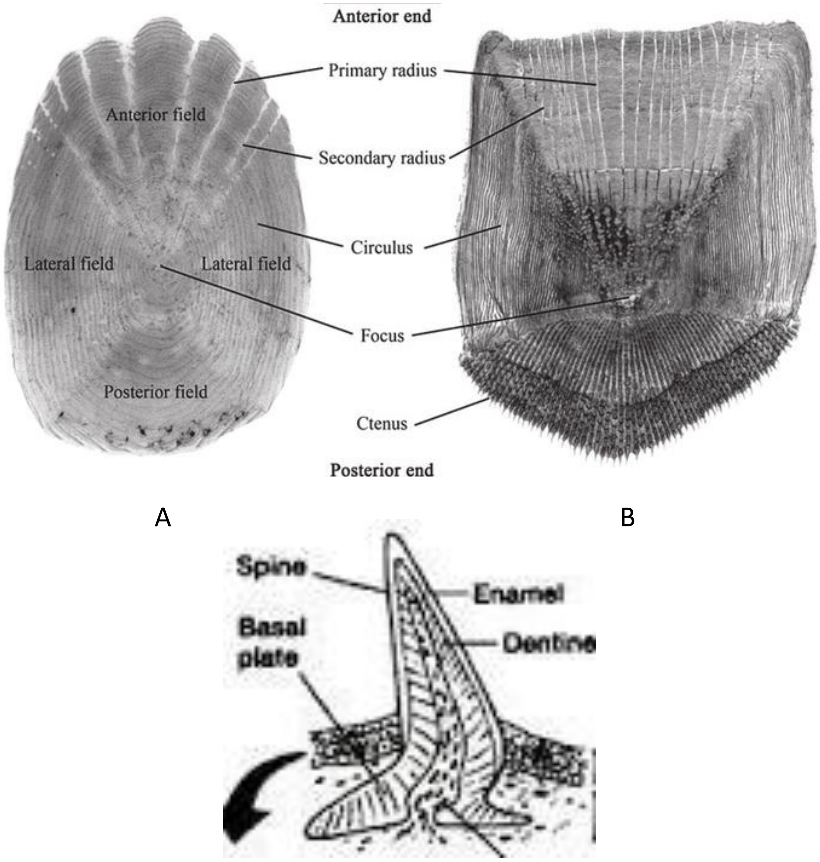
Fishes. Epidermal scales are lacking in fishes, but dermal scales, making up part of what is called the dermal skeleton, are abundant and of several types. Not all fishes have scales. They are lacking in the common catfish, eels, and some others. In chimaeras they occur only in localized region.

Modern dermal fish scales

Placoid scales. This type of scales is found in the cartilaginous fishes. Each scale consists of a basal bony plate embedded in the dermis, from which a spine projects outward through the epidermis and points posteriorly. The spine is composed of dentine covered with a hard layer of vitrodentine, both of mesodermal origin. A pulp cavity lies within the spine, opening through the basal plate.

Ctenoid scales. The ctenoid scale is a common type found in most teleost fishes, they are thin translucent plates composed of an underlying layer of fibrous material covered by a layer of which somewhat resembles bone. Each scale is embedded in a small pocket in the dermis. The scales are obliquely arranged so that the posterior end of one scale overlaps the anterior edge of the scale behind it. The basal end of the ctenoid scale is scalloped, its free edge bear numerous comblike projections (ctenii). Lines of growth are present, which if examined under a microscope will give an exact age of the fish, in same manner and seasonal pattern of plant stem growth lines.

Cycloid scales. Cycloid scales are roughly circular in outline. They too are located in pockets in the dermis and have lines of growth similar to those of ctenoid scales. In certain fishes both ctenoid and cycloid scales may be present, those on the underside being cycloid and those on the upper side being ctenoid. The scales covering the lateral line frequently perforated, permitting the passage of small connectives of the lateral-line canal to the outside.



C

FIGURE 13: Varied types of fish dermal scales: A. Cycloid, B. Ctenoid, C. Placoid.

Amphibians. The skin of modern amphibians is usually smooth, moist and lack scales except in a few toads and in some burrowing, limbless caecilians. The toads have a highly cornified area of epidermis called warts. True dermal scales are found in the integument of certain caecilians.

Reptiles. Highly developed epidermal scales are characteristic of members of the class Reptilia. In lizards, scales are thin, small, overlapping and periodically moulted in small pieces. In snakes also the scales are overlapping, enlarged on head and called **shields** (Fig.14 A), and are transversely arranged on the ventral side, called **scutes** (Fig.14B), which aid in locomotion.

Special modifications of epidermal scales of lizards and snakes include the **horns** of the horned lizard and the **rattle** of the rattle snake (Fig.15 A, B and C). A rattle is made up of a series of old, dried scales, loosely attached to one another in sequence or scutes.

In most turtles epidermal scales or scutes cover the plastron and carapace, but the pattern of the scales does not conform to that of the bony plates beneath. Each scale develops separately not overlapping but touching each other (Fig.16).

A **B**

FIGURE 14: A- Epidermal scales or shields on the head region, B- Transverse scutes, on ventral side of the body.

FIGURE 15: A- Horned lizard B- Horned snake C- Rattle of rattlesnake.

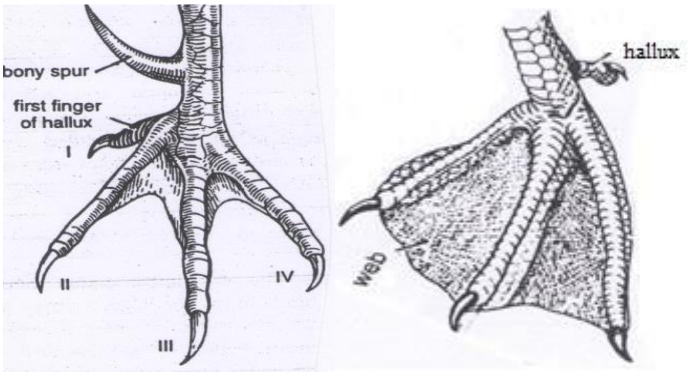
FIGURE 16: Dorsal and lateral scutes covered the turtle carapace.

The best example of highly developed dermal scales exists in turtles. The bony plates form a rigid dermal skeleton, a box-like structure around the trunk, and including a dorsally arched carapace and a ventral flattened plastron (Fig.17A and B).

A **B**

FIGURE 17: A- Carapace: the dorsal half of the chelonian shell. B-Plastron: the ventral half of the shell.

Birds. Epidermal scales of the birds are confined to the lower parts of the legs, feet, and the base of the beak, and the **spur**. Spur is a bony projection of the legs in the males of certain species of birds (Fig.18A). **Webs** on the feet of such aquatic birds as geese, ducks, and swans are modified regions of the integument which are characteristically scaled (Fig.18B).



A B

FIGURE 18: A- Spur covered by epidermal sheath; B- Web of aquatic birds.

Mammals. In the scaly anteaters (pangolin) the body is covered with large overlapping horny epidermal scales except on the ventral side (Fig.19). Ecdysis occurs in these scales singly. The large epidermal scales of armadillos have fused to form plates and bands (Fig.20. Instead of true ecdysis or moult there is a gradual wearing away from the outer surface. These scales or plates are supported beneath by dermal bony scales.

FIGURE 19: Overlapping horny epidermal scales covered the body of pangolin.

FIGURE 20: Epidermal scales form bands supported by dermal bony scales.

III. Epidermal or Horny Teeth

Epidermal teeth consist of hard, pointed, cornified epithelial projections. Only a few vertebrates have them and they are not homologous with true teeth.

i. The epidermal teeth found in the inner surface of the buccal funnel (Fig.21) and on the tongue of agnathans.

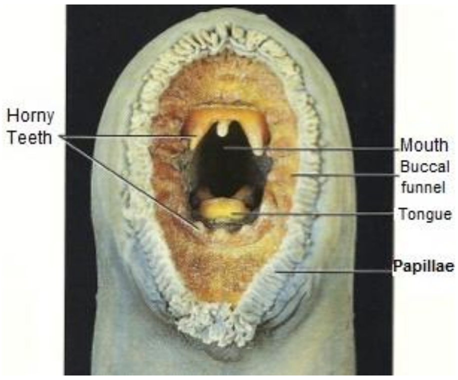


FIGURE 21: Horny teeth inside the buccal funnel of lamprey.

ii. Among amphibians, jaws of anurans' bear horny teeth.

iii. Epidermal teeth in the form of horny plates are found in adult platypus. This animal possesses true teeth during development, but they are lost even before birth.

iv. Toothless whale such as baleen whale lack true teeth, two transverse rows of numerous triangular fringed horny plates baleen hanged from the plate of the upper jaw (Fig. 22). These serve for straining plankton which forms their chief food.

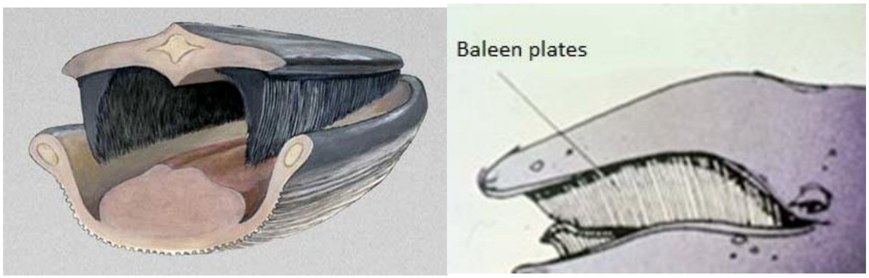


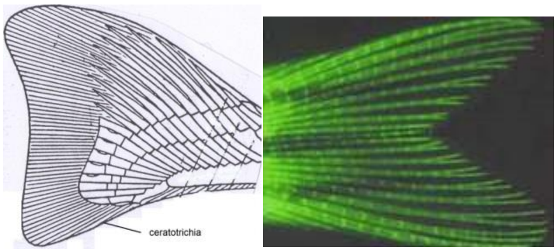
FIGURE 22: Two transverse rows of numerous triangular fringed horny plates, baleen or whalebone hanged from the palate of the upper jaw.

v. Egg tooth of the late embryo of oviparous vertebrates, which their eggs are covered by hard shell, is temporary cornified process of the upper jaw or upper half of the beak to enable the embryo to break the hard shell escape from it during hatching, as in oviparous reptiles, all birds (Fig. 23) and monotremes.

FIGURE 23: Egg tooth of bird hatchlings, as a temporary cornified process of the upper half of the beak.

IV. Dermal Fin Rays

Supporting the fins of fishes are long, flexible fin rays embedded in dermis. **i.** In chondrichthyes, they are keratinous, hair-like, made of fibrous connective tissue and called **ceratotrichia**. **ii.** In osteicthyes, they are, bony, branched, made of series of segments and called **lepidotrichia** (Fig. 24).



A **B**

FIGURE 24: A- Ceratotrichia, keratinized, thread like; B- Lepidotrichia, bony, segmented and branched.

V. Digital Cornification

All the three types of digital cornifications: **claws**, **nails**, and **hoofs**, are built on the same plan or basic structure. They are modification of epidermal cells. Since these three derivatives have same structure and origin, they are considered as **homologous** organs. Claws first appeared in reptiles and have persisted in birds and most mammals. Nails appeared in primates and hoofs in ungulates. Claws, hoofs and nails have same basic structures including the two curved parts, a horny dorsal plate, the **unguis**, and a softer ventral plate, the **subunguis** (Fig.25). They covered last phalanges.

Although claws in birds are often thought of as associated only with the feet, sharp claws are frequently borne on one or more digits of the wings of ostriches, geese, some swifts, and others.

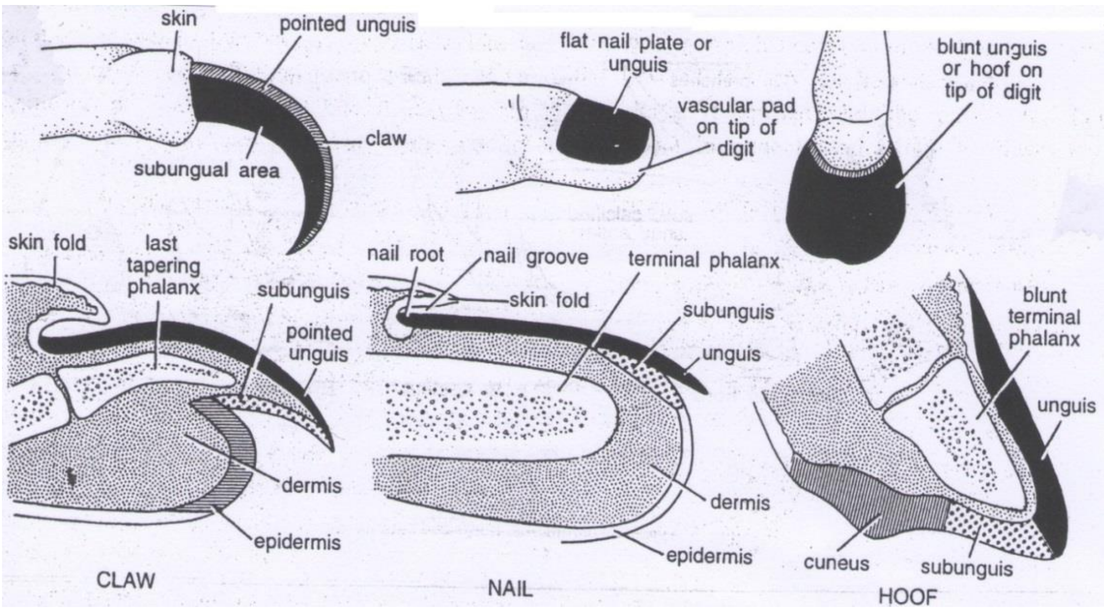


FIGURE 25: Three homologous corneal structures: claw; nail and hoof. They have same developmental origin and built up on same structure.

VI. Beaks or Bills

i. In turtles and tortoises and **ii.** in all modern birds teeth are lacking. Each elongated jawbone is covered with modified corneal material which forms solid structure called beak or bill. Among birds, great variation is found in the shape of the beak, correlated with its methods of obtaining food.

iii. The bill of the duck platypus is soft. It is not covered with corneal material and should not be confused with the type found in the birds. They are **analogous** structures.

VII. Feathers

Feathers cover all the body of birds also collectively called plumages. They are not found in any other group of animals. They are dry, non-living and epidermal derivatives. Feathers conserve the body heat and make broad surfaces of wings and tail used for flight, they are called remeges and rectrices respectively. Feathers are shed and replaced seasonally.

Three types of feathers are recognized: **contour feathers (plumae)**; **down feathers (plumules)**; and **hairlike feathers (filoplumes)**, (Fig. 26).

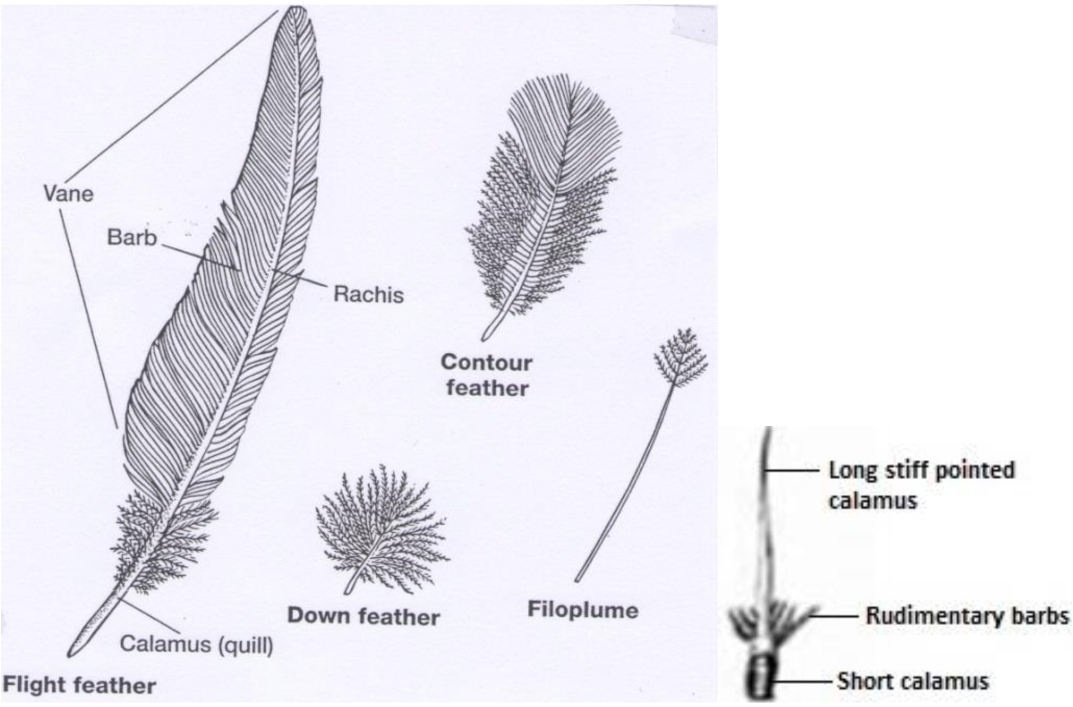


FIGURE 26: Four types of bird feathers, in addition to flight feather which is also considered as contour feather.

Structure of typical contour feather

Any contour feather from the general body covering or a flight feather present on wings (remiges) or tails (rectrices) provides the typical structure (Fig.27). A typical flight feather consists of :

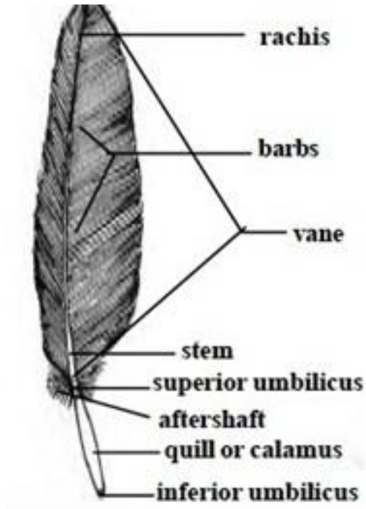


FIGURE 27: Typical structure of the contour feather.

1. Axis. The axis is divided into proximal lower portion, the calamus or the quill, and distal upper portion, the rachis or the shaft.

A. Calamus. The calamus or the quill is hollow, tubular in shape and semitransparent. At the lower end of the quill is a small opening, the inferior umbilicus, which receives a small conical nutritive papilla of the dermis, the dermal papilla, through which blood vessels enter to supply nutrients and pigments to developing feather. A second minute opening, the superior umbilicus, occurs at the junction of the quill and rachis on the inner or ventral side. In many birds, including some pigeons, a small tuft of soft feathers, called after-shaft, arise around the superior umbilicus.

B. Rachis. The rachis or the shaft, forms the longitudinal axis of the vane. It differs from the calamus in being stiff, solid and opaque. A longitudinal furrow, the umbilical groove, runs along the inner or ventral surface of the rachis throughout its length.

2. Vane. It is the expanded membranous part of the feather. It is divided by the rachis into two unequal lateral halves, and its distal end is narrower than the proximal end. The vane is formed by a series of numerous parallel and closely spaced, delicate, threadlike structures, the ***barbs***. The size of the barbs gradually decreases towards the two ends of the rachis. Each barb in its turn gives rise to a double row of delicate, oblique filaments, the ***barbules***. The barbules of the adjacent barbs overlap and connected by hooklets to form what is called interlocking mechanism. The feathers of ostriches and kiwi and other paleognaths, that have lost the power of flight, lack this interlocking mechanism.

Flight contour feathers of the wings termed remiges (singular, remix). The number of these feathers has a great value in classification.

Long contour feathers arise on the tail called rectrices (singular, rectrix), are arranged in semicircular or fan-like manner on the tail. The rectrices help the bird as a brake and in steering the flight.

Hairlike feathers (Filoplumes). These are small, delicate and hair-like feathers of unknown function, which remain sparsely, distributed over the body as seen in a plucked pigeon or chicken, and are commonly singed, or burned off. Filoplume consists of a short calamus, and a long thread-like rachis with a few weak barbs and barbules at the free tip and lack hooklets (Fig.26). The long colorful feathers of the peacock are conspicuous examples of filoplumes. **Bristles** resemble filoplumes but lack any terminal barbs. A few barbs do occur at the base of the shaft (Fig.26). Bristles occur on the head and neck where they screen eyes, ears and nasal openings of foreign matter. Those around the mouth are also tactile receptors, conveying information such as a possible insect meal for a flycatcher.

Down feathers (plumules). Down feathers are small, soft and wooly feathers. They lack rachis and have a short calamus with a crown of long and flexible barbs and with short barbules that lack hooklets (Fig.26). They form natal covering of the newly hatched birds, providing excellent insulation.

VIII. Horns and Antlers

Except for the hornlike structures in a few lizards and snakes, horns are found only in mammals. Among mammals many ungulates or hoofed mammals are endowed with organs of offense, defense, the horns and antlers. The term horn means that the surface is composed of keratin (hornified material). **Three varieties** of mammalian horns meet this criterion: **bovine horns**, which are hollow or true horns; **pronghorn** of American antelopes; **hair horns** of rhinos. **Antlers** and **giraffe horns <u>are not</u>** true horns but dermal bones. These two kinds, antlers and horns are analogous structures.

A. True hollow horns. Artiodactyles of the family Bovidae (oxen, cows, goats, sheep, true antelopes and others). The bovine horns are made of a dermal bony core arising from frontal bone of skull, and covered by a permanent epidermal horny hollow cap or sheath (Fig. 28). This type of horn are: **i.** true hollow horns, **ii.** unbranched, cylindrical, tapering, curved or recurved, **iii.** permanent structures and never shed, **iv.** usually found in both sexes, but there are exceptions, in some species they occur only in males. Polled cattle have lost their horns by selective breeding.

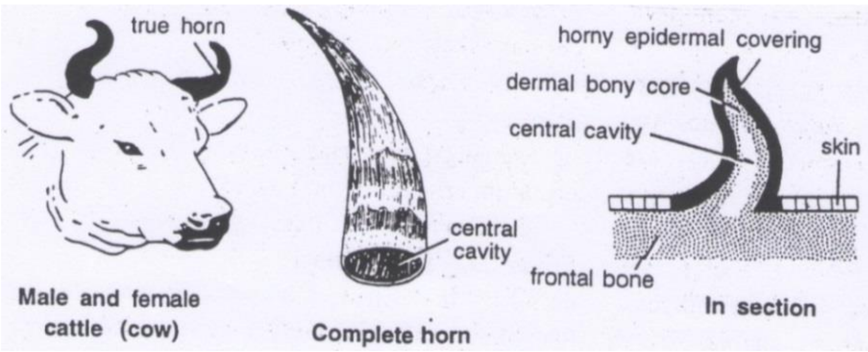


FIGURE 28: External feature and structure of true horn.

B. Pronghorns. The horns of the prong-horned American antelopes *Antilocapra americana* are also true horns. It is also formed by a small central permanent bony core arising from the frontal bone and covered by a thin hollow and horny epidermal horn in both sexes (Fig. 29). The chief differences between bovine horns and pronghorns is that: **i.** pronghorns are branched, where each horn bear 1 to 3 small branches or prongs, hence named pronghorn antelope, **ii.** the horny covering or sheath, but not the bony core, is shed annually. The permanent bony core becomes the base around which a new horn is developed. **iii.** Both sexes bear pronghorns.

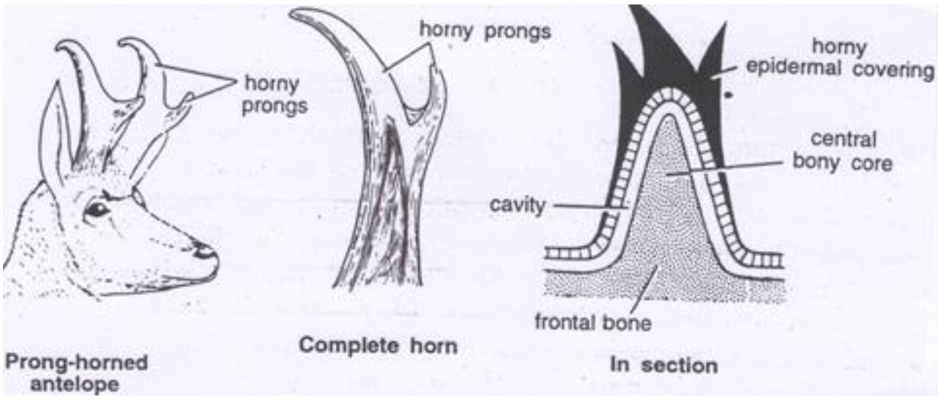


FIGURE 29: Pronghorn of American antelope, its morphology and structure.

C. Hair horns. Hair horns or **keratin fiber horns**, (Fig.30) are found in rhinoceros of both sexes. These differ from other horns in being composed of agglutinated keratinized hairlike epidermal fibers that form a solid horn, conical shaped, perched on the nasal bone. These types of horns are: **i.** permanent, **ii.** unbranched and if broken they again grow out. **iii.** Present in both sexes. Indian rhinos have a single horn, while the African species has two one behind the other, the larger one being more anterior.

FIGURE 30: African and Indian rhinos bear hair or keratin fiber or fibrous horn.

Antlers. Antlers are characteristic of deer family (Cervidae). **i.** They are found only on males but on both sexes in reindeer and caribou. **ii.** They are not cornified structures but **dermal bone** which in turn attached to the frontal bone. It is therefore of mesodermal origin, and properly should not be called a horn. **iii.** New growing antlers are said to be "in velvet" because they are covered with a soft vascular skin and velvety hair. When growth is complete, the velvet wears off, exposing the naked, branched antlers (Fig.31). **iv.** After the breeding season is over; male territory no longer must be defended; and the testosterone concentration declines in the blood circulation, all these factors lead the antlers to be shed and new antlers develop the following year. Each year new branches appear, and the structure becomes more complicated.

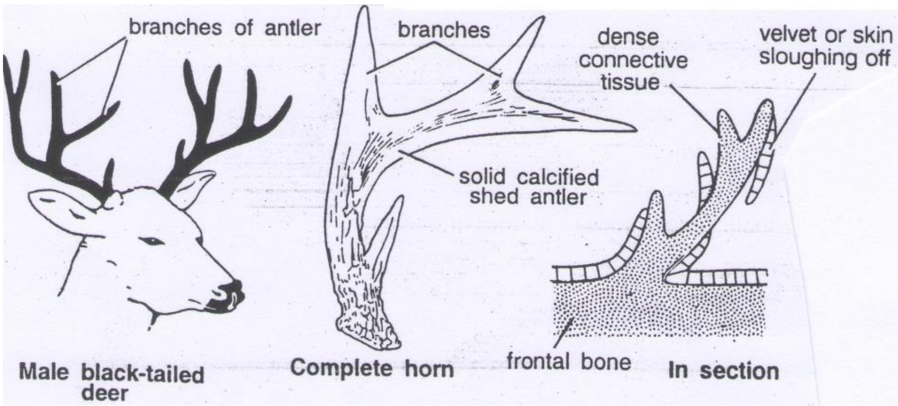


FIGURE 31: Antlers of the deer after complete development. The velvet wears off exposing the naked, branched antler.

Giraffe horns. Horns of giraffes are: **i.** stunted, **ii.** Unbranched, **iii.** Permanent, and **iv.** present in both sexes. They are short bony projections of the frontal bones that remain in velvet (hairy skin) throughout life (Fig.32). Compare between antlers and giraffe and deer.

FIGURE 32: Giraffe horn and its structure.

IX. Hair and Its Modifications

Hairs are characteristics of mammals. They may cover the entire body or may be reduced to patches (man) or to scattered hairs (whales). Like scales and feathers, hairs are also cornified epidermal products of the integument. Hairs are periodically lost by moulting and replaced by a new one. Hairs have several modifications such as **bristles** on the upper lip of whales; **spines** covered the dorsal and lateral sides of hedgehog's body; **quills** of porcupine and **wool** of sheep and **fur** of camels, llamas and seals.

Functions of the skin

After studying and understanding the structure and derivatives of the skin, it will be easy to conclude and understand the roles of skin, taking in account that the role of skin derivatives are also attributed to skin itself. The following are some skin functions.

1. Protection.

2. Exteroception. Skin functions as a sensory organ. Free nerve endings are scattered in the dermis of the entire skin.

3. Respiration. Skin is a main respiratory organ in amphibian due to high vascularity of the dermis.

4. Salt-water regulation. Carried out by sweat glands in mammals.

5. Thermoregulation. Fur and feathers insulate against cold. Sweat cools by evaporation.

6. Locomotion. Locomotion by adhesive pads; by claws that assist in climbing; scutes that assist in slithering and feathers for flight. Integumentary webs and patagium have a role in swimming and flying respectively.

7. Maintenance of homeostasis. Some fishes keep homeostasis by dermal scales, stratum corneum of terrestrial species conserves water.

8. Nourishment. Teleost hatchlings feed on mucus secreted by the mother's skin and mammary glands nourish new born mammals.

9. Sexual selection. Male competition to fertilize female is an essential component of sexual selection, for which males develop various kinds of **secondary sexual characters** that are modifications of skin. Long and colourful feathers of male birds and mane of lions are all contributions of skin in sexual identification and attraction.

10. Reproduction. Some skin derivatives and secretions in the body of male that help it to embrace the female during copulation.

11. Brood pouch. Brood pouch is a bag of skin that is usually attached to the belly in marsupials. Some other animals such as sea horse, and some amphibians develop brood pouches for keeping their eggs or juveniles.

12. Defense and offence. Creator, exalted is He, provided all creatures by methods that can protect themselves from enemies and hard environment. Some of these protective methods or structures are skin derivatives, like the turtle's shell; claws of reptiles, birds and mammals and horns of mammals.

13. Signs for some internal diseases. Dermatologists find that the skin offers a window to what is going on inside the body, and changes to the skin may signal a more serious health problem. In some cases, the skin can show signs of an internal disease before the disease advances and becomes more serious; in other cases, a symptom is noticeable on the skin long after the disease begins causing damage internally.

CHAPTER TWO
Endoskeletal System

The endoskeleton is composed of mineralized connective tissue and of ligaments and tendons. The mineralized tissue for the most part is bone, but there are also cartilage, dentin (often considered a variety of bone) and enamel. All these tissues are originated from mesenchyme. Before these tissues can be deposited a preskeletal **blastema** must be developed. A blastema is any aggregation of mesenchyme that gives appropriate stimulus to differentiate into some tissue such as muscle, fibers, cartilage and bone. The specialized cells of these solid tissues arise from less differentiated scleroblasts that arise from mesenchyme. These scleroblasts are: osteoblasts which produce bone; chondroblasts which produce cartilage; odontoblasts which produce dentin and ameloblasts which produce enamel.

Most of the skeletons of the vertebrates lies within the principal body muscles forming a living or growing structure and is called **endoskeleton** (Gr. Endo, within + skeleton); it provides a system of rigid levers to which muscles can be attached. This must be regarded as its chief function. Secondarily, too, the endoskeleton may take on a protective function by being developed around such organs as the heart, lungs, etc.

Types of vertebrate skeleton

Three types of skeleton develop in vertebrates. The first two types: epidermal horny exoskeleton and dermal bony exoskeleton are mentioned in chapter one, where they are attributed to skin. The third type of vertebrate skeleton is endoskeleton.

Endoskeleton. Greater Part of vertebrate skeleton lies more deeply, forming the endoskeleton. Endoskeleton is the framework of the animal body in vertebrates it is composed of cartilage or bone, or combination of the two. At early embryonic stage, endoskeleton is composed of cartilage, which is replaced by bone in most adult vertebrates. Such bones deposited in place of preexisting cartilages, are called **replacement bones** or **cartilage bone**. Thus, they are distinguished from the dermal or membrane bones which **i.** directly form more superficially in dermis **ii.** without any preexisting cartilage. Despite this difference in the mode of their development, the two types of bones are similar histologically.

Functions of endoskeleton

Chief functions of vertebrate's endoskeleton can be enumerated as follows:

1. To provide physical support to body by forming a firm and rigid internal framework.
2. To give definite body shape and form.

3. To protect by surrounding delicate internal organs like brain, heart, lung, etc.
4. To permit growth of huge body size (whales, elephants, extinct dinosaurs), since it is living and growing.
5. To provide surface for attachment of muscles, and serve as levers on which muscles can act during their contraction and relaxation.
6. To aid in hearing, through the ear ossicles.
7. To help in breathing, where tracheal rings and ribs are made up of cartilage.
8. Important storage place for calcium and other mineral salts, therefore participate in maintaining homeostasis.
10. Production of blood corpuscles from bone marrow, in the cavity of bones.

Two Main Parts of Endoskeleton

For convenience the skeleton may be considered in two parts. First, that which lies in the long axis of the body, the **axial skeleton** and second, that which is associated with appendages (fins or limbs) and forms the **appendicular skeleton**.

1. Axial skeleton. The parts of this type of endoskeleton lie along the median axis of the body. These are: the **skull**, **vertebral column**, **ribs** and **sternum** of tetrapods. Ribs and the tetrapod sternum form in the lateral and ventral body wall, respectively. **Skull** in its turn constitutes from:

i. The **cranium proper**, which encloses the brain.

ii. The **sensory capsules, capsules of the olfactory, optic and auditory sense organs**.

iii. The **skeleton of the jaws** and **hyoid apparatus**.

2. Appendicular skeleton. The parts of this type are lying on both sides of the body axis. These are**:** the two girdles, the **pectoral** and **pelvic**; the skeleton of the **forelimbs**, which articulate with the pectoral girdle, and the skeleton of the **hind limbs** which articulate with the pelvic girdle.

In this study the endoskeleton of two vertebrates were selected: Frog which represent as intermediate evolutionary and environmental condition, neither pure aquatic nor pure terrestrial; bird, represented by pigeon with modified endoskeleton to fit the aerial environment.

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 (Fig.1). 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** (Fig. 2). 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.

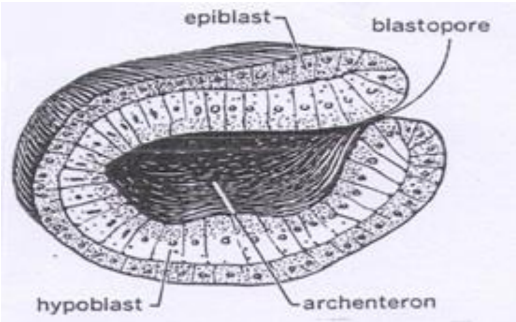


FIGURE 1: Amphibian's gastrula stage, showing the presumptive of the digestive tract which is called the gut or archenteron.

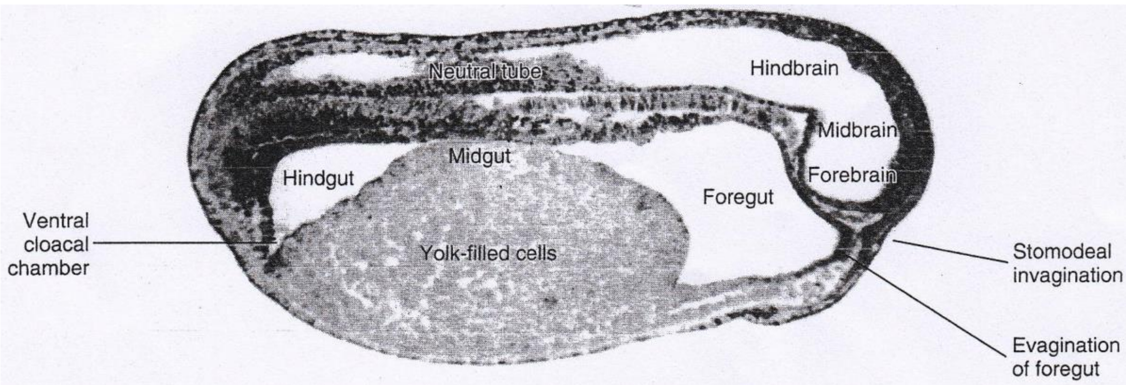


FIGURE 2: Sagittal section of 3.5mm frog tadpole, showing three regions of the gut and the beginning of the formation of the stomodaeum and proctodaeum.

Alimentary canal connected with the body wall via two mesenteries: The dorsal mesentery connects the alimentary canal with the dorsal wall of the body and remains throughout the life, while the ventral mesentery connects it with the ventral wall of the body which is eventually disappear except at the level of the liver, to form falciform ligament.

Three Main Regions of the Digestive System

It is preferable to divide the digestive system into three main regions:

1. Buccal (in water breathing vertebrates) or **buccopharyngeal cavity** (in air breathing vertebrates).

2. Digestive tract or alimentary canal.

3. Digestive glands.

Functions of the digestive system

A lump of food in the mouth is called a **bolus**; both mechanical and chemical processes break up the bolus, reducing it into many smaller pieces and their by increasing the surface area available for chemical digestion by enzymes. As mechanical and chemical action work on the **bolus**, in buccopharyngeal cavity and stomach, it soon becomes a pulpy mass of fluid more commonly called **chyme**, or **digestia**. Muscles encircling the walls of the digestive tract produce waves for contraction, termed **peristalsis**, that forcing food from one part of the tract to the next.

The following steps along the length of the digestive tube will occur, where the accessory organs process and the digestive glands pour their secretion via ducts:

1. **Ingestion** and **grinding** take place in buccal or oral cavity due to the presence of lips, teeth and tongue in addition to the secretion of saliva or mucus.
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 small 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**; **rectal cecae**; **villi** to increase the surface of absorption, and longitudinal folds of the lining of intestine also increased surface of absorption of the nutrient. Absorbed nutrients enter blood circulation to reach it to different body cells where another process takes place called assimilation.

The final main functions of the digestive system after these processes is: to change organic food or macromolecules (polymers) to small molecules (monomers), where proteins change to amino acids; carbohydrates to simple sugar (monosaccharides), nucleic acids to nucleotides, lipids to fatty acids and glycerol. The cells lined alimentary canal can easily absorb these simple molecules which are collectively called nutrient. Nutrients pass through the lining of the digestive tract and into the blood to reach all the cells of the body.

Assimilation is the movement of the digested food molecules (nutrient) into the cells of the body from where they are used. The liver is important in assimilation, for example, glucose is used in respiration to provide energy, and also amino acids to build new proteins to build up body materials; fats for energy reserve.

7. **Elimination** or **egestion** of the undigested and unabsorbed food as waste products via the skeletal muscles of the rectum.

Variations in digestive system among various chordates

It is essential to know the variations in digestive system parts or organs among different chordates, where these variations are due to variations in mode and habit of feeding.

I. Buccal or buccopharyngeal cavity:

1. Merges or separation of mouth and pharynx.
2. Separation of the pharynx from esophagus in adult lamprey only.
3. Teeth arrangement (dentition).
4. Tongue.
5. Modifications in some glands of buccal or buccopharyngeal cavity to produce blood anticoagulant as in adult parasitic lamprey or to be poisonous as in most snakes and North American lizard, Gila monster *Heloderma sp.*

II. Alimentary canal or Digestive tract:

1. Alimentary canal's length and whether it is: straight, curved or curved and coiled.
2. Modification in esophagus, especially in birds to be crop and in mammals (ruminants) to form two or three chambers.
3. Presence, absence, or highly differentiated stomach and its form in correlation to animal trunk whether it is wide or long.
4. Undifferentiated or highly differentiated intestine and its different subdivisions.
5. Types of projection or methods of absorption in the lining of intestine to increase surface of food absorption, like ceca, spiral valves, rectal ceca, villi or longitudinal folds.
6. Final or posterior opening of the alimentary canal whether it is cloaca or anus.

III. Digestive glands:

1. Salivary glands. Its absence or presence, or only mucous glands as in aquatic animals. Salivary glands essential for terrestrial animals as in reptiles, birds and mammals.

2. Liver. Whether it is absent, unlobed, with two main lobes, and subdivisions of these two main lobes, in addition to presence or absence of gall bladder.
3. Pancreas. Whether it is in a form of mass or diffused form. Its duct poured in beginning of intestine independently or share with bile duct in their bases when they poured in the beginning of intestine.

Comparative Anatomy of the Buccal or Buccopharyngeal Cavity and Structure Associated with It

The term which is applied to the anterior part of the digestive system of chordates shows variation from group to another and often depends on their mode of feeding and respiration. The names which applied are: **buccal funnel**, as in lancelets and adult agnathans; **buccal cavity**, as in water or gill breathing animals including larval lampreys, amphibian larvae and larval and adult stages of fishes, where the pharynx is separated from oral cavity and occupied with gills. The last term is **buccopharyngeal cavity** for those terrestrial air breathing vertebrates, including adult anurans and some adult urodeles in addition to all other tetrapods (reptiles, birds and mammals).

Amphioxus

Mouth or enterostome of amphioxus is surrounded by numerous cirri and tentacles, such as buccal cirri; wheel organ and velar tentacles. Velum is a transverse membranous partition, contains the true mouth opening in its center and which bears several **velar tentacles**. All these structures are shown in Fig. (3).

Feeding. Amphioxus is a ciliary filter feeder animal, hence all cirri and tentacles, (Fig.3), are help in driving a current of water loaded with small food particles, includes bacteria, fungi and zooplanktons, into the mouth.

Water passes from the mouth into the large pharynx, Ciliary action pushes the food to the rest of the digestive tract. The water enters an atrium surrounding the pharynx, then exits the body via the atriopore.

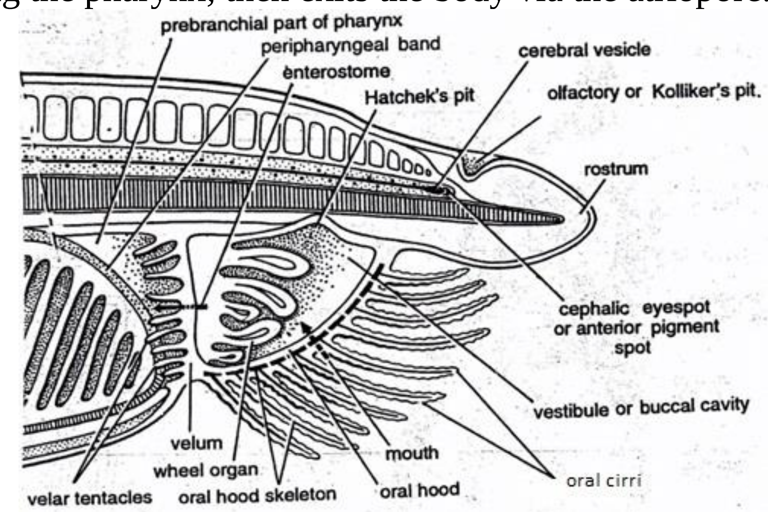


FIGURE 3: Structure of the amphioxus buccal funnel.

Lamprey

The anterior end of the adult lamprey differs from that of its larva due to their variation in mode and habit of feeding. The **buccal funnel**, of the adult lamprey, is present at the anterior end. It is a large, circular downwardly directed basin-like depression and remains permanently opened in rounded form supported by a circular cartilage; hence lamprey and other agnathans are called cyclostomes, where no jaws are present. Buccal funnel is bordered with **adhesive papillae**, and lined with radiated rows of yellowish-brown **horny teeth** (Fig.4). At the end of the funnel is a narrow mouth opening, located above the tongue which is projecting from the bottom of the buccal funnel. The tongue also bears large horny teeth. Both sets of teeth are horny and epidermal in origin; consist of a cone of keratinized epidermal projections on the surface and not homologous with teeth of higher vertebrates, but analogous.

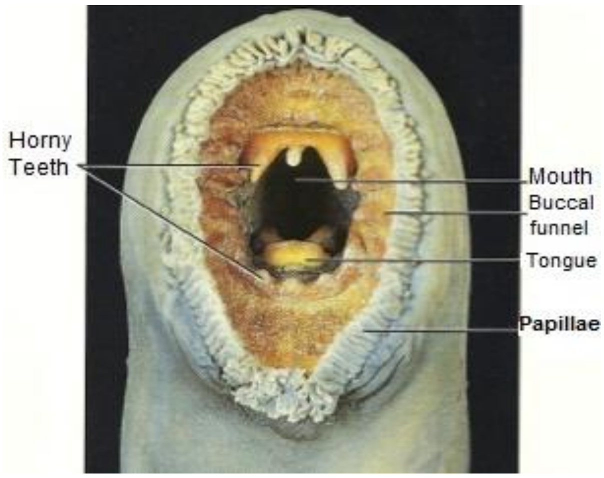


FIGURE 4: Buccal funnel of adult lamprey.

Dogfish

The **mouth** is located in the ventral side of the head. It is a crescent form opening bounded by folds of integument. The **jaws** bear several rows of **homodont teeth** and are used for holding, tearing and preventing the escape of living prey but not for chewing. The lining membrane of the buccal cavity is rich in **mucous gland**. In the floor of the **buccal cavity** is the primitive **unprojected tongue** (Fig.5), really a pad of tissue uses in swallowing by pressing the food backwards against the hard floor of the cranium, which is the **palate** or roof of the buccal cavity.

The nares or nostrils are present ventrally and anterior to mouth, one on either side. They are exclusively olfactory and have no respiratory function as they are not connected to mouth cavity by internal nostril.

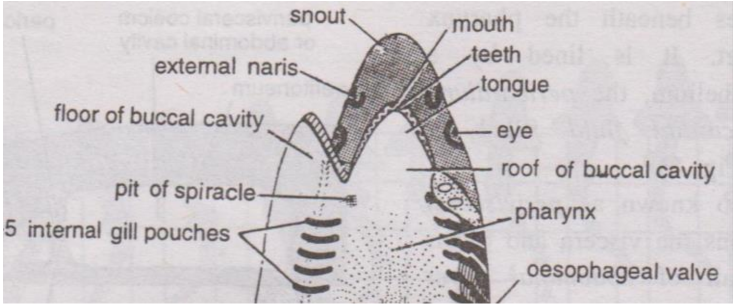


FIGURE 5: Dogfish buccal cavity.

Frog

Mouth is bounded by two bony jaws covered by immovable lips. Upper jaw is fixed while the lower jaw can move up and down to close and open the mouth. Mouth opens into a large, wide and shallow cavity result from the fusion of buccal cavity and pharynx, where no demarcation between them. Hence, the two are described as **buccopharyngeal cavity**. This cavity is rich in mucous glands and ciliated. Various structures and openings are associated with this cavity (Fig.6):

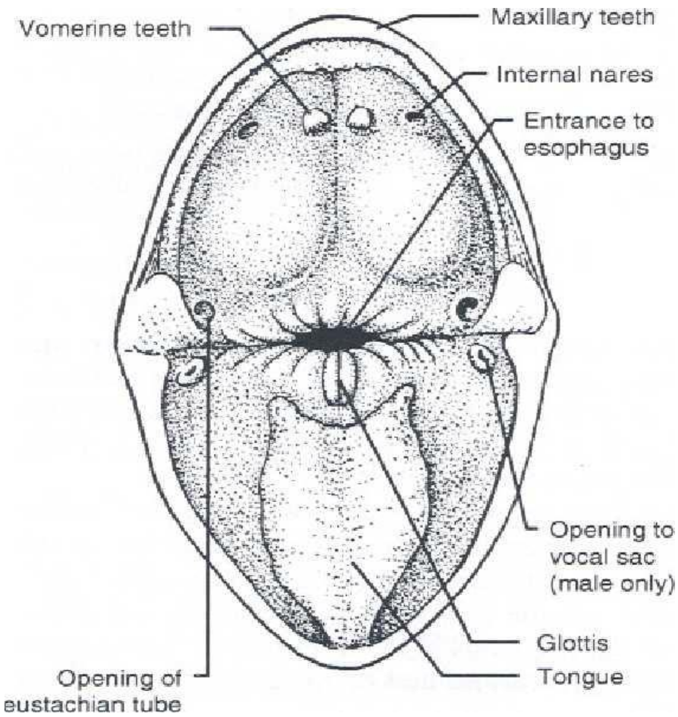


FIGURE 6: Frog buccopharyngeal cavity.

i. Teeth. The lower jaw lacks teeth, but small conical and pointed teeth occur in the upper jaw. Besides, two small bones in the roof mouth called vomers, also bears vomerine teeth. Frog teeth are homodont; not set in a socket (no root), and are not meant for chewing, they simply hold the prey and prevent it from slippering out.

ii. Tongue. On the floor of buccopharyngeal cavity lies a large, muscular sticky protrusible tongue. Its attachment is unusual, where its anterior end is fixed and attached to the inner border of lower jaw, while its posterior end is free and bifid which can be flicked out and retracted suddenly after capturing the prey with its slimy surface.

iii. Bulging of the orbit. Roof of buccopharyngeal cavity shows two large oval and somewhat pale areas, the floor of eyeballs.

iv. Hyoid apparatus. In the floor of the buccopharyngeal cavity and beneath the tongue, lies the body of hyoid, its raising and lowering has a role in breathing.

v. Internal nostrils or **nares** (singular: naris). At the anterior end of the buccopharyngeal cavity are two internal nares, which communicate with the exterior through the olfactory organs and the external nostrils.

vi. Eustachian openings. In the two lateral borders of the posterior region of the upper jaw is a wide Eustachian aperture which leads to middle ear.

vii. Glottis. A median elevation, on the floor of buccopharyngeal cavity, carries a longitudinal slit-like aperture, the glottis leading into the respiratory passageway.

viii. Gullet. Dorsal to the glottis and between two perfectly opened jaws is a transverse slit, the gullet which is the opening of the buccopharyngeal to the esophagus.

ix. Vocal sac openings. In male frog, on the floor of buccopharyngeal cavity on either side near the angle of two jaws, is present the small opening of a vocal sac, which acts as a resonator during **croaking**.

Lizard and Other Reptiles

Lizard's **buccopharyngeal cavity** has same structures and openings as in frog, but **protrusible tongue** fixed posteriorly, free and bifid anteriorly and their openings as in frogs include: **internal nares**, **Eustachian tube openings**, **gullet** and **glottis** (Fig.7). Their males lack vocal sac openings. The roof of most reptilian's buccopharyngeal cavity, as in amphibians, covered with **primary palate** and perforated anteriorly by pair of internal nares, but **only** in case of crocodilians, palate separate the nasal passage from buccal cavity and the internal nares open posteriorly in the pharyngeal region.

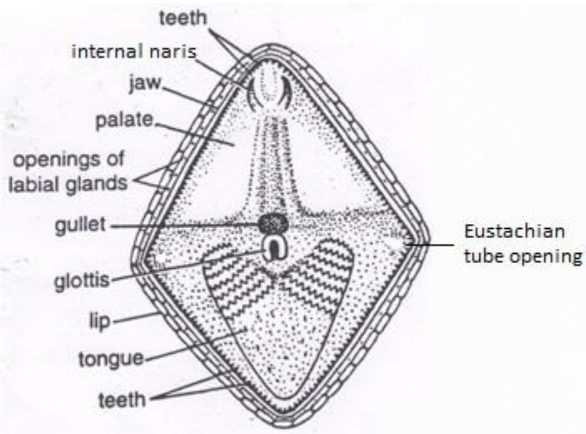


FIGURE 7: Lizard's buccopharyngeal cavity.

The tongue of turtles and crocodiles is **not** protrusible and lies on the floor of buccopharyngeal cavity. Most snakes and lizard have well developed and protrusible tongue and mostly bifurcated. They project their tongue out of the mouth retrieve chemicals that their sensory vomeronasal organ (Jacobson's organ) evaluates to locate its prey. Some lizards clean their transparent eyelids with tongue. Few snakes have no tongue.

Birds

Mouth is fairly large opening bounded by two elongated upper and lower jaws, they in turn covered by **horny beaks** or **bills**. At the base of upper bill is a naked swollen portion of sensitive skin forming the cere. The fleshy part of the mouth is in the angle of the bill. Mouth leads to a **buccopharyngeal cavity** (Fig.8). A large **tongue**, of pigeon, pointed anteriorly is present on the floor and has triangular shape. Taste buds and mucous glands are present on the tongue. The two small nostrils are obliquely situated in the cere. The **internal nares** are two narrow slits lying close together in the roof of buccopharyngeal cavity. The aperture of the **Eustachian tubes** is a single median opening which lies just behind the internal nares. The **glottis** is an oval opening with tumid lips located in the floor of pharynx just behind the base of the tongue in lower jaw.

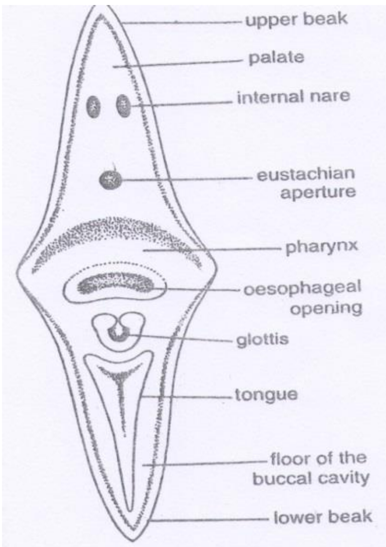


FIGURE 8: Pigeon's buccopharyngeal cavity.

Rabbit and Some Other Mammals

The upper and lower boundaries of the mouth opening are known as lips. In all vertebrate groups below mammals' lips are immovable. **Movable lips** occur only in mammals. Notable exceptions include the platypus and whales. The bill of the platypus is not horny, but it is soft and extremely sensitive.

The movable upper lip of the rabbit is divided by a median cleft which connects the mouth with external nares or nostrils.

The mouth leads into a cavity called buccopharyngeal cavity. The roof of the cavity is the **palate**. Anteriorly, the palate is supported by bone and with transverse ridges called **rugae**, which are prominent in herbivores, including the rabbit (Fig. 9), and carnivores. Posteriorly, the palate, has no bony support and known as **soft palate**. In man the soft palate ends in a fleshy, pointed elongation, the **uvula**, which hangs downward and backward. It serves to close off the nasal passageway from the buccal cavity during the act of swallowing.

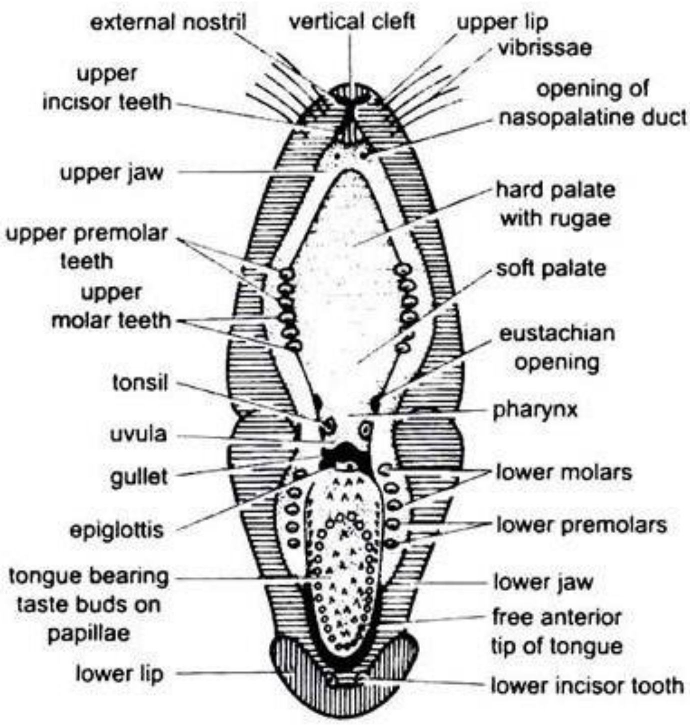


FIGURE 9: Rabbit's buccopharyngeal cavity.

The buccopharyngeal cavity contains **teeth** of heterodont type, which is a characteristic of mammals. Teeth are provided with roots, implanted deep in the sockets of the jaw. Each half of upper jaw, of the rabbit, has two incisors born by premaxilla, while each half of lower jaw has single incisor. Incisors of rabbit are characteristically elongated; they have open roots. Canines are absent in both the jaws and the wide toothless gap left due to their absence is called **diastema.**

The tongue bears **papillae** of various forms, most of them are associated with the taste buds.

Important role of the tongue in the life of mammals

1. digestion due to presence of the scattered types of mucous and serous alveoli which secrete mucus and saliva; 2. moving the bolus; 3. tasting the food due to the presence of taste buds on the papillae; 4. sensation; 5. cleaning the fur (grooming) by presence of long filiform papillae; 6. long vascular tongues function in overheated mammals as a site for cooling the blood by evaporation of saliva while panting, as in terrestrial carnivores; and 7. in addition to all these mentioned role, the tongue has a role in human speaking.

Teeth and Their Arrangement (Dentition)

Teeth (singular: tooth), are hard structures derived from both ectoderm and mesoderm. The arrangement of teeth in vertebrates is termed **dentition**. They are primarily employed by animals in cutting, grinding, crushing food, attack and defence and hold or capture prey.

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 clue to the diet of the mammal.
Among vertebrates and with respect to development or origin, two types of teeth are found:

i. True or **bony teeth.** This type of teeth is found among fishes, amphibians, reptiles and mammals with few exceptions. Lacking bony teeth are sturgeons, numerous teleosts including sea horse, a few amphibians, all turtles and modern birds; and among mammals, whalebone whales, South Americans scaly anteaters, and the adult monotremes. Edentates are New World mammals include sloth, armadillo and giant anteater they are either toothless or else have degenerated teeth, without enamel.

ii. Keratinized or **horny teeth.** These types of teeth are derived from the skin epidermis and later 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). More details in chapter one.

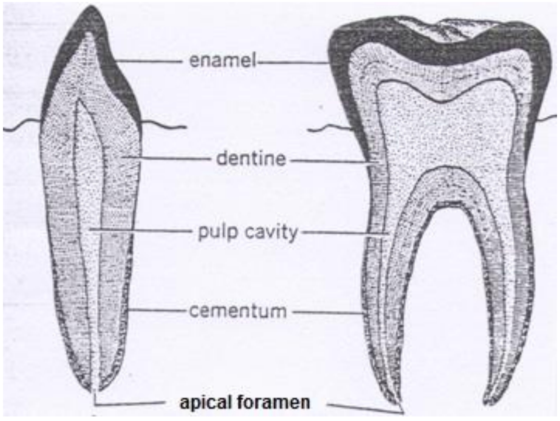
Structure of true tooth

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. The **cusps** are tiny, raised peaks or ridges on the surface of crown (Fig. 10). Three hard tissues compose the tooth: enamel, dentin and cementum.

Enamel. It is the hardest substance in the body and forms the surface of the tooth **crown only**.

Dentin. It resembles bone in chemical composition but it is harder. It lies beneath the surface of enamel and cementum and forms the walls of the pulp cavity from all sides.

Cementum. Like bone, it has cellular and acellular regions. Cementum rests upon the dentin and grows in layers on the surface of the **roots only**.



A B

FIGURE 10: Tooth structure. A- Tooth with single root, B- tooth with two roots.

Methods of Dentition in Vertebrates

Teeth are confined to the jaws in crocodilians, fossil toothed birds and mammals, while in amphibians and other lower vertebrates they also distributed and developed on other bones, such as vomer, palatine and pterygoid bones and parasphenoid, and even developed on gill arches.

As mentioned before, the arrangement of teeth in vertebrates is termed **dentition**. Teeth show variation in arrangement among the groups of vertebrates, as shown in the following methods of vertebrate's dentition:

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

i. Homodont dentition. Generally, in most vertebrates other than mammals, all the teeth are similar in general appearance, shape and size, throughout the mouth. In certain mammals such as toothed whales, dolphins, porpoise and armadillos, teeth become secondarily uniform or homodont.

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. Teeth of some teleost fishes and crocodiles are inclined to be varied in size and shape.

Heterodont teeth are distinguished into several types known as: **incisors, canines, premolars** and **molars.** This differentiation depends upon the nature of food eaten and the manner of securing it.

2. Teeth attachment. The manner of attachment of teeth at their bases with the jaw bones varies throughout vertebrates (Fig.11):

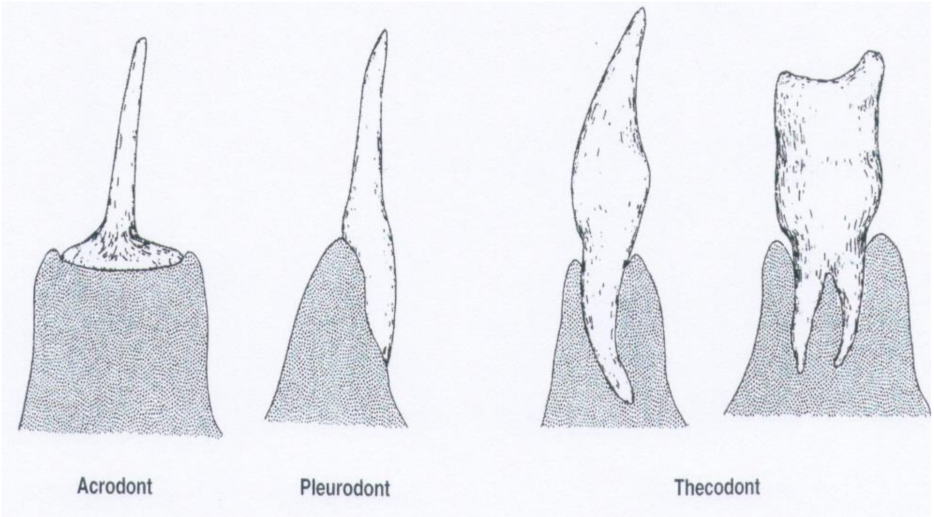


FIGURE 11: Variation in the relationship of vertebrate's teeth to jaws.

i. Acrodont dentition. It is the simplest method of attachment. The tooth is not directly attached to the jaw cartilage or bone but its base is embedded in the tough, fibrous, mucous membrane which cover the jaws**.** Acrodont teeth are attached either at the outer surface of the jaw or, as shown, at the summit. Most teleost, sharks, skates, rays and snakes have this manner of teeth attachment**.**

ii. Pleurodont dentition. In this condition, common to urodeles, anurans and lizards, Teeth are attached to the inner side of jaw bone by their base as well as one side.

Acrodont and pleurodont teeth are rootless, so that nerves and blood vessels enter the pulp cavity along lateral side.

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 and fossil or extinct toothed birds. The sockets are deepest in mammals.

3. Teeth replacement or succession. According to their permanence or 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. It has been estimated that an elderly crocodile may have replaced its front teeth 50 times.

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**. They usually erupt after birth, but in guinea pigs, bats and others, they are formed and shed even before birth. In human milk teeth consist of: incisors, canines and molars, but no premolars. Later milk teeth are replaced by the **permanent teeth** which last throughout the life, if lost they are not replaced. Permanent teeth consist of a second set of incisors, canines, premolars and molar, where premolars have no predecessors. Eruption of tooth number 8, the last molar, is delayed in higher primates, **wisdom tooth**, and sometimes imperfect, unerupted or missing.

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

Kinds of teeth. As already mentioned, 4 types of teeth occur in mammals: incisors, canines, premolars and molars.

i. Incisors. These are the front teeth borne by the premaxilla in upper jaw and tip of dentaries in lower jaw. They are single-rooted, monocuspid and long. They are adapted for seizing, cutting and biting.

ii. Canines. A **single** canine tooth occurs in each half of each jaw, just outside the incisors. Upper canines are the first teeth on maxillae. Canines are generally elongated, single-rooted and with a conical sharp monocuspid crown. They are meant for piercing, tearing and offence and defence.

iii. Cheek teeth. Canines are followed by **premolars,** which in turn are followed by **molars.** Both types are collectively called **cheek teeth**. Their crowns have broad surfaces with ridges and tubercles meant for crushing, grinding and chewing. Premolars usually have two roots and two cusps.

Dental formula

In mammals, number of teeth varies in different species. However, surprisingly enough, 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 a sort of 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. A typical mammalian dentition includes 44 permanent teeth which are shown by the dental formula as follows:

$$i\ 3/3, c\ 1/1, pm\ 4/4, m\ 3/3 \quad 2 = 44$$

To simplify further, it is customary to omit the initial letters, so that the same formula may be written as 3.1.4.3/3.1.4.3=44. When a certain type of tooth is lacking, it is indicated by zero (0). 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

Carnivores use their incisors and canines for cutting the flesh, while herbivores use their premolars and molars for grinding and chewing.

Unusual forms of teeth

The elongated unusual teeth are called **Tusks**, which are protrude out from the mouth of certain mammal species. They are: i. varied in number according to species ii. most commonly **canine** teeth, or **may be incisors**. iii. Present in male or in both sexes.

Elephant and extinct mastodon tusks are **i.** two modified upper incisor teeth (Fig.12). **ii.** Both female and male African elephants have tusks. In Asian elephants, most males possess tusks, while those of females are much smaller or nonexistent. In **walruses, i.** the two upper canines become large, **ii.** both sexes have tusks. walruses may use their tusks to penetrate ice above them to create breathing holes. Male walruses also use their tusks to defend their mates and territories from other bulls. In **musk deer, i.** the two long upper canines are elongated and protrude **ii.** males only have modified canines (Fig.12). Musk deer used them for self-defense. The **warthog** of Africa bears **i.** four upward curving tusks, modified canines **ii.** both sexes have four tusks (Fig.12). Males generally have both larger tusks and warts than females. Tusks are not solid but have a cavity. These are transformed **canines of both jaws**. These are used for digging in the soil for storage roots and tubers of the plants. **Babirusa** a speedy pig found throughout much of Africa, often **i.** has four tusks (Fig.12). The tusks grow vertically and curve backwards the forehead. The upper tusks passing through the skin of the upper lip and penetrate it. These dramatic features may grow to 30cm in length, **ii.** though they are usually absent or much smaller in females. The tusks, usually upper pair, are probably useful to the males for defense and fighting.

The **narwhal**, or narwhale (*Monodon monoceros*), **is a medium-sized toothed whale. It is also known as the "unicorn of the sea".** The animal's most distinguishing characteristicits: **i.** its 9-foot long tusk in their upper jaw and may be two (Fig.12), **ii.** it is found only in males. The narwhals have two teeth in their upper jaw, after first year of a male narwhal's life; its left tooth grows outward spirally, so the **narwhal males** are distinguished by a long, straight, helical tusk, where it rotate as a drill. **iii.** Some narwhals have up to **two tusks**, while others have none. This whale of the Arctic remains an oddity and its tusk one of the great unsolved mysteries of the marine world. But what thought about the functions of narwhal tusk or tusks are: for fighting, and they do not use their tusks for killing prey. Because the tooth is sensitive to temperatures and chemicals in the water so scientists also think it enables males to find food as well as females ready to mate. The presence of a tusk in only the male narwhals suggests that for these whales the tusk is a secondary sex characteristic.


Warthog


Mastodon


Male and female walrus


Babirusa


Male musk deer

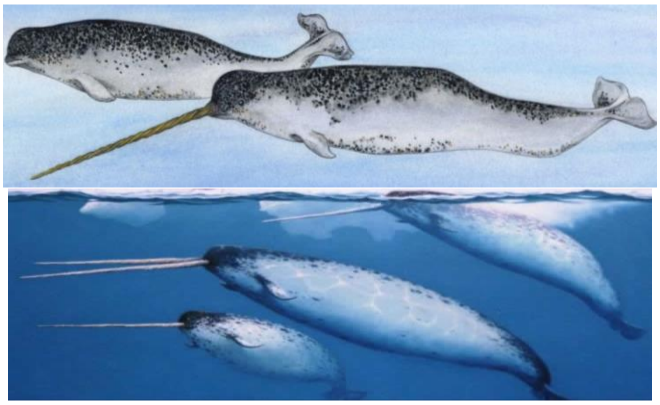

Narwhales

FIGURE 12: Unusual forms of mammalian teeth.

II. Alimentary Canal or Digestive Tract

Main organs and their subdivisions

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** or **anus**. 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.

In air breathing vertebrates, pharynx merges with oral cavity to form oro- or bucco-pharyngeal cavity. The cloaca is a common chamber into which the intestine, urinary ducts and reproductive canals discharge.

A **cloaca** is present in the adult stage of birds, reptiles, amphibians, many fishes, and lamprey, being notably absent in teleost, chimaeras, *Polypterus*, Sturgeons and others. Among adult mammals, also a cloaca is lacking except in monotremes and in the pika (American rabbit).

Comparative Anatomy of the Alimentary Canal and Digestive Glands

Amphioxus

Alimentary canal is a straight and complete tube from enterostome to anus. The midgut diverticulum is the sole digestive gland in amphioxuses (Fig.13).

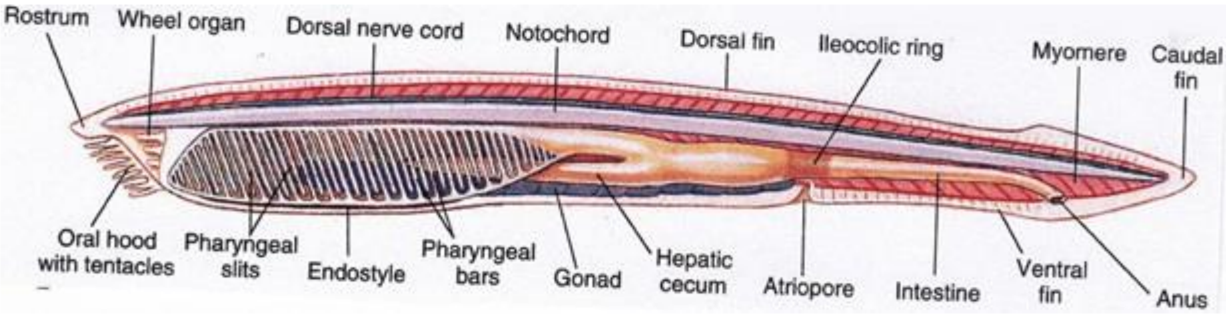


FIGURE 13: Amphioxus whole mount, showing the three regions of the digestive system: buccal cavity in addition to alimentary canal (enterostome to anus) and the digestive gland represented by midgut diverticulum or liver or hepatic cecum.

Enterostome. Posteriorly, the vestibule is closed by a circular ring-like vertical membrane, the velum. It is perforated by a central circular aperture, the **enterostome** which leading to pharynx behind.

Pharynx. It is a high and laterally compressed chamber forming the widest and largest part of alimentary canal. It occupies the anterior half of the body and remains suspended in the atrial or branchial cavity which surrounded it on all sides except the dorsal.

The lateral walls of the pharynx are perforated by more than 100 pairs of close, narrow and obliquely vertical openings called: branchial aperture, gill slits or gill clefts, through which the pharyngeal cavity communicated with the atrial cavity. The **atrium** is a cavity which surrounds the pharynx and the anterior part of the intestine. It opens to the exterior by the atripore. The gill clefts bear no gills.

Epipharyngeal groove is a prominent groove present mid-dorsally along the roof of the pharynx, and **endostyle** in its floor. Both these structures carry cilia which help in the process of feeding. Protochordates including amphioxuses, have endostyle, this organ and thyroid gland in adult agnathans and other vertebrates are two related organs have a role in iodine metabolism.

Esophagus. Posteriorly the pharynx opens into a short narrow and tubular esophagus having ciliated internal lining and leading into the gut or intestine. At the junction of the esophagus with the intestine is the large blind pouch, the **hepatic diverticulum** or **midgut diverticulum** or **liver.**

There is **no distinct stomach**.

Intestine. The gut or intestine is as long as the pharynx. It is undifferentiated into small and large intestine, the highly staining ring in its middle region it thought to be the separate part between small intestine and large one, hence called **ileo-colonic ring**. Its internal epithelial lining has several ciliated tracts. Its distal narrower part opens to outside by anus.

Anus. It is a small circular aperture controlled by sphincter. It opens at the base of caudal fin. It is worthy mention that amphioxus intestine has its own and separate opening, the anus because it has neither urinary nor genital ducts.

Digestive glands

Amphioxus lacks all true digestive glands: salivary glands, liver and pancreas. The long blind cecum or diverticulum, which comes off the alimentary canal at the junction of esophagus with intestine, is called liver or midgut diverticulum does the function of the liver. No gall bladder exists in the amphioxus.

Lamprey

An alimentary canal consists of: pharynx, esophagus and undifferentiated slightly curved intestine lead to the exterior by cloaca. No evident stomach.

Pharynx and **esophagus.** In adult lamprey (Fig.14) a very specialized condition occurs which has no parallel in other vertebrates. Buccal funnel leads to two tubes: a dorsal esophagus and a ventral pharynx. The pharynx ends blindly and is entirely concerned with respiration. At the entrance to the pharynx is a valve-like velum. In ammocoete larva and the larval stage and adult hagfishes the condition is much as in other vertebrates and the esophagus merely extends posteriorly from the pharynx.

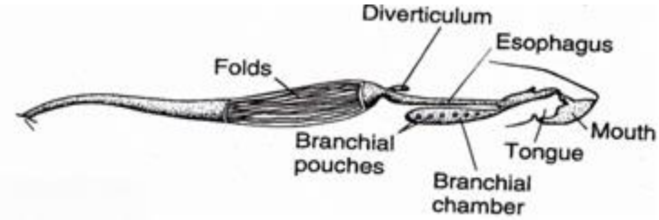


FIGURE 14: Alimentary canal of adult lamprey, see how buccal funnel leads to two tubes: dorsal esophagus and ventral pharyngeal or branchial chamber.

Intestine. It is short, straight and undifferentiated. In larval lamprey, a prominent longitudinal fold, the **typhlosole**, as a blind fold, projects from one wall of the intestine into its lumen. The typhlosole is a site of hemopoiesis, blood formation, in the larva, but it also increases the surface area available for absorption. In the adult lamprey, the typhlosole is generally lost and is replaced by numerous longitudinal folds in the mucosal wall, which dramatically increase the intestinal absorptive area. Intestine terminates in an anus.

Digestive glands

Three types of glands have role in digestion: pair of buccal glands; liver and patches of cells comparable to pancreatic acini.

Buccal glands. The adult lamprey is marine and parasitize on fishes, have become a major pest in the North American Great Lakes. for it attaches itself to the body of the fish and rasps off the flesh by its teeth. The buccal glands of lampreys develop during metamorphosis and occur in the adults of both the parasitic and non-parasitic species. Their secretions contain anticoagulant called lamphedrin, presumably prevent coagulation of blood sucked from the host.

Liver. The liver of cyclostomes or agnathans is usually small. In the lamprey it appears to be single-lobed, but in the hagfish it consists of two halves, this representing the most typical condition. The ducts from these two parts in the hagfish open separately into the gall bladder. Neither gallbladder nor bile duct is present in an adult lamprey. The ammocoete larva, however, possesses both.

Pancreas. In living agnathans, including lampreys, there is no definitive pancreas, the exocrine and endocrine components are spatially separated, and many exocrine cells remain in the intestinal epithelium.

Dogfish

The alimentary canal is divisible into: pharynx, stomach, intestine which terminates into cloaca (Fig.15). Intestine is short, wide and curved posteriorly. Scientists are varied in their opinions about the differentiation of the intestine. The ancient reports intended toward the differentiation of the intestine into small and large intestine and the former part subdivided into duodenum and ileum, while short and narrow rectum represents the large intestine. But hence the small intestine in dogfish is wider than large intestine and this case reverse the reality of division of intestine to small and large parts in accordance to their diameters, thus new reports consider the intestine of fishes is undifferentiated.

Stomach. There is practically no distinction between esophagus and stomach in fishes, and the longitudinal folds of the former may extend for some distance into the stomach. A considerable variety of stomach shapes may be observed in fishes. Some are simple, straight tubes without any digestive function, as in dipnoi, chimaeras and a number of teleost. In others as *Polypterus*, the cardiac and pyloric limbs have fused along the line of the lesser curvature so that the stomach appears much as blind pouch.

In elasmobranch which the dogfish is attributed the J-shaped stomach is the dominant type, many other fishes have similarly shaped stomachs. The **cardiac limb** is wider and longer than **pyloric limb**. The lining of the pyloric stomach is smooth, rough and slightly folded distally. At the end of the pyloric limb is present a strong circular muscle band, called pyloric valve or **pyloric sphincter**.

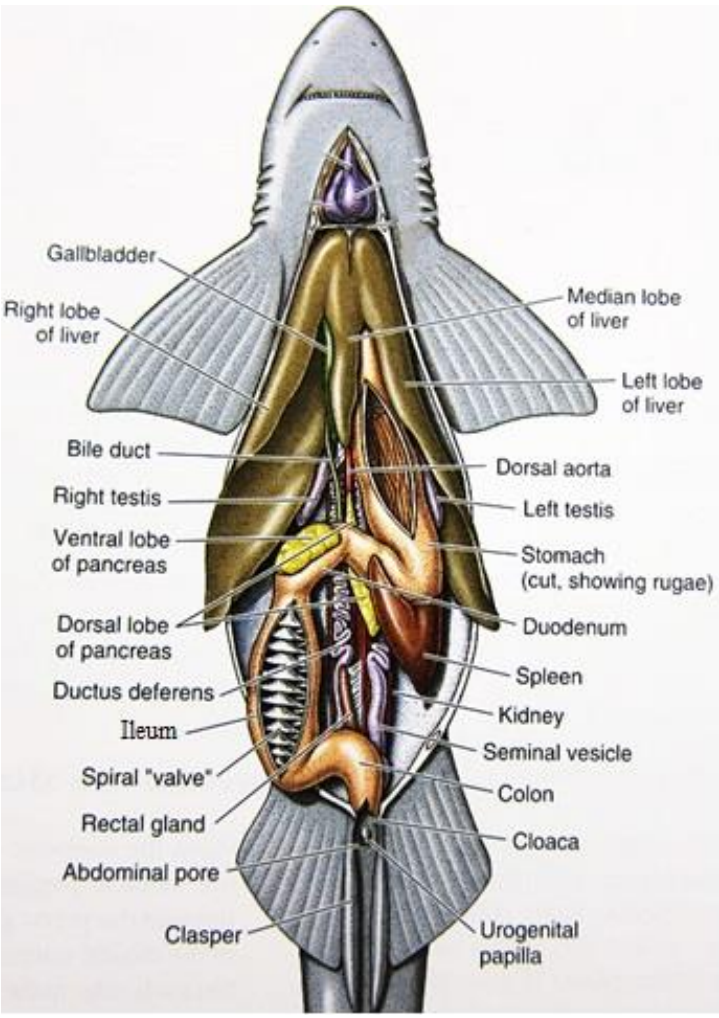


FIGURE 15: Alimentary canal and digestive glands.

Intestine. Beyond the pyloric sphincter, the alimentary tube bends backwards to pass in an almost straight intestine terminates into cloaca between the two pelvic fins. Externally, the intestine increase considerably in width as it passes backwards, though there is very little demarcation into regions until the narrower end, the rectum. However, some authors consider the narrower beginning of the intestine as duodenum, since it receives dorsally the bile duct and ventrally the pancreatic duct. In same time they named the other wider part of intestine ileum.

On the surface of the capacious part of the intestine, in which some named it ileum, are present the marking of **spiral valve** which can better be seen if this part of intestine is longitudinally cut. These valves render the passage of food through the intestine which leads to increasing the amount of time the bolus spends in the intestine and prolonging digestion and increase the digestive and absorptive area of the intestine. Spiral valves present in sharks, skates and rays slow the transit rate of digesta through the gut and provides increased surface area for the absorption of nutrients (Fig.15).

In dogfish and other sharks, the finger-shaped **rectal gland** empties into the short, narrower posterior part of the intestine (Fig.15). However, this gland has no digestive function. It extracts and excretes excess sodium chloride from the blood.

Digestive glands.

Buccal glands. Like agnathans, fishes do not possess salivary glands. Salivary glands appear primarily as unicellular mucous glands in the epithelium of the buccal cavity that secrete mucus to moisten the food.

Liver. The liver of the fishes is lobed and relatively large. Some are of economic value because of the oil and vitamins which they contain. In dogfish the liver is a large bilobed organ occupying much of the body cavity. The left lobe is frequently shorter than the right which is subdivided anteriorly to form a smaller median lobe. The gallbladder is usually almost completely embedded in the small median lobe. From the gallbladder arises the bile duct, which in turn enters the posterior end of anterior, narrower part of intestine, which called duodenum by some authors, on its dorsal side.

Pancreas. It 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.

Although it has no physiological relation with alimentary canal the spleen may note here, attached as a fringe to the pyloric limb of the stomach.

Frog

The alimentary tract of frog is moderately curved and coiled, including the organs: short esophagus, glandular stomach and differentiated coiled intestine. Small intestine subdivided into duodenum and ileum, while large intestine is represented by wide and short rectum which terminates into cloaca (Fig.16).

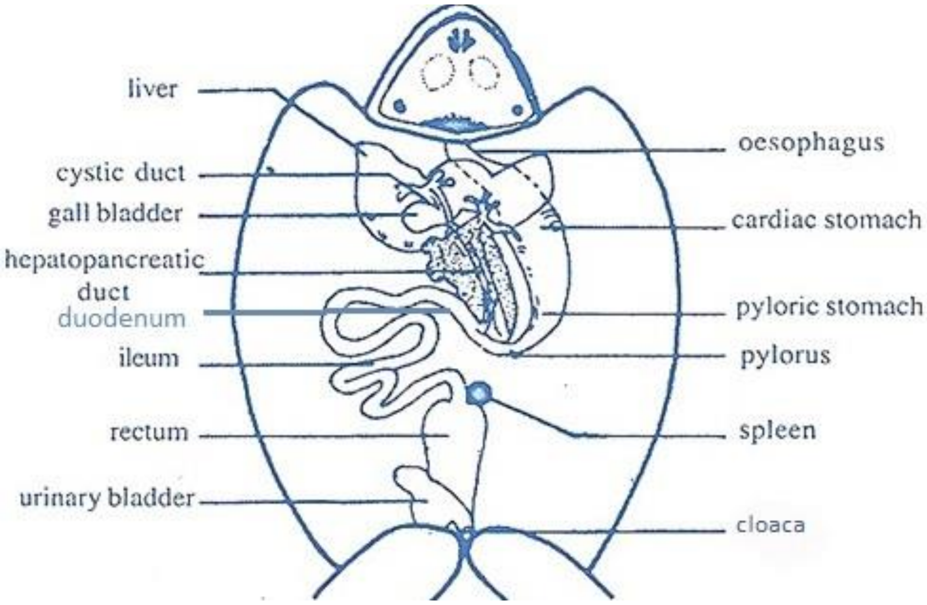


FIGURE 16: Frog digestive system.

Stomach. It is a muscular, thick-walled and slightly curved sac. Its lining epithelium is folded longitudinally to provide for expansion as the food accumulates, glands are present. Stomach has two ends: a **cardiac**, into which the esophagus opens and a **pyloric** end, which leads to intestine. The termination of the stomach is marked by **pyloric constriction**.

Digestive glands

Buccal glands. Like fishes, amphibian have solitary mucus secreting cells to moisten the food. Amphibians with protrusible tongues have lingual mucous glands to make the tongue sticky to aid in capturing the prey. Lingual glands absent in caecilians.

Liver. It is a large organ consisting of two main lobes of which the left is again subdivided into two. Between the two main lobes lies the spherical **gall bladder** from which arises the bile duct, which also receives the supplementary ducts from the main lobes of the liver. On its way backwards to the duodenum, the bile duct passes through the substance of the **pancreas** which lies in the mesentery between the stomach and duodenum in form of two lobes: dorsal and ventral. In this region pancreatic duct opens into bile duct to form a short **common hepato-pancreatic duct** pours in the duodenum.

The **spleen** is a dark-red spherical body attached to the mesentery between the ileum and rectum.

Lizard

The alimentary canal of lizard is moderately curved and coiled, including the organs: esophagus, glandular stomach and differentiated coiled intestine. Small intestine subdivided into duodenum and ileum, while large intestine is represented by wide and short rectum which terminates into cloaca (Fig.17).

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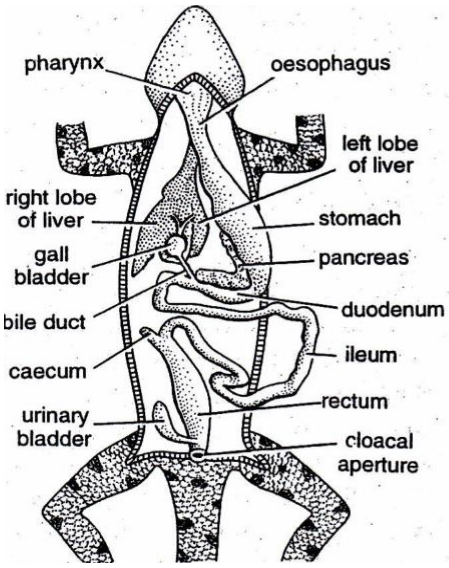


FIGURE 17: Lizard alimentary canal and digestive glands.

Stomach. It is a thick-walled, somewhat dilated tube lying in the left side of the body cavity behind the heart and dorsal to the liver. Snakes and lizards have long, spindle-shaped stomachs in correlation with their elongated and narrow body shape. It has two ends: a **cardiac**, into which the esophagus opens and a **pyloric** end, which leads to intestine. The termination of the stomach is marked by **pyloric constriction**. The mucous membrane is thrown into longitudinal folds.

It is worthy mention that crocodiles, among other reptiles, have stomach similar to that of birds, where it includes two parts; proventriculus and gizzard. The first is powerful and muscular, the other stomach is the most acidic, it can digest mostly everything from their prey, including bones, feathers, and horns.

Intestine. It is curved and coiled muscular tube differentiated to **small** and **large intestine**, in accordance to their diameter. The small intestine is divisible into short and slightly curved anterior region, the **duodenum** and the rest long, looped part **ileum**. The mucous membrane of the small intestine is also thrown into longitudinal folds. The large intestine, which is represented by **rectum**, is much wider than small intestine and at their junction there is a short **rectal cecum**. Reptiles, then, are the first vertebrates to have true rectal ceca. Intestine terminates with cloaca.

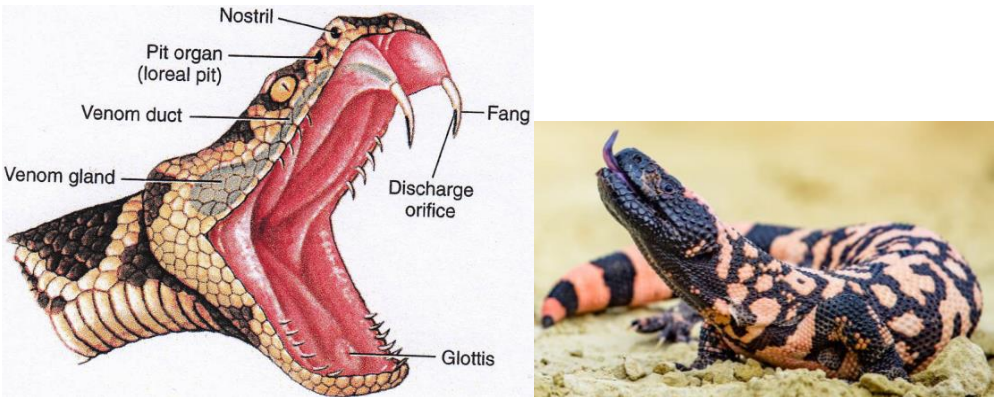
Digestive glands.

Buccal glands of lizards and snakes facilitate swallowing and they may play a part in capturing prey and in digestion. They are usually named according to their location:

i. Labial glands open into the base of the lips.
ii. Palatine glands open onto the palate.
iii. Lingual glands open onto the tongue.
iv. Sublingual glands open under the tongue.

Palatine gland secretes a sticky mucus covers the tongue and helps many lizards like chameleon to capture its prey.

In poisonous snakes and lizards, certain buccal glands serve as dangerous organs of defence. In poisonous snake, the labial glands modified to poisonous glands which secrete venom, the duct of each gland opens into the cavity or groove in the poison fang (Fig.18). In the lizard Gila monster, *Heloderma sp.*, of Mexico and Arizona, the sublingual glands modified to poison gland produce venom injected through grooves in the teeth of the lower jaw that paralyzes prey, it must chew their victim in order to inject poison. In marine turtles and crocodiles, oral glands are poorly developed.



A B

FIGURE 18: A. Snake venom gland, its duct opens in cavity in the poison fang. B. Gila monster, *Heloderma sp.*

Liver. It is large**,** dark red in color, situated dorsal to stomach and consists of two lobes. A small rounded **gall bladder** is embedded in its right lobe. The alkaline bile secreted by the liver and stored by gall bladder is poured into duodenum through **bile duct.**

Pancreas. It is an elongated whitish structure lying in the mesentery between stomach and duodenum. Its alkaline pancreatic juice is drained into duodenum by numerous ducts or, in some lizard species, the bile duct receives these pancreatic ducts and opens as **hepatopancreatic duct** at the beginning of the duodenum.

Spleen, not a digestive organ, is a small, dark red and lies close to the stomach

Birds

The digestive tract of birds is short with respect to the size of bird and adapted for rapid and efficient digestion, thus it is highly modified due to loss of teeth and areal mode of life. Its successive components are: esophagus, stomach, small and large intestine.

Pigeon's alimentary tract and digestive glands are shown in Fig. (19).

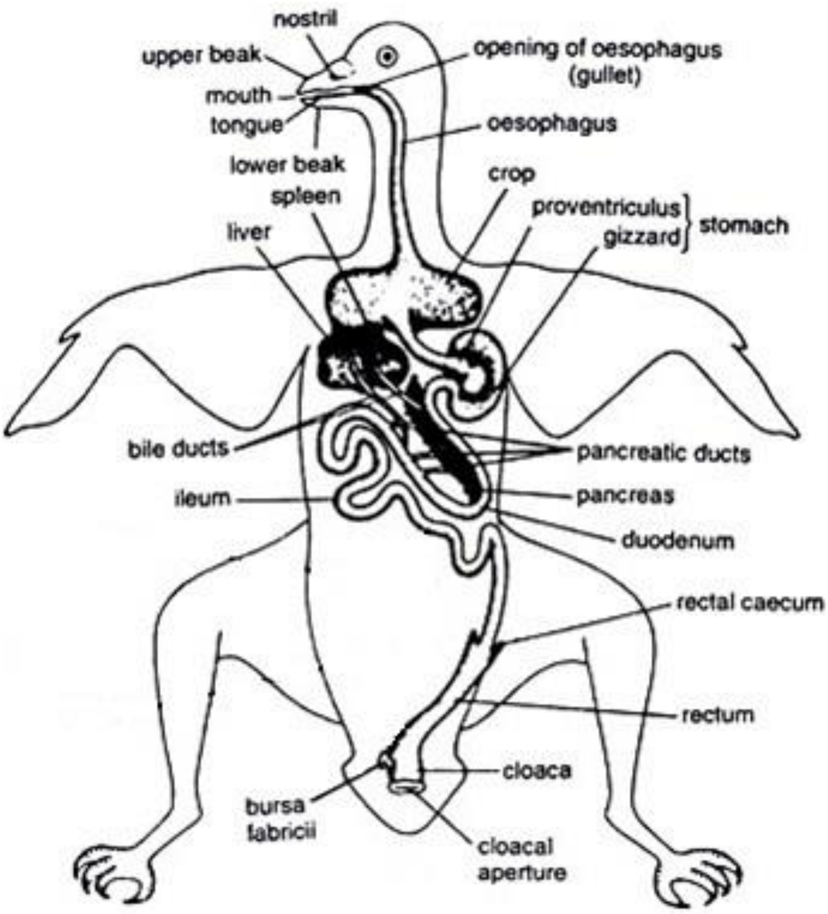


FIGURE 19: Pigeon digestive system.

Esophagus. It is a long wide, distensible and thick-walled tube. It runs through the neck side by side with the trachea. In grain-eating birds, as well as birds of prey, either the esophagus forms a large sac, or a ventral pouch-like outgrowth, the **crop**. Crop has important role in birds' life:

i. It is primarily useful in permitting the bird to secure an abundance of food in a hurry and short period, thus lessening the time during which it is danger from enemies. **ii.** It also enables the bird to compete with others for a limited amount of food. **iii.** The main another benefit of this reservoir is to moisten and soften the hard food-grain to be easily broken down and digested later as a compensation for teeth loss. **iv.** The crop also plays an important role when in raising baby chicks. Parent bird species including **Psittacines** (hook-billed birds such as parrots, cockatiels, and parakeets) and **Passerines** (such as canaries, finches), regurgitate their food from their crop to feed their chicks. For growing birds, it is important to ensure young chicks always have food in their crops. **v.** In pigeon it has a further use in that during the breeding season it becomes softer and secretes a milk-like substance, in both sexes, called **"pigeon milk"** on which the newly hatched pigeons are fed. It is formed by the degeneration of the epithelial cells lining the crop. It is regurgitated into the mouth of the young birds until they are old enough to manage a grain-diet like their parents. Pigeons are the only animals apart from mammals to do anything like this. Interestingly the production of pigeon milk is controlled by the hormone prolactin which is the same hormone that controls the production of milk in mammals. The crop also contains mucus-secreting glands. Beyond the crop, the esophagus again becomes thick-walled, as it enters the stomach.

Stomach. In accordance with the lack of teeth and the type of food eaten by birds, the stomach of most of them has been modified greatly for trituration. It has become differentiated into two regions: the **digestive proventriculus** and the larger **mechanical stomach** or **gizzard** and also called **ventriculus** which represent as a pyloric part of stomach.

i. Proventriculus. It is a small but thick-walled sac, externally appearing like a slight dilation of esophagus. Its thick mucus lining secretes the gastric juice, hence called glandular stomach.

ii. Gizzard. It is large, hard, laterally compressed and has a shape of biconvex lens. Its wall is thick and powerfully muscular, so called muscular stomach, performs the same role in birds that jaws and teeth perform for us. It is bluish-red in color, and in the center of each of its lateral surfaces there is a tendon, from which the fibers of the gizzard muscles radiate. The small and narrow lumen is lined by epithelium which is thick, rough, horny and yellow or green in color. The cavity of gizzard always contains grit or small pebbles (stones) called gastroliths swallowed by the bird. These stones help the gizzard in grinding or triturating the food. The opening of the gizzard into small intestine is guarded by a sphincter, called **pyloric valve** or **pylorus.**

Intestine. It is differentiated into long coiled **small intestine** and short **large intestine**. Small intestine comprises an anterior **duodenum** and posterior **ileum**. The duodenum leaves gizzard dorsally, so that the pyloric opening of gizzard into duodenum lies close to the cardiac opening of proventriculus into gizzard. The duodenum forms a distinct U-shaped loop enclosing the pancreas between its two limbs. The rest of the small intestine, or ileum, is a very long and extensively convoluted tube of uniform diameter. The villi along the lining of small intestine increase the surface of absorption.

The slender ileum passes without any change of diameter into the large intestine. The junction of two is externally marked by the presence of a pair of small conical, blind pouches, the **rectal** or **colic ceca**, which probably absorb some water from the food. Colic ceca are lacking in parrots, woodpeckers and few others, but most birds have one or two such structures. In certain birds, such as ducks, geese, turkeys, ostriches, etc., the colic ceca attain a very large size and their lining may even bear villi. The large intestine or rectum is relatively short tube, because the faecal matter is relatively small. It terminates in cloaca.

Digestive glands

Buccopharyngeal cavity is rich in mucous and salivary glands, of these are: The **anterior** and **posterior sublingual glands** and the **angle glands**. Their secretions easy the process of swallowing and also secrete ptyalin enzyme.

In addition to the microscopic glands along the epithelial lining of the alimentary canal, there are two main large glands: liver and pancreas.

Liver. It is relatively large, compact, dark-red and bilobed, consisting of larger right lobe and smaller left lobe. There are two **bile ducts**, one from each liver lobe and both are open directly in the duodenum, where common pigeon lack gall bladder may be as adaptation f or flight, though it presents in some birds and even in some species of pigeon. The liver secretes bile.

Pancreas. It is a compact reddish gland, lying between the two arms of the duodenum into which it discharges its secretion. There are three short **pancreatic ducts**, all opening in the distal arm of the duodenum. The pancreatic juice contains several enzymes.

Spleen is a small oval and red body attached by peritoneum to the right side of the proventriculus. It has no digestive function.

Rabbit

The alimentary canal of rabbit (mammal) is more specialized than other vertebrates. It is long and coiled tube with variation in diameter of its organs included: esophagus, stomach, intestine terminates in anus (Fig.20).

Esophagus. It is a long, narrow, elastic and muscular tube. It runs straight down through the neck, dorsal and parallel to the trachea. On the way to the stomach it must passes through the diaphragm after piercing it. Immediately after its entry into the abdomen it opens into the stomach through its concave side.

Stomach. It is the broadest part of the alimentary canal, bag-shaped and takes transverse position to correlates with the wide trunk. It is situated on the left side of the anterior part of the abdominal cavity. It has a smaller inner concave surface and large outer convex surface, known as the **lesser** and **greater curvature** respectively. The larger anterior portion of the stomach is known as **cardiac portion** and the smaller posterior part is **pyloric portion**. The expansion to the left of the cardiac portion is the **fundus**, which is formed by the greater curvature. The end of the pyloric stomach is marked externally by a circular groove, the **pyloric constriction.** Internally, this constriction has the distal opening of the pyloric stomach into duodenum, called **pylorus**, which is guarded by a circular **pyloric sphincter valve**.

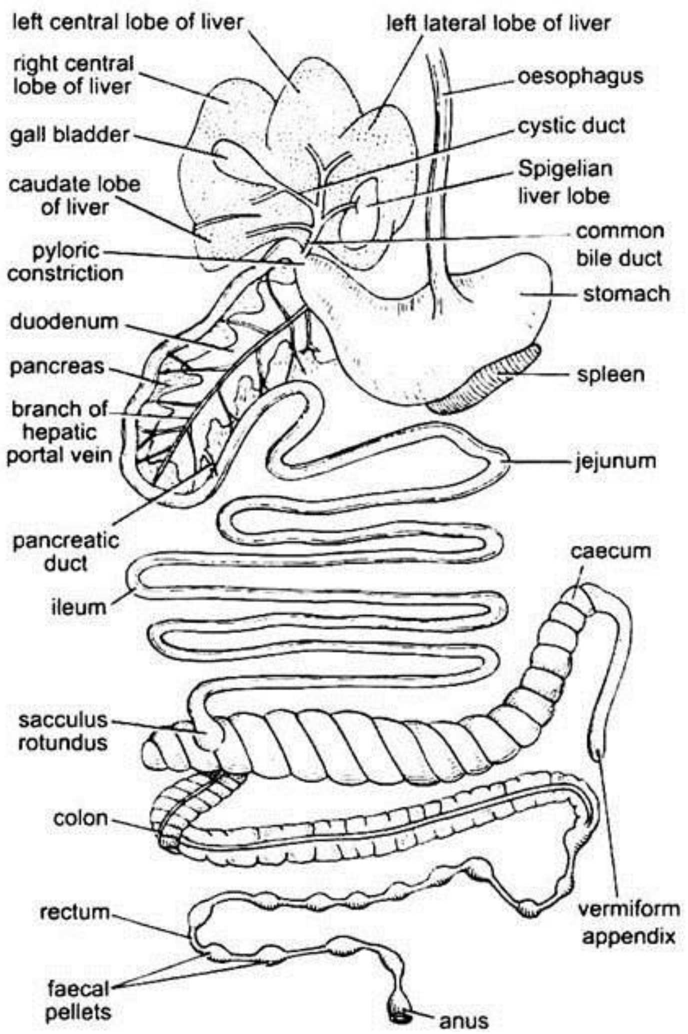


FIGURE 20: Rabbit alimentary canal with related digestive glands, liver and pancreas.

Intestine. The intestines of mammals, including rabbit, are more elaborately developed than those of other vertebrates. The coiled long part is **small intestine,** which in turn made up of three regions: **duodenum, jejunum** and **ileum**. Jejunum is a Latin word meaning empty. This part of intestine is usually found to be empty soon after death. The duodenum is in the form of a U-shaped loop. Following the duodenum is the jejunum and this is followed by the rest of the small intestine, the ileum. Both jejunum and ileum are not well differentiated from each other in the rabbit.

The distal end of the ileum is expanded to form a small, rounded and witish sac, the **sacculus rtundus**. It opens to the cecum through an **ileo-cecal valve.**

Cecum. This part of the intestine is recognized by its large size, thin wall and has a spiral constriction which marks the internal partitions of the pouch-like dilations of the cecum. The cecum ends by a thick-walled, smooth and finger-like **vermiform appendix**. The cecum of the rabbit is long, a feature of herbivores, but is much smaller in carnivores.

Hyrax (a hyracoid) much related morphologically to rabbit, and feeds on seeds, fruits and leaves, has in addition to rectal cecum another bicornuate cecum farther along on the intestine.

Large intestine is formed of colon and rectum. The **colon** extends from the sacculus rotundus is markedly sacculated to delay the passage of food and lead into the narrower **rectum** which extends into the pelvis to end into the **anus**. Among the mammals only the monotremes and pikas (a lagomorph) possess a cloaca. The rectum usually contains faecal pellets.

Digestive glands.

Salivary glands. Mammals have many small mucous glands on the palate and tongue that secrete mucus. For the first time in vertebrates, mammals usually have three pairs of large true salivary glands which includes: parotid, submandibular and sublingual glands. In rabbit another pair infraorbital gland present (Fig.21). The parotid glands lie below and little in front of the ear pinna. The submandibular glands lie in the posterior region of the lower jaw (mandible). The sublingual glands lie under the tongue. In whales, the salivary glands have secondarily become reduced. Salivary glands secrete saliva. Saliva, alkaline fluid, contain: water, salts, mucin and an enzyme ptyalin. Salivation is activated by the sight, smell, thought, talk and by presence of food in the buccal cavity.

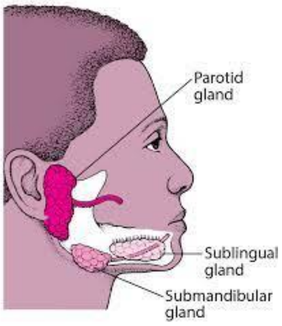


FIGURE 21: Mammals' three pairs of salivary glands, named according to their location.

Liver. It is a very large, dark red in color and fits against the diaphragm by its convex anterior surface. 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** which is an elongated thin-walled sac. The **bile duct** opens into the proximal limb of the duodenum near the pylorus.

Pancreas. It lies between the two limbs of duodenal loop. It is somewhat diffuse, creamy in color and its **pancreatic duct** opens into the beginning of the distal limb of the duodenum.

The spleen is not digestive organ. It is a dark, red elongate body which lies close to the posterior cardiac portion of the stomach.

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. The nonglandular region of the stomach is lined with: i. stratified epithelium; ii. devoid of gastric glands that in some species also may keratinized, while glandular parts of stomach lined by: i. simple and ii. glandular epithelium. Nonglandular stomach varies in size in different vertebrates especially mammals. It reaches its maximum size in ruminants, where their stomachs are often divided into several distinct muscular chambers (Fig.24), depending on their mode of nutrition. The first three chambers are modified esophagus and only the last one, abomasum is true stomach.

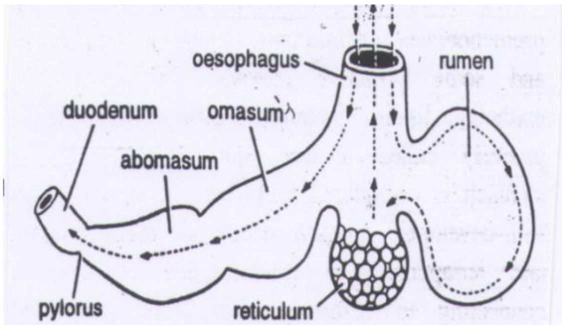


FIGURE 25: Stomach of ruminant or cud- chewing mammal, arrows indicate course of food.

Human stomach and some other mammals have only one true chamber stomach.

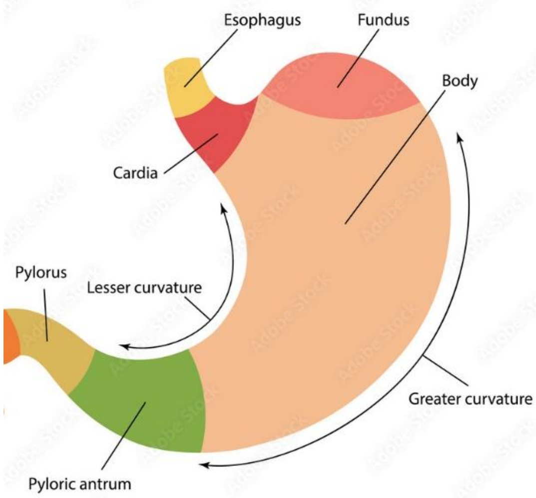


FIGURE 25: Human stomach, all its parts are glandular and lined by simple epithelium.