Introduction

Types of anatomy

Anatomy is the study of the structure of animals.

Anatomy of three types:

i. **Gross anatomy** is the study of animals body structures by naked eyes.

ii. **Microscopic anatomy (histology)** is the study of the fine structure of body organs by using microscope.

iii. **Comparative anatomy** is the study of similarities and differences in the body structure of animal species belonging to different animal groups.

Purpose of study of comparative anatomy

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

2. 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 what Darwin claimed in his theory **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).

Two major concepts of comparative anatomy

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

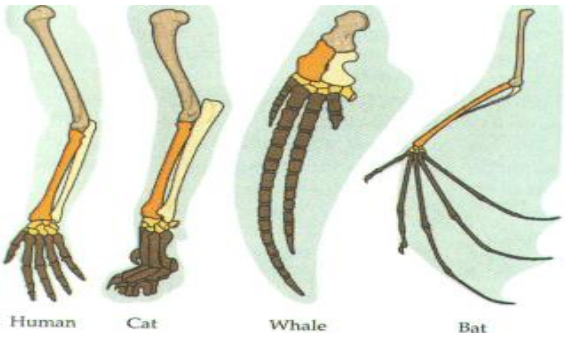
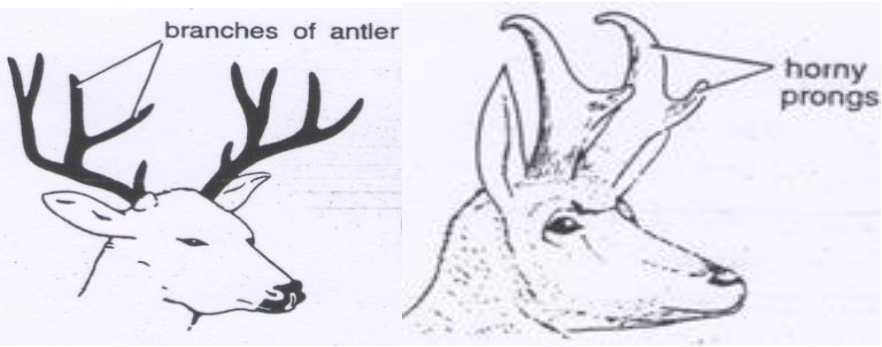


FIGURE 1: Forelimbs of different vertebrates are considered as homologous organs.

2. Analogous organs. These organs show same shape and perform same function, but differ in structure and origin because they evolved in a similar environment, and adapted for similar conditions. 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).



A B

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

Seven selected species for comparative anatomy

During this study **seven** chordates have been selected. Each selected chordate represents its group to compare between their various body organs and systems to reveal the similarities and differences between them.

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.

CHAPTER ONE
Integumentary System

This system includes the skin and its various derivatives. Skin which is the original part of this system. 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. 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**. Epidermis is generally distinguished into three regions.

Skin is the first line of defense

In addition to the general cover of the body, skin is also directly continuous with the mucous lining of mouth, rectum, nostrils, eyelids, and urogenital ducts. Macrophages, mast cells and lymphocytes present in dermis, all these properties make the skin a first line of defense in front of the entrance of microorganism, and pathogens. Dermatologists find that the skin offers a window to what is going on inside the body. The skin can show signs of an internal disease before the disease advances and becomes more serious.

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 epithelium). Hence epidermis is epithelial tissue, it lacks blood vessels, so nourishment take place through diffusion from underlying dermis, which is vascularized.

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).

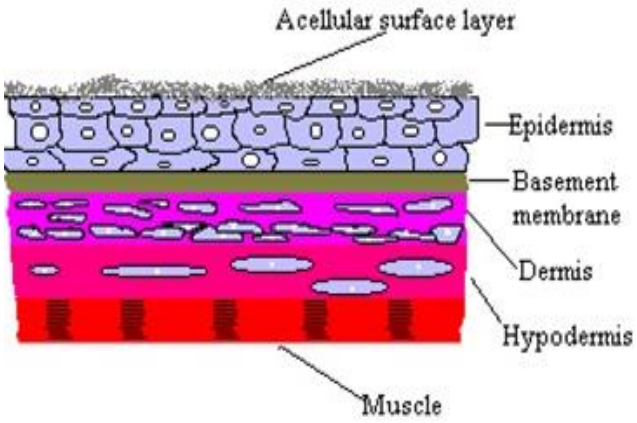


FIGURE 1: Basic plan or typical layers of chordate skin.

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. iii. mucous glands reduced or absent and other glands present. Most skin derivatives are derived from epidermis.

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 skin epidermis. 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 cannot survive in dry land.

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.

Four main variations between 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.

Dermal bones

Heavy bony plates were common in ostracoderms and placoderms (extinct fishes) and persist in some living fishes. Most amphibians lack dermal bones in their skin except, for vestiges of dermal scales found in a few tropical caecilian species. In reptiles dermal bones provide the armor of crocodilians, the bended skin of many lizards, and contribute to the shell of turtles. Dermal bone also gives rise to antlers, as long as to the bony core of true horns.

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).

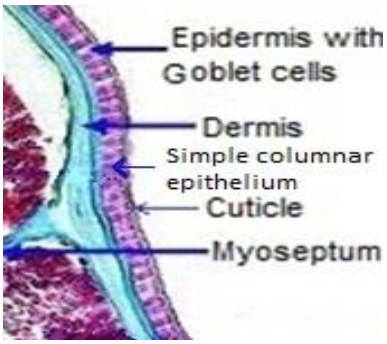


FIGURE 2: Vertical section through Amphioxus skin.

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.
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.
5. No scales.

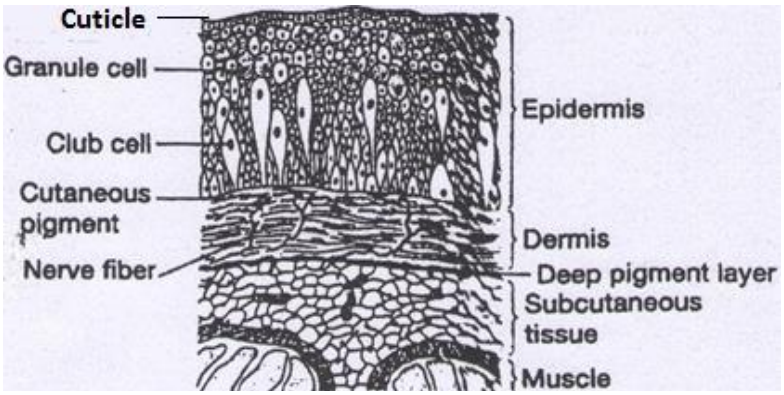


FIGURE 3: V.S. through the skin of lamprey.

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 is the presence of, at least, five types of **dermal scales** projecting above the surface. Of these cartilaginous fishes (elasmobranchs) have placoid scales (Fig.4A), other four types present in bony fishes (Fig.4B). 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.

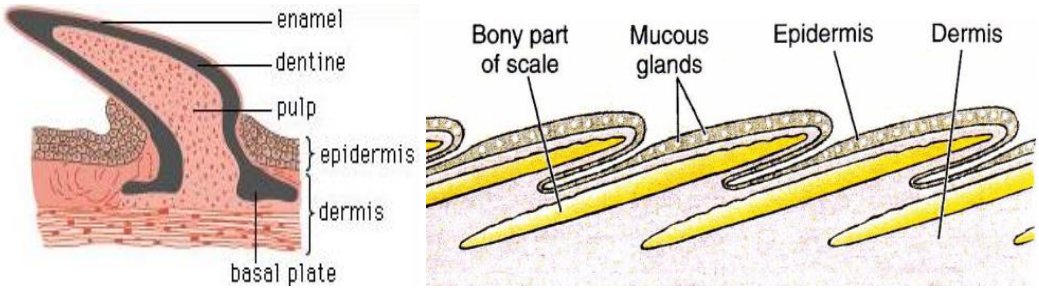


FIGURE 4: Vertical sections (V.S.) of skin of: A- cartilaginous fish, B- bony fish.

Amphibians

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

1. Amphibians are the first 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 are the lowest vertebrates having 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.1.5).
5. Chromatophores lie for the most part, between epidermis and dermis.

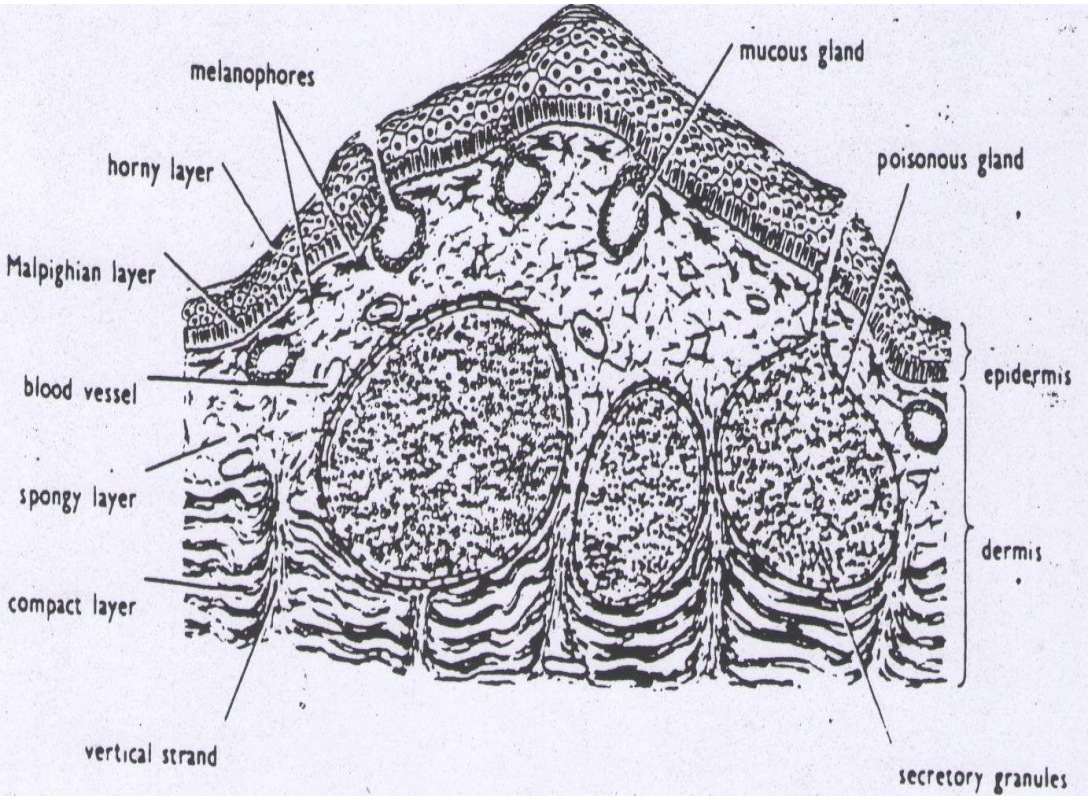


FIGURE 5: V.S. of frog skin.

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. Reptiles have no mucous glands.

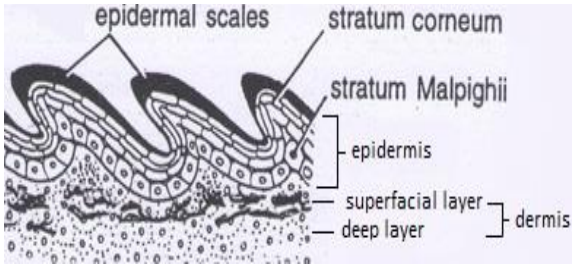


FIGURE 6: V.S. of lizard skin.

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 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.

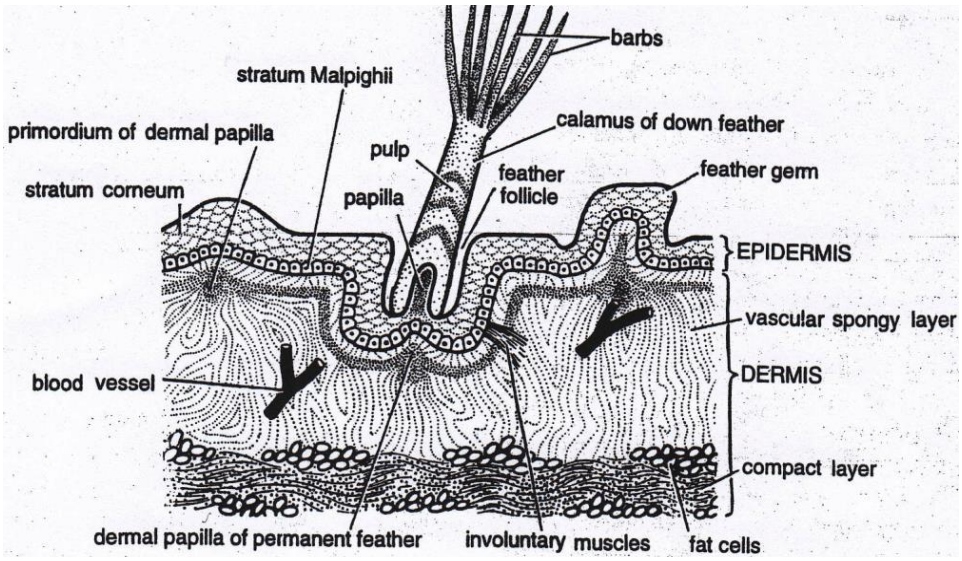


FIGURE 7: Vertical section of bird skin.

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 epidermis 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.

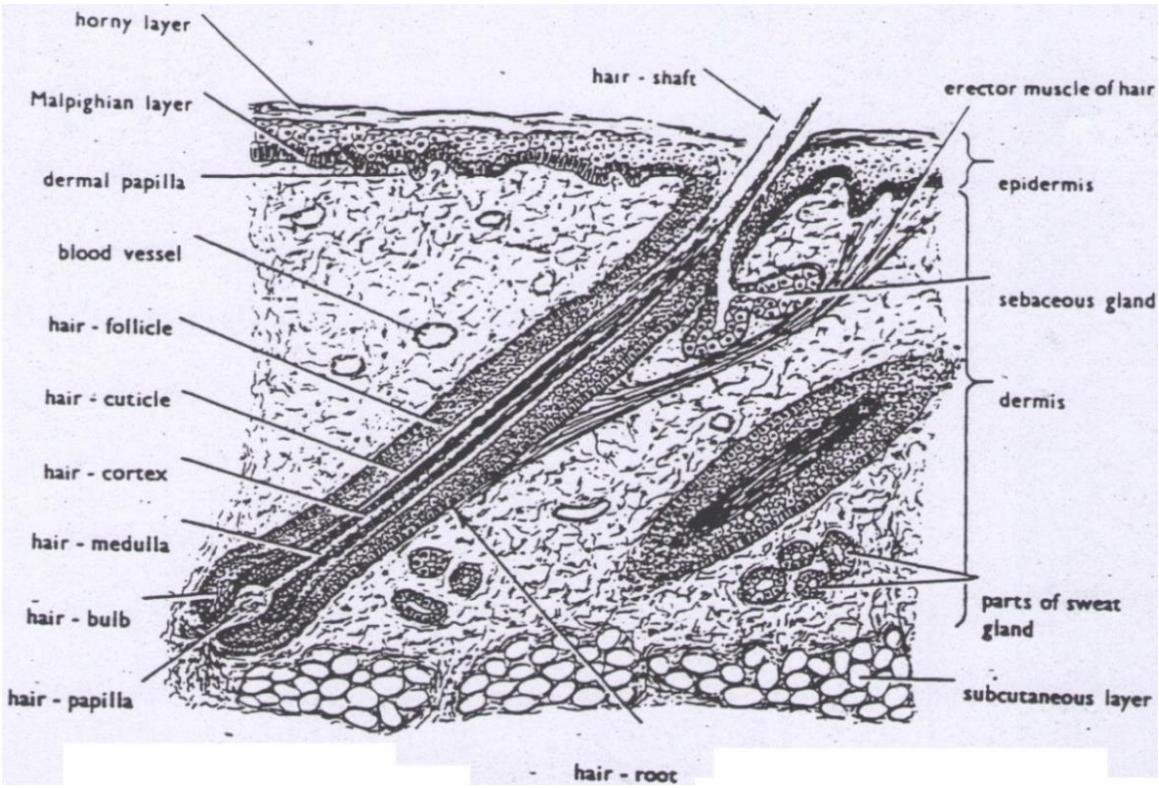


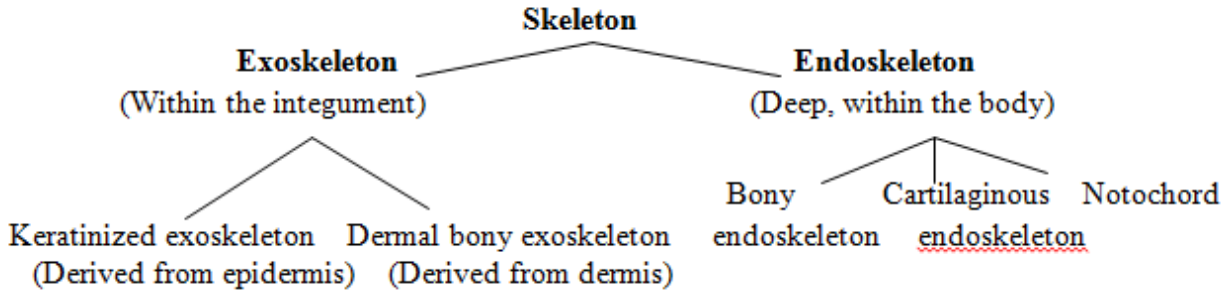
FIGURE 8: V.S. through the rabbit skin.

Three main groups of skin derivatives

Skin derivatives can briefly 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: scales, bills, feathers, claws, nails, hoofs, hair, horns.
3.Dermal bones. They are derived from the skin dermis, and remain within the integument, such as: dermal scales, dermal shells and plates, antlers.

Two body skeleton

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



Gathered 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 in detail to nine groups, instead to three main groups, to be easy to study:

I. Epidermal glands
II. Scales; Dermal Bony Plates and Armors
III. Epidermal or Horny Teeth
IV. Dermal Fin Rays
V. Digital Cornification
VI. Beaks or Bills
VII. Feathers
VIII. Horns and Antlers
IX. Hair and Its Modifications

I. Epidermal glands. According to structure, skin glands are of two general types: **unicellular** or **multicellular**, depending upon whether they consist of isolated cellular units or number of cells joined together to form the glandular element. The 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 basal layer of epidermis the stratum germinativum then 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 gland.

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.

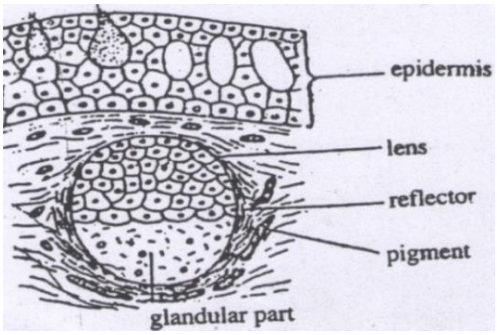


FIGURE 9: V.S. through the luminous organ (photophore) of bony fish.

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 paleognathae, 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. Sweating is one of the major mechanisms for cooling the body of many mammals. Horses can sweat up to 30 litres 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. 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 spiny scaly anteaters; 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.

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.

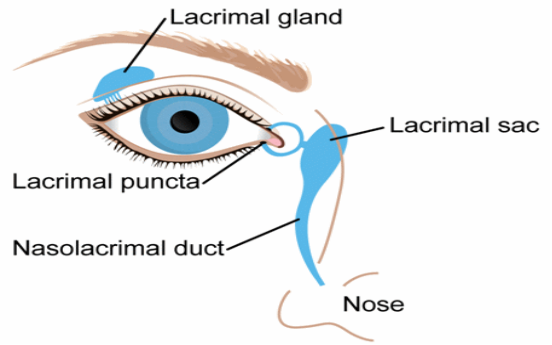


FIGURE 11: Human lacrimal apparatus.

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.

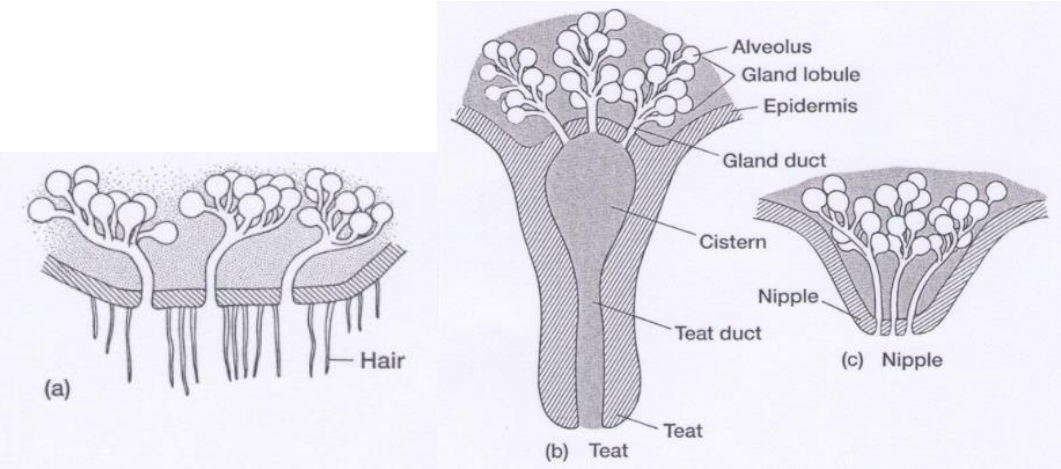


FIGURE 12: Longitudinal sections through the breast of mammals, showing three forms of mammary glands: (a). Mammary glands of monotremes; (b). Mammary glands of perissodactyles and artiodactyles, and (c). Mammary glands of marsupials and most placental mammals except perissodactyles and artiodactyles. 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 (Fig.13). 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.

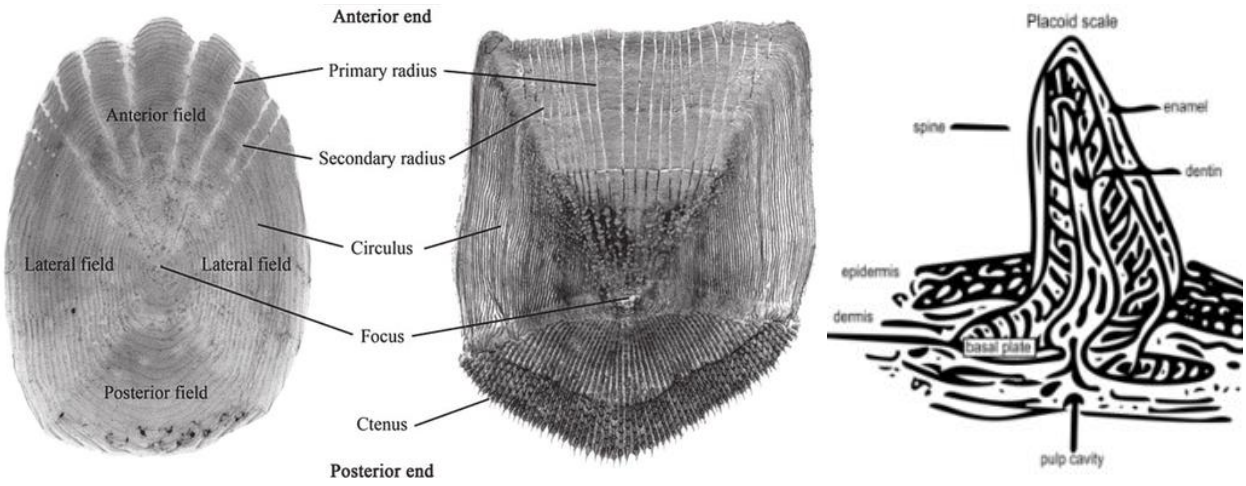


FIGURE 13: Varied types of fish dermal scales.

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.

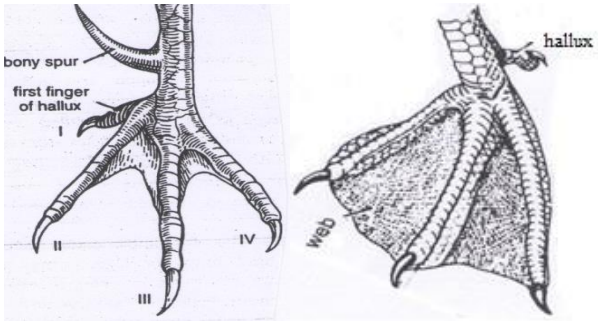
FIGURE 16: Dorsal and lateral scutes covered the turtle carapace.

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**, 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 in tegument 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 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.

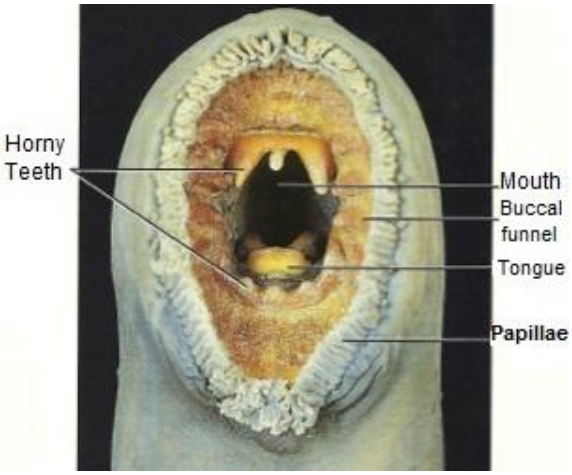


FIGURE 21: Horny teeth inside the buccal funnel of lamprey.

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

iii. Epidermal teeth in the form of horny plates are found in the 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.

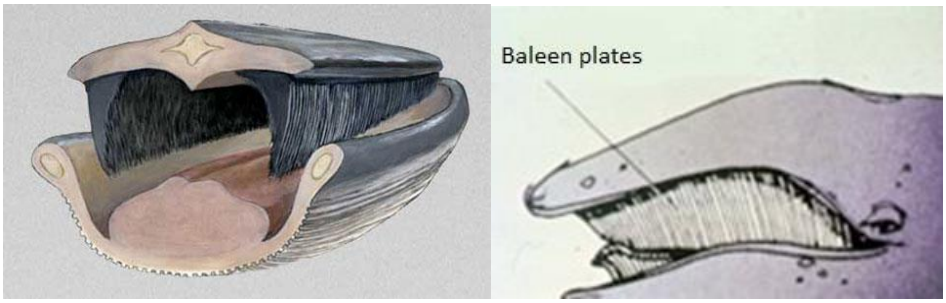


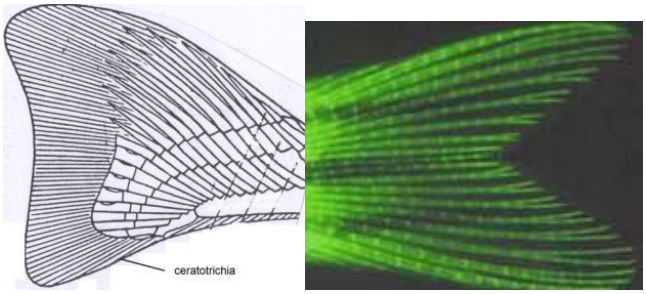
FIGURE 22: Two transverse rows of numerous triangular fringed horny plates, baleen or whalebone hanged from the palate of the upper jaw.

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 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 horny, hair-like, made of fibrous connective tissue and called **ceratotrichia. ii.** In osteicthyes, they are branched, made of series of segments and called **lepidotrichia** (Fig. 24).



A B

FIGURE 24: A- Ceratotrichia, thread like; B- Lepidotrichia, 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 turtles 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).

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.

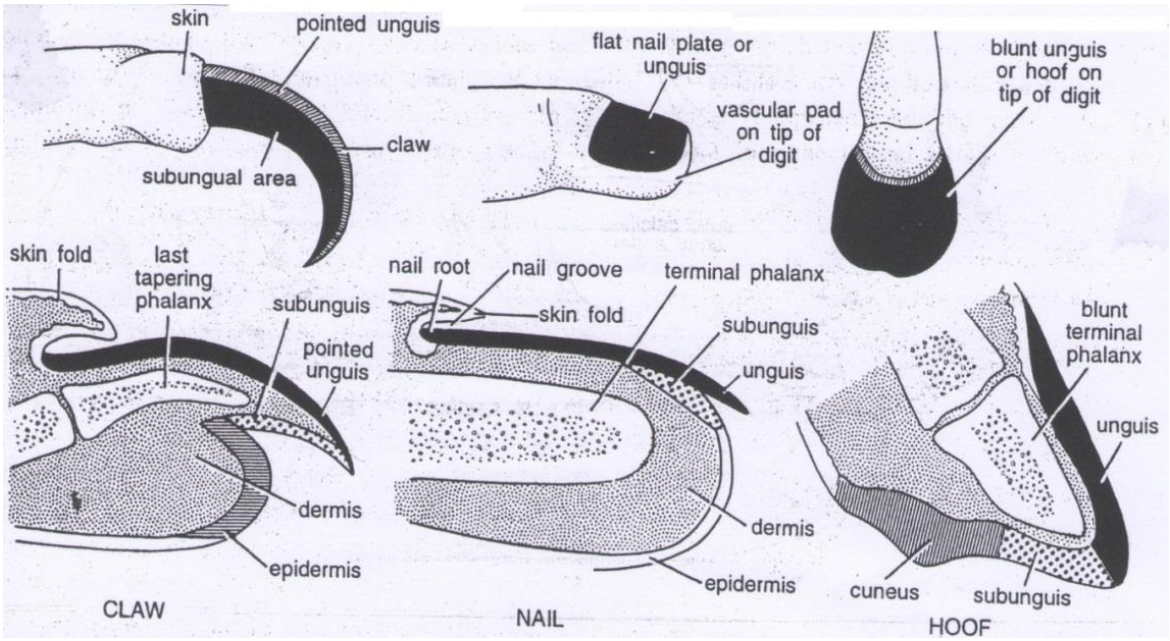


FIGURE 25: Three homologous corneal structures: claw; nail and hoof. They have same developmental origin and built up on same structure.

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 the body of birds and 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 remiges 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).

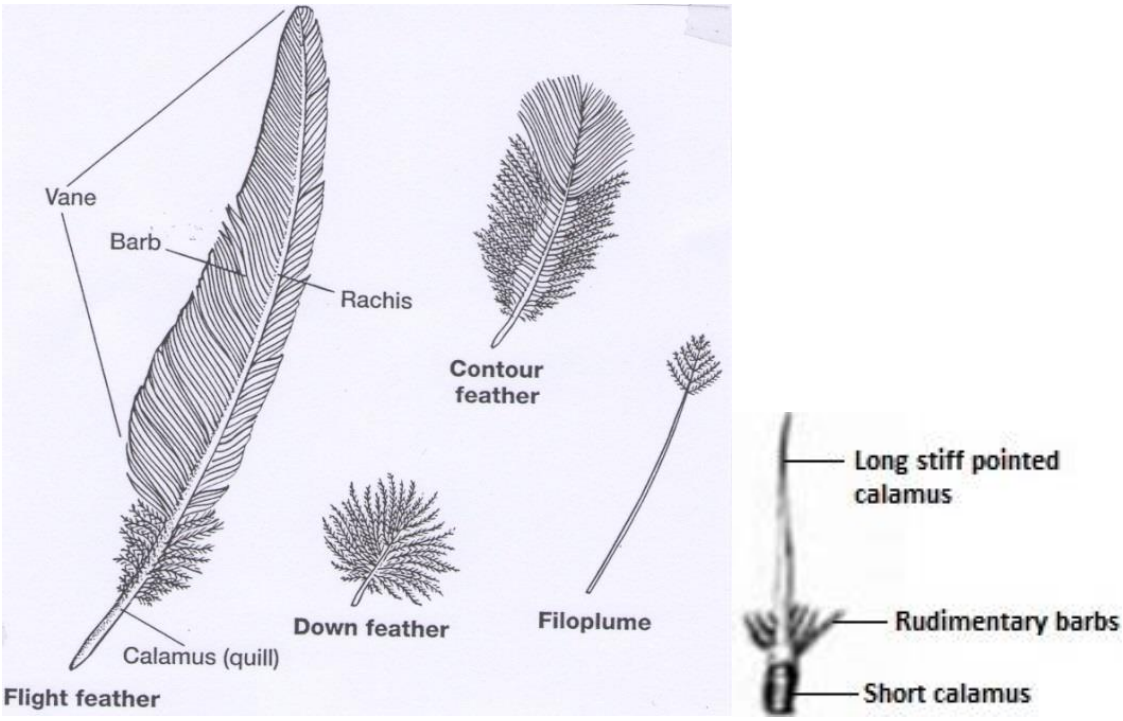


FIGURE 26: Four types of bird feathers, in addition to flight feather which is also considered as contour feather.

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 :

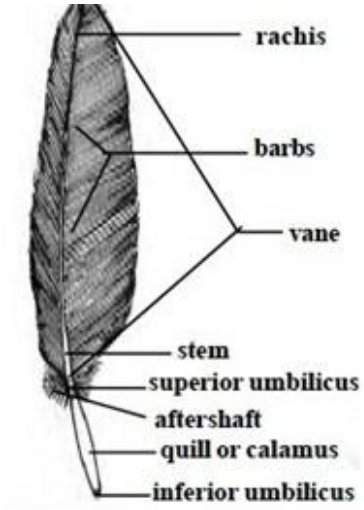


FIGURE 27: Typical structure of the contour feather.

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. They 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 hollow 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.

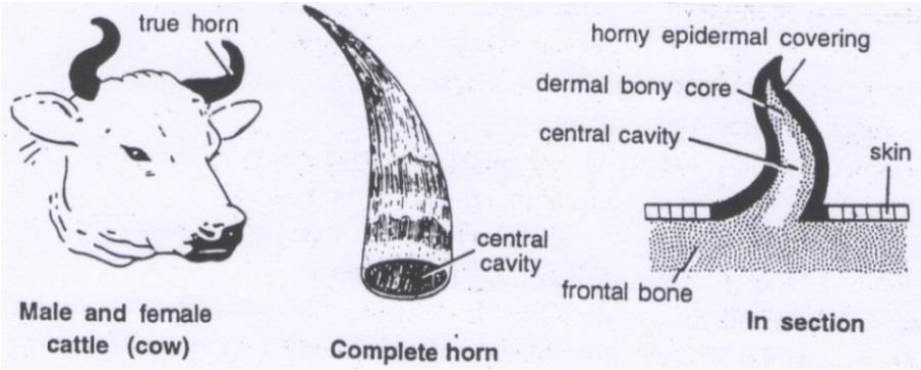


FIGURE 28: External feature and structure of true horn.

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.

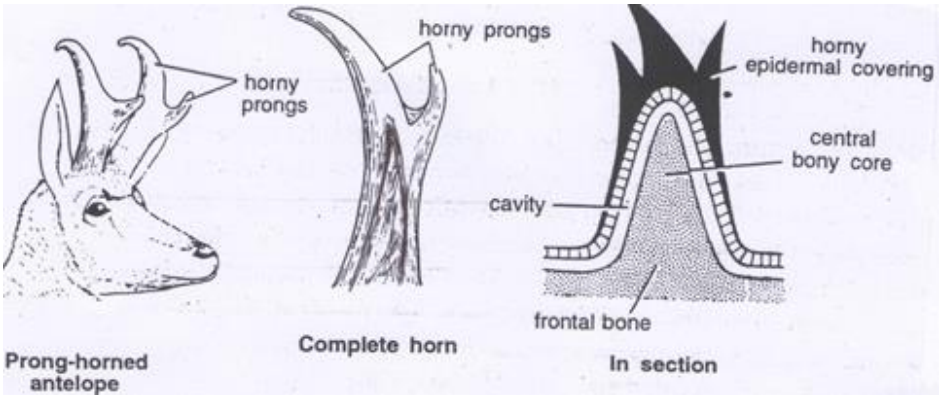


FIGURE 29: Pronghorn of American antelope, its morphology and structure.

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 has 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.

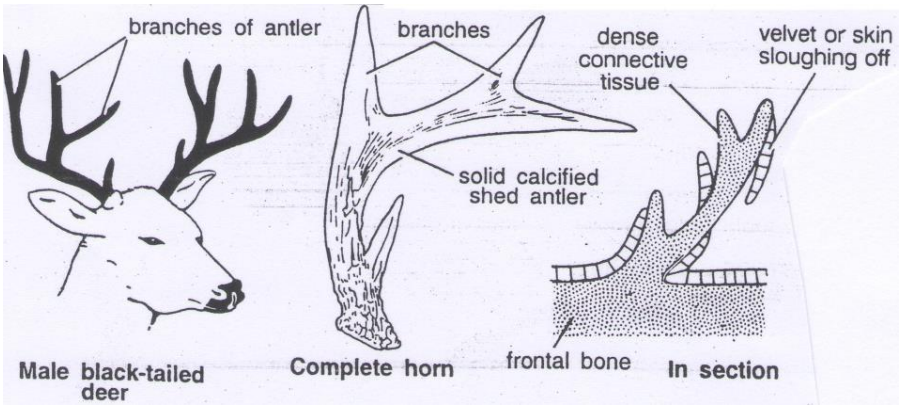


FIGURE 31: Antlers of the deer after complete development. The velvet wears off exposing the naked, branched antler.

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 throughout life (Fig.32). Compare between antlers of giraffe and deer.

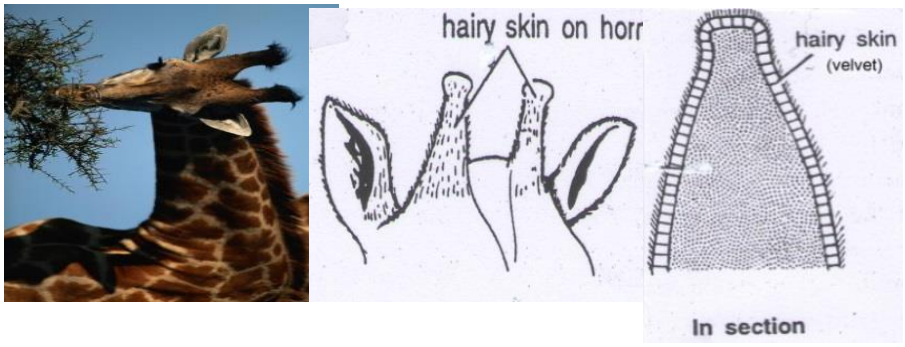


FIGURE 32: Giraffe horn and its structure.

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 derivative 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. Bone, cartilage, dentin (often considered a variety of bone) and enamel are mineralized tissue. All these tissues are originated from mesenchyme. Before these tissues can be deposited a preskeletal blastema must be developed from mesenchyme. A blastema is any aggregation of mesenchyme that gives appropriate stimulus to differentiate into some tissue such as muscle, fibers, cartilage, bone, dentin and enamel, as shown in the following scheme.

Three types of animal's skeletons have role in locomotion

Animals are able to move because their muscles contract and relax against a rigid skeleton. Skeleton of invertebrates is most often secreted on the surface, forming a lifeless or dead **exoskeleton** (Gr. exo, outside + skeleton), as in mollusks, arthropods and many other invertebrates. Exoskeleton may be mainly protective, but it may also perform a vital role in locomotion. Many invertebrates groups, like worms, use their body fluids (coelomic fluid) as an internal **hydrostatic skeleton**. 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.

Two types of vertebrate skeleton

The first two subtypes: i. epidermal horny exoskeleton and ii. dermal bony exoskeleton (bone inside the integument), both are attributed to skin and form the body **exoskeleton**, iii. All bones and cartilages, which are deep and within the body are joined together to form framework body **endoskeleton** covered by muscles.

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. 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 the latter is **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

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.

Test the endoskeleton of frog (Amphibia) and bird, they show high percentage resemblance, same terms but somewhat differ in form (Fig.1-2).

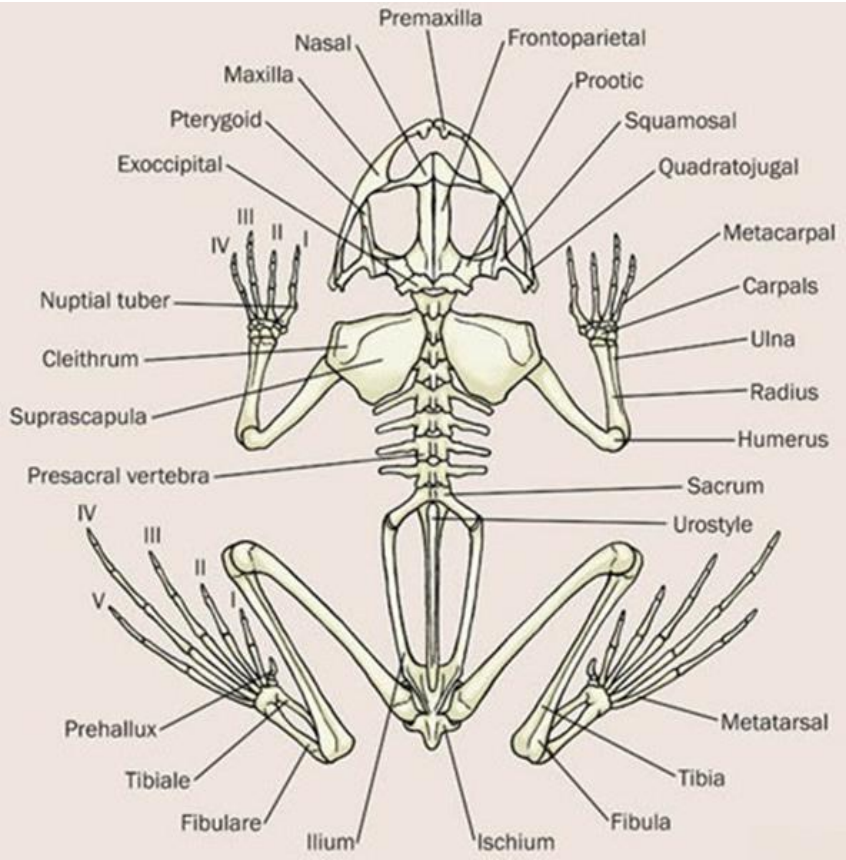


FIGURE 1: Frog endoskeleton.

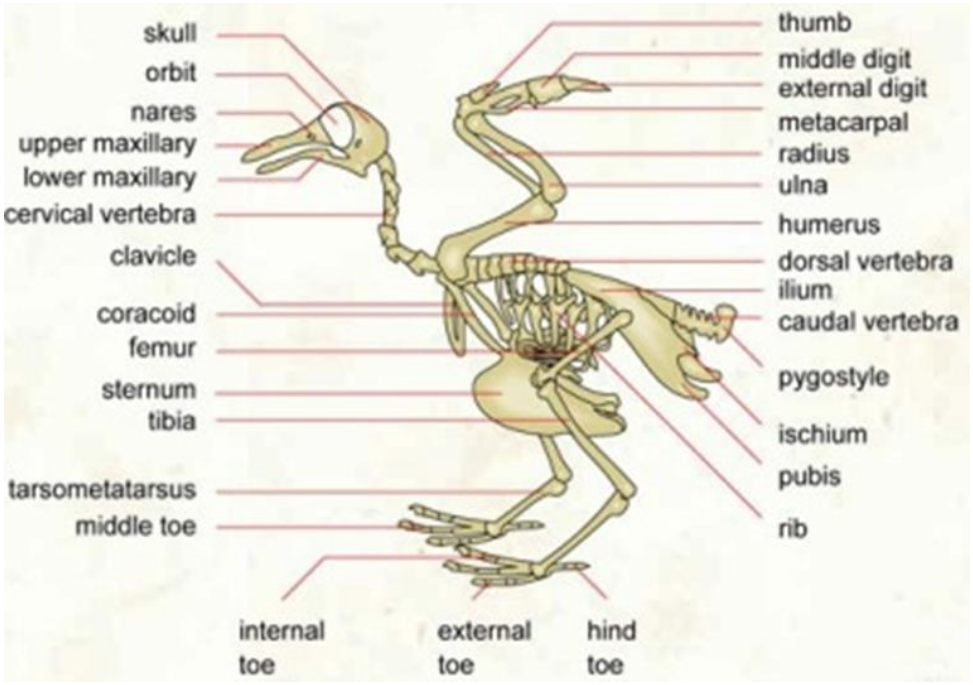


FIGURE 2: Endoskeleton of birds.