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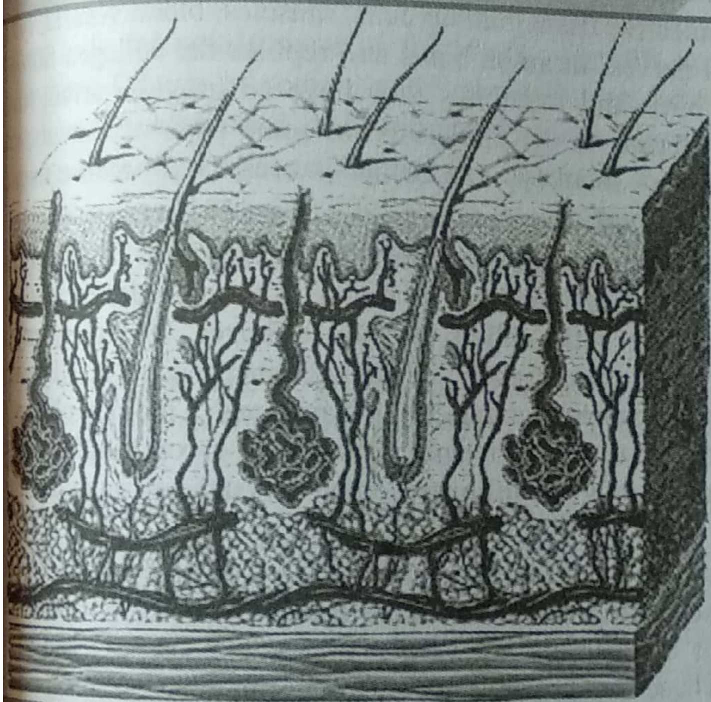
Chapter

Integument and its Derivatives in Vertebrates



Contents of this Chapter

The integument or the skin forms the external protective vering of an animal (vertebrate). It is continuous with the icous membrane lining the mouth, rectum, nostrils, eyelids, d the opening of urinogenital ducts. Conjunctiva of eyeball d outer surface of eardrum is also skin. The skin comes contact with the environment, terrestrial or aquatic, and influences the character of the skin. The evolution of the tebrate integument is correlated with the transition of tebrates from an aquatic to a terrestrial environment.

Structure of skin. The vertebrate skin differs from that of ertebrates in having two layers, an outer **epidermis** derived m the ectoderm, an and inner **dermis** or **corium** formed m the mesenchyme of the dermatomes (mesoderm). The ative amount of the two layers varies with the environment.

1. Epidermis. The epidermis is made of stratified ithelium (several layers of columnar epithelial cells).

These cells are held together tightly by minute **intercellular bridges** found on the surface of cells. The innermost layer of the epidermis is the **stratum Malpighii** or **stratum germinativum** placed over a thin basement membrane. The cells divide constantly to produce new cells. These cells move upwards and tend to become flattened and their protoplasm becomes horny, this is called **keratinisation**. In aquatic fishes and amphibians the keratinised layer forms a cuticle, but in amniotes the outermost keratinised layer forms a layer of cells called **stratum corneum** of hard, horny, flat, and cornified cells made largely of **keratin** which is a tough, waterproof and insoluble protein. It affords protection against mechanical injuries, fungal and bacterial attacks, and prevents desiccation. In many tetrapoda the dead stratum corneum is shed periodically in pieces or all at once. There is no stratum corneum in cyclostomes and fishes since they are completely aquatic but it is found in animals exposed to air. In aquatic vertebrates the epidermis has mucous glands, secreting the mucus which keeps the skin slimy and protects it from bacteria. There are no blood vessels in the epidermis.

2. Dermis. The dermis below the epidermis has an outer **loose layer** and an inner dense **layer**. The dermis is made of dense connective tissue having cells, muscles, blood vessels, lymph vessels, collagen and elastic fibers, and nerves. In amphibians and reptiles the collagen fibres lie at right angles in their planes, but in birds and mammals they have an irregular arrangement. Substances pass by diffusion from the dermis to the epidermis. In some parts of animals, such as the comb of a cock, face and buttocks of monkeys, the colour is bright red because they are intensely vascularised and contain much **blood**.

The skin also contains pigment. If the pigment is present in the epidermis, then it occurs as a diffuse substance or as granules and if the pigment is found in the dermis, then it is in the form of granules in special branching cells called **chromatophores**. The pigment can either collect as a central ball making the skin lighter, or spread out into all the branches making the skin darker, thus, chromatophores bring about colour variations. Chromatophores are of three kinds, **melanophores** contain brown to black melanin, **lipophores** or **xanthophores** have yellow red fatty pigments, and **iridocytes** or **guanophores** contain crystals of guanine which refract light.

Under the dermis the skin has loose subcutaneous areolar tissue which separates the skin from the underlying muscles. It may also contain fat and muscles, especially in mammals. During the course of evolution the integument of anamnia shows a decrease in thickness and also a decrease in the degree of ossification. These trends are of advantage in allowing greater mobility. In amphibians they permit respiration by the skin. But in amniota the skin becomes progressively thicker to prevent loss of water and to retain the body heat.

FUNCTIONS OF THE INTEGUMENT

1. Protection. The integument forms a covering of the body and is protective. It protects the body against entry of foreign bodies and against mechanical injuries. It protects the tissues against excessive loss of moisture, this is very important because both aquatic and terrestrial animals are dependent upon water in their bodies for various metabolic activities. The integument forms protective derivatives, such as scales, bony plates, layer of fat, feathers and hair which reduce the effect of injurious contacts. In some animals the skin shows protective colouration which makes the animals resemble their environment, thus, making them almost invisible to their enemies. Poison glands of toads, slippery skin of aquatic animals and an armour of spines of some mammals are protective devices of the integument. The skin forms a covering which prevents the passage of water and solutes in one of the following ways : (*a*) by formation of **cuticle** in Protochordata and embryos of fishes and amphibians, (*b*) by secreting a coat of **mucus** in fishes and aquatic amphibians, and (*c*) by formation of **keratin** layers in the epidermis of tetrapoda. Keratin is formed from the cytoplasm of degenerating cells of the epidermis which finally form a layer of horny stratum corneum.

2. **Temperature control.** Heat is produced constantly by oxidation of food stuffs in tissues. This heat is distributed evenly by the circulating blood. The body heat is lost constantly with expired breath, with faeces and urine, and from the surface of the skin. The integument regulates heat and maintains a constant temperature in endothermal animals. In birds the heat is regulated by adjustment of feathers which retain a warm blanket of air, when feathers are held close to the body they remove warm air and body cooled, when feathers are fluffed out they keep the warm air enclosed. In mammals constant evaporation of sweat regulates the body heat. In cold weather contraction of skin's blood capillaries reduces the loss of body heat. In some animals fat in the skin prevents loss of heat because it is a non-conductor of heat.

3. **Food storage.** The skin stores fat in its layers as reserve food material which is used for nourishment in times of need. In whales and seals the fat of the skin forms a thick layer, called **blubber** which is not only reserve food but also maintains the body temperature.

4. **Secretion.** The skin acts as an organ of secretion. Glands of the skin are secretory. In aquatic forms there are secretory mucous glands whose secretion keep the skin moist and slippery. In mammals sebaceous glands secrete oil which lubricates the skin and hairs. Mammary glands produce milk for nourishment of the young. In birds uropygial glands secrete oil for preening the feathers. Odours of scent glands attract the opposite sex. Lacrymal glands' secretion wash the conjunctiva of eyeball in mammals. Ear wax (cerumen) secreted by the glands of auditory meatus greases the eardrums and avoids insects to enter the canal.

5. **Excretion.** The integument acts as an organ of excretion. Shedding of the corneal layer during ecdysis removes some waste substances. In mammals metabolic waste (salts, urea and water) is removed from the blood by means of sweat. Chloride secreting cells are found in gills of marine fishes.

6. **Sensation.** The skin is an important sense organ because it has various kinds of tactile cells and corpuscles which are sensory to touch, temperature changes, heat, cold, pressure and pain.

7. **Respiration.** In amphibians, the moist skin acts as an organ of respiration, in frogs the respiratory function of the skin is greater than that of the lungs.

8. **Locomotion.** Derivatives of the integument bring about locomotion in some animals, such as the fins of fishes aid in locomotion in water, the web of skin in the feet of frogs and aquatic birds aid in swimming, feathers of the wings and tail of birds are used for flying, and extensions of the integument forming "wings" of flying lizards, extinct pterodactyls, flying squirrels and bats.

9. **Dermal endoskeleton.** The skin contributes to the endoskeleton. It forms the dermal bones of vertebrates and also forms parts of the teeth. Endoskeleton of head protects the brain and sense organs. In the body it protects the soft, tender viscera.

10. **Sexual selection.** The skin acts as an organ of sexual selection. It provides the feathers of birds which often have brilliant colours which are for sexual attraction. Some integumentary glands of mammals produce odours far attracting the opposite sex. Antlers of male deer distinguishes it from female.

Besides the above functions, mammalian skin synthesises the vitamin D with the help of sebum of sebaceous glands. Brood pouches beneath skin in some fishes and amphibians protect unhatched eggs. Nasal glands of tetrapods keep the nostrils free of dirt and water. Skin also have the power of absorption of oils, ointments, etc.

DERIVATIVES OF THE INTEGUMENT

Both layers of integument have given rise to various types of derivatives. The epidermis gives rise to integumentary glands, epidermal scales, horns, digital structures, different corneal structures, feathers, and hairs. The dermis forms dermal scales of fishes and of some reptiles, plates or scutes in reptiles, fin rays in fishes and antlers in mammals.

I. EPIDERMAL DERIVATIVES

Epidermal derivatives are epidermal glands (unicellular and multicellular), epidermal scales and scutes, horns, digital structures (claws, nails and hoofs), feathers and hairs.

1. Epidermal Glands

Epidermal glands are formed from the Malpighian layer of the epidermis. They arise from the epidermis and often penetrate the dermis. According to their structure they are unicellular or multicellular, tubular or alveolar and simple or compound (branched) glands. These are lined by cuboidal or columnar cells.

(*a*) **Unicellular glands** are single modified cells found among other epithelial cells, they are present in amphioxus, cyclostomes, fishes and larvae of amphibians. Unicellular glands are known as **mucous cells** or **goblet cells**. They secrete a protein **mucin** which combines with water to form mucus which lubricates the surface of the body. Other unicellular glands are **granular cells** and large **beaker cells** of cyclostomes and fishes, they also secrete mucus.

(*b*) **Multicellular glands** are of two types :

(*i*) **Tubular glands** are multicellular tubes of uniform diameter formed as ingrowths of the Malpighian layer into the dermis, *e.g.*, glands of Moll on the margin of the human eyelids. Tubular glands may become coiled at the base deep in the dermis, *e.g.*, sweat or sudoriferous glands of mammals, or they may divide into many tubules which are then called **compound tubular glands**, *e.g.*, mammary glands of females and of males in monotremes and primates etc., and gastric glands in stomach.

(*ii*) **Alveolar or saccular glands** are multicellular downgrowths of the Malpighian layer into the dermis, having a tubular duct whose terminal parts form a rounded expansion to become flask-shaped, *e.g.*, mucous and poison glands of amphibians. Alveolar glands may branch into many lobules which finally open into a common duct, they are then called **compound alveolar glands**, *e.g.*, mammary glands of eutherians, and salivary glands.

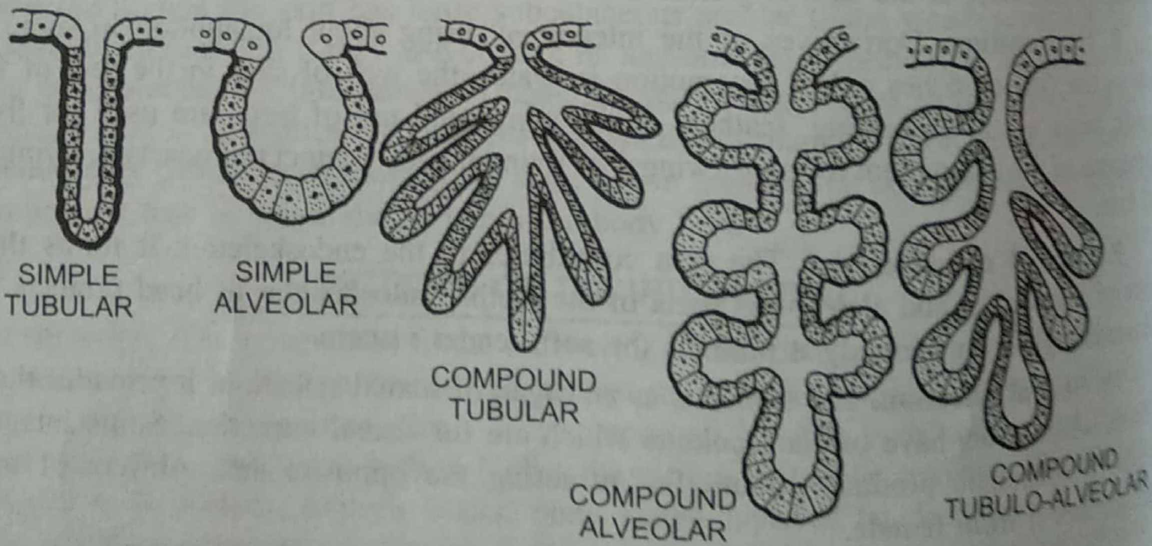


Fig. 41.1. Different types of epidermal glands.

Kinds of epidermal glands. According to function, the epidermal glands of vertebrates are of the following types :

1. Mucous glands. They may be unicellular or multicellular. The unicellular glands are mucous gland cells, granular cells and beaker cells of amphioxus, cyclostomes and fishes. They secrete mucus which keeps the skin moist and slippery, and also affords protection against bacteria and fungi. Mucous cells and granular cells lie near the surface, but the beaker cells lie more deeply and extend from the Malpighian layer to the surface.

Multicelluar mucous glands are alveolar found in some fishes and amphibians. They occur all over the surface of the body and produce mucus for lubricating the skin and in amphibians they keep the skin moist to aid in respiration.

2. **Poison glands.** Amphibians also have alveolar **poison glands** which are larger but less numerous than mucous glands. In toads masses of poison glands form **parotoid glands** behind the head. The secretion of poison glands has a burning taste and is used as a defence. Caecilians have giant poison glands. Some tubular glands are found on the feet and suctorial discs of tree frogs which aid in climbing. Tubular glands are also found on the swollen glandular thumb pads of male frogs and toads during the breeding season. They aid in clasping the female during amplexus.

3. **Luminescent organs or photophores.** They are found in longitudinal rows near the ventral side of the body in those fishes which live in deep sea where no light penetrates. Each photophore is a group of epidermal cells lying in the dermis. Each photophore has a lower layer of luminous cells below which is a layer of reflecting pigment cells, and the upper layer of mucous cells forms a lens. The glandular cells produce phosphorescent light which is transmitted to the outside by other cells. The light helps to attract the prey of deep sea fishes.

4. **Femoral glands.** Femoral glands are found in male lizards (*e.g., Uromastix*) below the thighs in a row from the knee to the cloaca. They secrete a sticky substance which hardens into short spines that are used for holding the female during copulation.

5. **Uropygial glands.** These are the only glands in birds, and they are best developed in aquatic birds. Uropygial glands are branched alveolar glands located on the dorsal side at the base of the tail or uropygium in the form of swelling. They secrete an oil which is odoriferous and attracts the opposite sex. The oil contains **pomatum** which is picked up with the beak and used for preening and water-proofing the feathers.

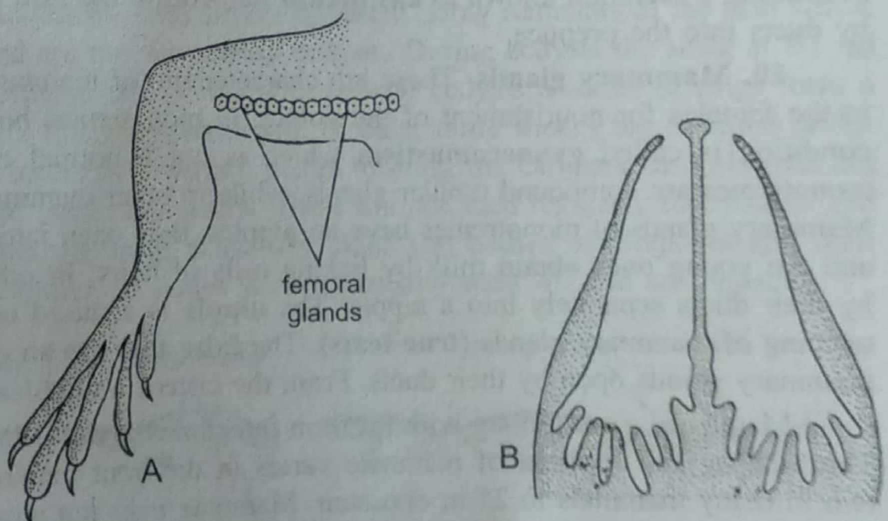


Fig. 41.2. Epidermal glands. A–Femoral glands of lizard; B – Uropygial glands of bird.

6. **Sweat glands.** The largest number and variety of epidermal glands are found in the skin of mammals. They are tubular or alveolar and multicellular. **Sudorific** or **sweat glands** are long, coiled tubular glands embedded deep in the dermis. Their upper part forms a duct which opens on the surface by a pore and the lower coiled part lies in the dermis surrounded by a network of blood capillaries. Sweat is secreted by sweat glands continuously, may or may not be visible. Sweat contains a large amount of water having dissolved salts of sodium, potassium and urea. Sweat removes some metabolic wastes and regulates the body temperature by evaporation.

Sweat glands are not uniformly distributed. In man they are more numerous on palms, soles, and arm pits. In cats, rats, and mice they are confined to the soles of the feet. In rabbit they are around the lips; in bats on the sides of head; in ruminants on the muzzle and the skin between the digits and in hippopotamus they are found only on the pinnae. There are no sweat glands in *Tachyglossus*, Sirenia, and Cetacea. In some mammals the secretion of sudorific glands is red-coloured. In hippopotamus it is red and spreads on the head and back. The male giant kangaroo *Macropus rufus* secretes red sweat. Modified sudorific glands form **glands of Moll** in the margins of the human eye in connection with eye-lashes. **Ceruminous glands** in the external ear passages of mammals are modified sweat glands and secrete a waxy substance which combines with the secretion of sebaceous glands to form earwax which catches dust. Oil glands form ceruminous glands in the external ears of some gallinaceous birds.

7. Sebaceous glands. Sebaceous glands are alveolar glands opening in hair follicles containing hairs. They also independently open at the skin surface around the genital organs, tip of the nose, and edges of the lips. Sebaceous glands secrete an oil **(sebum)** to lubricate the hairs and also covers the skin with a film of oily coating. The oily secretion of sebaceous glands contain waxes, fatty acids, and cholesterol, which makes the skin **pliable**.

Sebaceous glands are absent in *Manis* (pangolin), and Sirenia, and Cetacea which practically have no hairs. Modified sebaceous glands form **Meibomian glands** in the eyelids, each has a long straight duct into which separate alveoli open. They produce an oily secretion which forms a film over the lacrimal fluid or tears holding them evenly on the surface of the eyeball for keeping the eye moist, in weeping the oily film is broken and tears flow out. **Ceruminous glands** of external auditory meatus are modified sebaceous glands. Their greasy or waxy secretion, called the **cerumen** traps the insects and dust particles.

8. Scent glands. Scent glands are modified sebaceous glands or sweat glands. Their secretion is an allurement to the opposite sex. Scent glands are located in the deer family on the head near the eyes. Skunks and carnivores have scent glands around the anus, and pigs and goats have scent glands between their toes.

9. Preputial glands. These are found in many kinds of mammals. In beaver, large sacs containing a secretion known as **castoreum** lie beneath the skin on either side of penis and open by ducts into the prepuce.

10. Mammary glands. These are characteristic of mammals. They secrete milk generally in the females for nourishment of the young. In monotremes both sexes may secrete milk, this condition is called **gynaecomastism** which is not a normal condition. Mammary glands of monotremes are compound tubular glands, while in other mammals they are compound alveolar. Mammary glands of monotremes have no nipples, they open into pits on the surface of the skin, and the young ones obtain milk by licking tufts of hairs. In others the mammary glands open by their ducts separately into a nipple. The **nipple** is a raised outgrowth of the breast, bearing opening of mammary glands **(true teats)**. The **false teat** has an elongated cistern into which the mammary glands open by their ducts. From the cistern a tube leads to the surface of the nipple.

Mammary glands along with fat form integumentary swellings called **mammae** or breasts. The number and location of mammae varies in different mammals. The number ranges from two in many mammals to 25 in opossum. Mammae may run along two ventral **milk lines** from the arm pits to the groin, or they may be axillary, thoracic, abdominal or inguinal in position.

2. Epidermal Scales and Scutes

1. Epidermal scales. After the evolutionary loss of dermal scales of fishes, amniotes developed an entirely new type of scale derived from the epidermis. The skin of vertebrates is rarely naked, and it is usually provided with protective scales, bony plates, feathers or hairs. There are no epidermal scales in fishes and amphibians. They appear for the first time in reptiles. They are cornified derivatives of the Malpighian layer and are generally shed and replaced. The scleroprotein called the **keratin** is continually accumulated in the permanently growing layer of the epidermis called the **stratum germinativum**. These cells are called cornified and they become dead. Thus, the stratum corneum cells become cornified and form hard horny structures, such as scales and scutes in reptiles, beaks, claws, horns, nails, hoofs, feathers and hairs in different vertebrates.

Scales are most noticeable on lizards and snakes. They are continually being produced by the permanently growing layer of the **stratum germinativum** and are generally folded so to overlap one another. When they are fully grown they become separated from the stratum erminativum and appear as non-living, cornified structures.

The epidermal scales form a protective covering of the body (a continuous armour). The ales in snakes and lizards are continuous and undergo ecdysis periodically. Before ecdysis, the ew scales that will replace the old ones are formed. The entire corneal layer of scales is shed whole in snakes. The old epidermal covering becomes loosened first in the head region. This in, including even the transparent plates over the eyes, is turned back and the snake finally awls out of the old covering, leaving the old covering inside out. The scales on the ventral side most snakes differ from their other scales in being long and transversely arranged, they aid locomotion. Turtles and crocodiles have different kinds of scales which do not overlap, nor ndergo periodic ecdysis, but the scales are gradually worn off and replaced. **Large epidermal cales**, such as those on the shell of turtles and on the head of snakes, are generally called **scutes**. birds the scales are confined to the shanks and feet and some at the base of the beak. They enerally overlap as in snakes and lizards. In mammals epidermal scales are found on the tail and aws of rats, mice, beavers, musk rats and shrews. These scales are not much cornified, nor do hey undergo ecdysis; hairs project from beneath the scales. In scaly ant-eaters large epidermal cales cover the entire body, except the ventral side, the scales are reptilian and undergo ecdysis ingly. In armadillos there are large scales which fuse to form plates on the head, shoulders and ips; in the middle of the body, except mid-ventrally, the scales fuse to form ring-like bands; these scales do not undergo ecdysis but are gradually worn off and replaced.

Some epidermal scales of the tail of a rattle-snake are modified to form a rattle. It consists of a series of old dried scales. Rattles of rattle snakes represent horny remnants of the skin which adhere to the base of the tail and are not lost during ecdysis. During ecdysis the scale at the tip of the tail is not shed and it forms a ring. Thus, after several ecdysis a series of rings form a rattle, each new ring being larger than its predecessor. In older rattle snakes the terminal rattles are often lost. In tortoises and turtles, the dermal plates forming the carapace and plastron are covered externally with cornified epidermal scales. These are not shed regularly like lizards and snakes. A few turtles lack scales and have a leathery skin. The bodies of alligators and their relatives are also covered with epidermal scales which gradually wear off and are replaced.

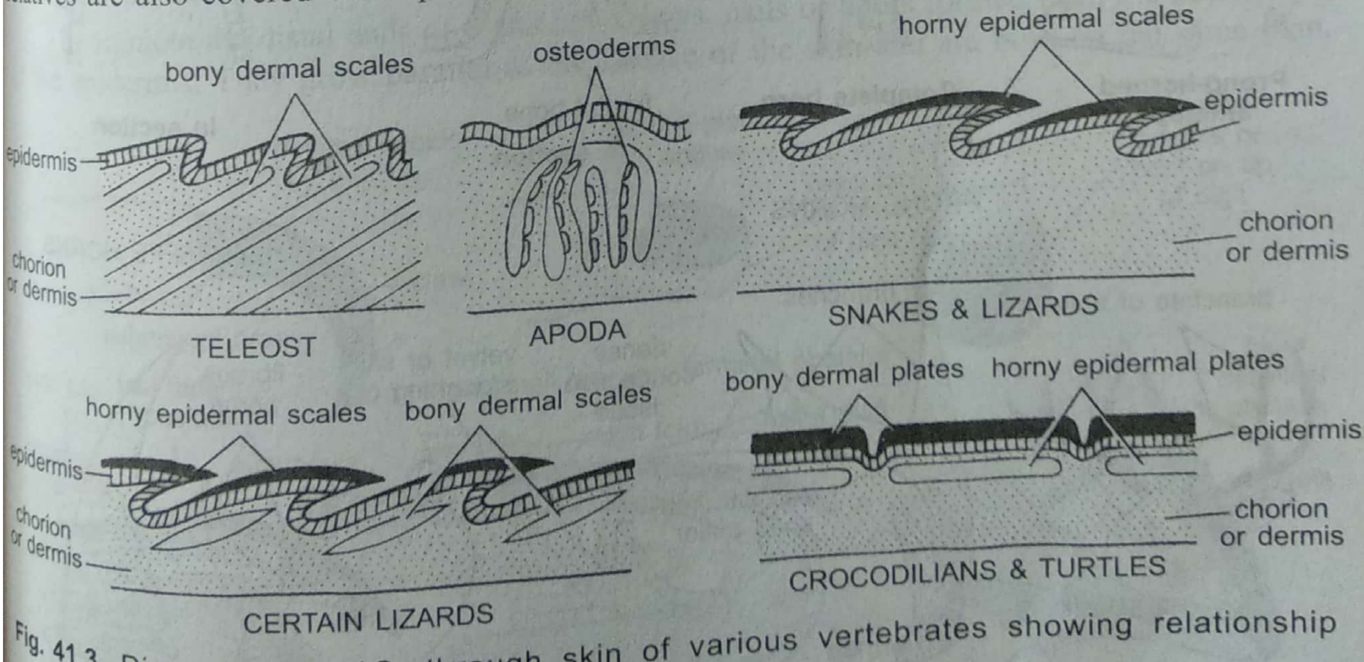


Fig. 41.3. Diagrammatic V.S. through skin of various vertebrates showing relationship of various types of scales.

In turtles, tortoises and modern birds there are no teeth. Each jaw bone being covered with horny sheath formed of several fused plates or scales which form a beak. In monotremes there is a soft bill which differs from the beak of birds is not being covered with modified epidermal scales.

3. Horns

Horns are found in ungulate (even-toed hoofed) mammals only. **True horns** of the hollow type are found in pronghorn, cattle, antelope, sheep and goats consist of an inner core of bone which is an outgrowth from the frontal bone. It is encased in a keratinised, epidermal covering. True horns continuously grow throughout life and are not shed. Five types of horns are recognised :

(*a*) **Rhinoceros** or **keratin fibre horn** has no skeletal element. It is made by keratinised cells of the epidermis and consists of matted keratin fibres bound together, but its fibres are not true hair. It is a permanent epidermal structure and if broken it grows again. There is one horn in the Indian rhinoceros and two in the African species.

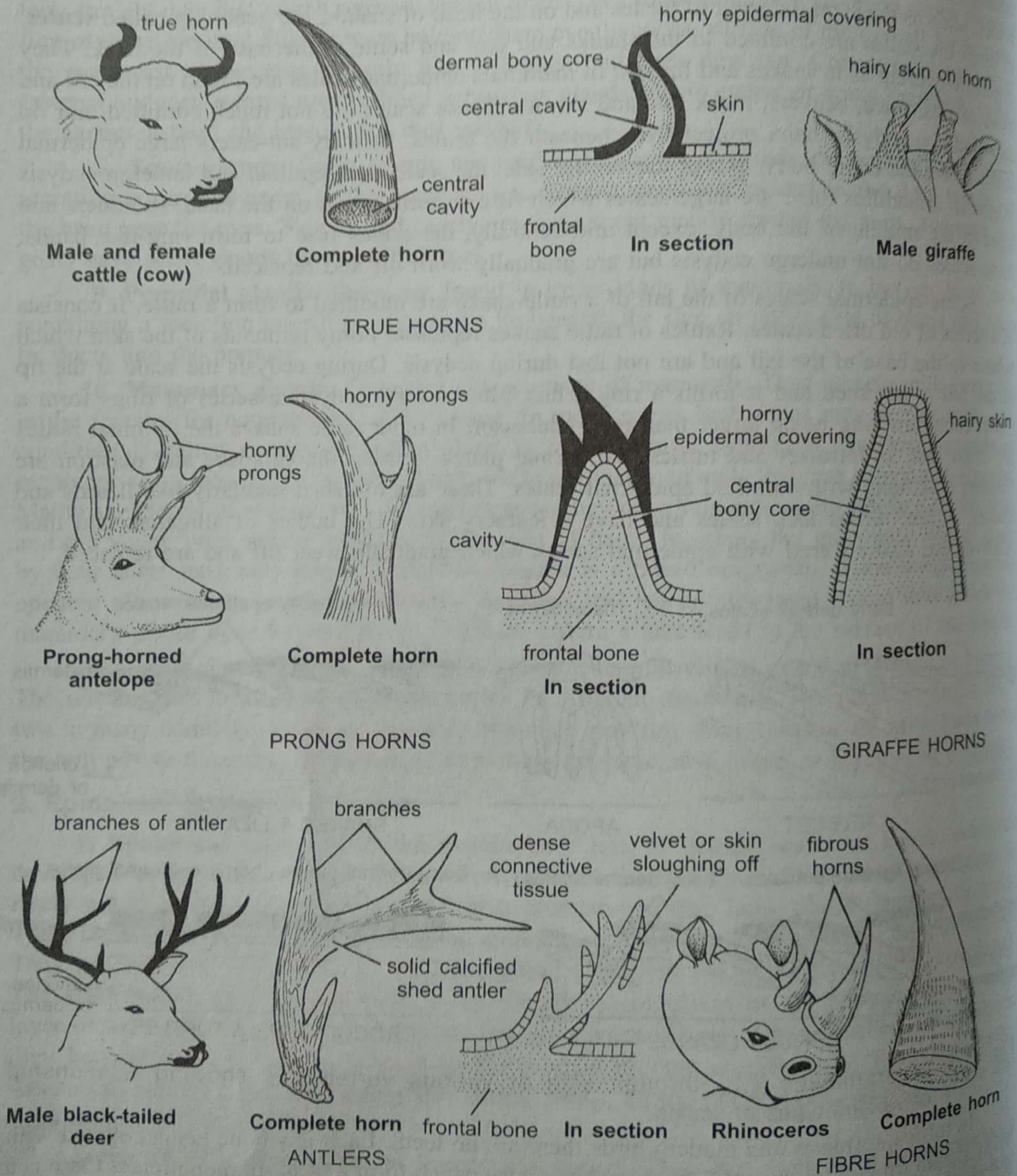


Fig. 41.4. Types of mammalian horns and antlers.

(*b*) **Pronghorn** is a **true horn,** consists of a permanent projection of the frontal bone overed by a hard, horny epidermal sheath. The sheath is forked bearing one to three prongs ade only of horny sheath. The horny sheath is shed annually and is replaced by another which ows from the skin that surrounds the core. It is found in Russian antelope *Antilocapra*.

(*c*) **Giraffe horns.** They develop from cartilaginous protrusions which are present at birth. hey ossify and fuse at the top of the skull, where they appear as knobs permanently covered ith living skin and hair. Giraffe possesses three of these knobs, one is median and anterior to the ther two. These horns are short, unbranched and are permanent, and are present in both sexes.

TABLE 41.1. DISTINCTION BETWEEN ANTLERS AND HORNS.

Antler	Horn
. Anters are outgrowths over the head of artiodactyls.	1. Same
. Antlers are found only in Cervidae, but absent in Asiatic genera *Moschus* and *Hydropotes*.	2. Horns (hollow) are found in Bovidae and in Antilocapridae in a modified form.
. Normally present in males except *Rangifer.*	3. Commonly occur in both sexes–larger in males.
. Shed annually.	4. No shedding and if occurs only outer sheath is shed.
. Antler is made of bone and covered by velvet (skin + hairs).	5. Horn consists of inner core of bone, an outgrowth of frontal bone covered over by keratinised epidermal covering.

(*d*) **Antlers** are found in the males of deer family, but they are present in both sexes in eindeer and caribou. An antler consists of a branching solid outgrowth of the frontal bone formed of dense connective tissue. It is covered during growth by hairy, vascular skin called 'velvet'. The velvet is shed exposing the antler naked when the antler reaches full growth. Thus, the antler consists only of dermal bone. The bony antler is also shed annually after the breeding season, and a new antler develops. Antlers are solid mesodermal bone, but they are formed under the influence of the integument. Formation of antlers is controlled by the hormones of testes and anterior lobe of the pituitary.

4. Digital Structures

In amniota the distal ends of digits have claws, nails or hoofs formed from the horny layer of the epidermis. They grow parallel to the surface of the skin and are built on the same plan.

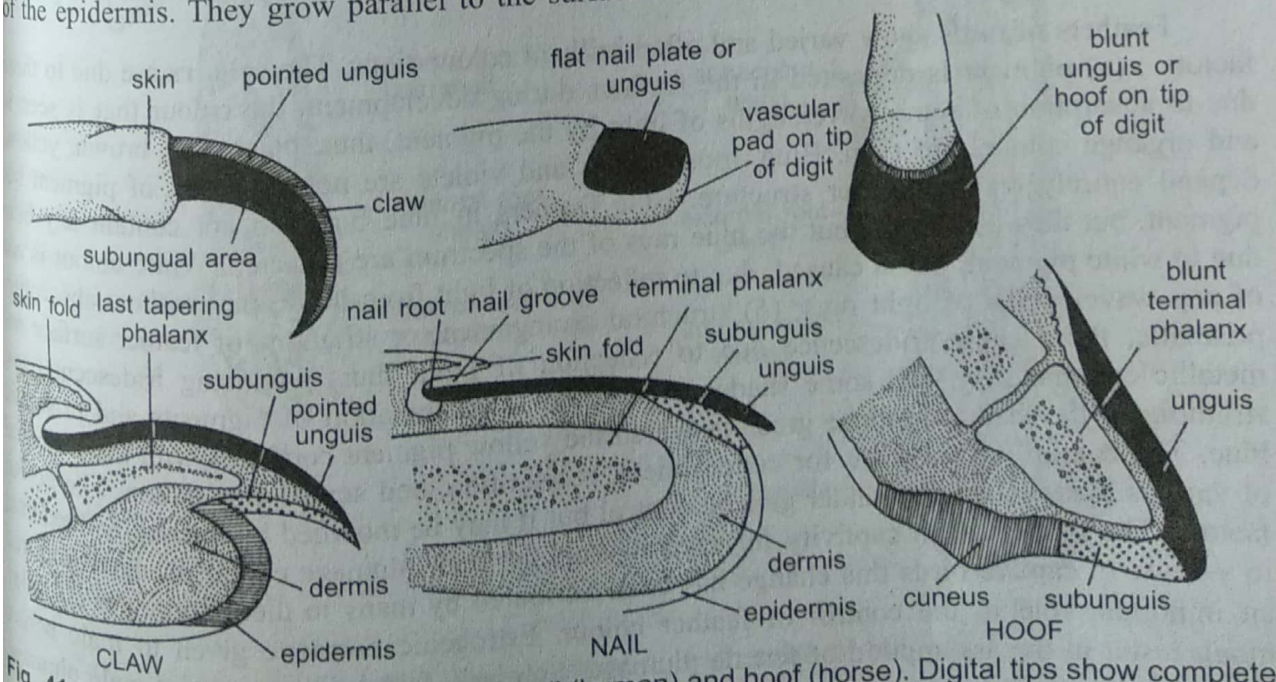


Fig. 41.5. Relation between claw (eagle), nail (human) and hoof (horse). Digital tips show complete above and in sagittal section below.

The hairs trap air which does not transmit body heat and, thus, act as insulators for the body. In some animals the colours of hair are protective. Hair in nostrils and ears prevent entry of dust, eyebrows and eyelashes protect the eyes, vibrissae are delicate organs of touch (act as tactile organs), hairs on the tail are used to drive away insects. In some animals, such as lions and some monkeys the **mane** distinguishes the male. Hairs are also modified in spines, scales, horns, etc., in some mammals.

Structure. Hairs are not modified scales but are new outgrowths of the epidermis only. A hair has an upper projecting **shaft** and a lower **root** lying in a **hair follicle** which is a sunken pit in the dermis. The **shaft** is made of only dead, keratinised cells. The part of the hair protruding above the skin is dead. At the base of the follicle the root is expanded into a **bulb** and growth of the hair takes place only in the root where the cells of the Malpighian layer divided actively. Below the bulb is a **dermal papilla** having connective tissue and blood vessels, it nourishes the hair. Beyond the bulb the cells gradually die so that the shaft is made of dead cornified cells. The hair shaft has an external **cuticle** of transparent overlapping cells which have lost their nuclei, inside the cuticle is a **cortex** (middle part of hair) containing shrivelled cells and pigments, and a central core or **medulla** having air spaces. In the follicle the hair root is surrounded by two layers of hair sheath cells forming an outer and inner **root sheaths**. They do not extend beyond the follicle. A sebaceous gland opens into the upper part of the hair follicle for oiling the hair. An **arrector pili** muscle composed of smooth fibres extends from the upper part of the dermis to the basal part of the hair follicle on the side towards which the hair slopes. It pulls the hair base causing the hair to stand when an animal is confronted with danger. Hair does not project vertically but at an acute angle from the skin.

Development of hair. A thickening of the epidermis (stratum germinativum) pushes into the dermis and becomes cup-shaped at its lower end. The dermis extends into the cup forming a **hair papilla** which has blood vessels for supplying nourishment. The epidermal downgrowth which at first is a solid cord of cells now splits to form a central **shaft** of cornified keratinised cells, and a space around it. The epidermal cells around the space form the **hair follicle**. The lower part of the hair follicle becomes swollen and is known as a bulb. The cells of the follicle thickened and bud off a sebaceous gland. The central shaft by addition of new keratinised cells from the root grows in length and pushes through the solid epidermal cells to emerge outside the skin. Thus, the development of hair differs from that of a feather. It is formed entirely from the solid column of epidermis, while in the feather there is a mesodermal feather pulp extending into the hollow quill.

II. DERMAL DERIVATIVES

The **scales** arise from the dermis and are, thus, mesodermal in origin, they are found only in fishes, some reptiles and a few mammals. Ostracoderm fishes, the earliest known vertebrates, had an armour of large bony plates.These bony plates became very small in placoderms to give rise to **cosmoid scales** which are not found in any living forms today (except in *Latimeria*). **1. Cosmoid scales** were also present in primitive Choanichthyes. A cosmoid scale had four distinct layers, the lowest layer is of **isopedine** or **dentine** resembled compact bone, the next layer was a **spongy bone** with vascular spaces consisting of pulp cavities having odontoblasts, the third layer was of hard compact **cosmine** with canaliculi and the outermost layer was thin but hard **vitrodentine** or enamel. **2. Ganoid scales** are the other type of scales found in earliest primitive bony fishes are **ganoid scales**. This implies that two different lines of evolution with regard to scales appeared very early in the history of fishes. A **ganoid scale** has a basal layer of **isopedine**, above which there may be a reduced **cosmine** layer or it may be absent and the uppermost layer is made of a hard, translucent substance called **ganoin**. Ganoid scales with a reduced cosmine layer are found in *Polypterus*, and with no cosmine in *Lepidosteus*. **3.** The evolution of the ganoid scale by the loss of its upper layer of ganoin gave rise to a thinner **leptoid scale**. There are two types of leptoid scales, namely, (*i*) **cycloid** and (*ii*) **ctenoid** scales. In the other line of evolution the cosmoid scale lost its three lower layers, only the fourth enamel-like dentine layer was retained and somewhat elaborated to form the **placoid scale**. Thus, in the present fishes there are four types of dermal scales : placoid, ganoid, ctenoid and cycloid scales.

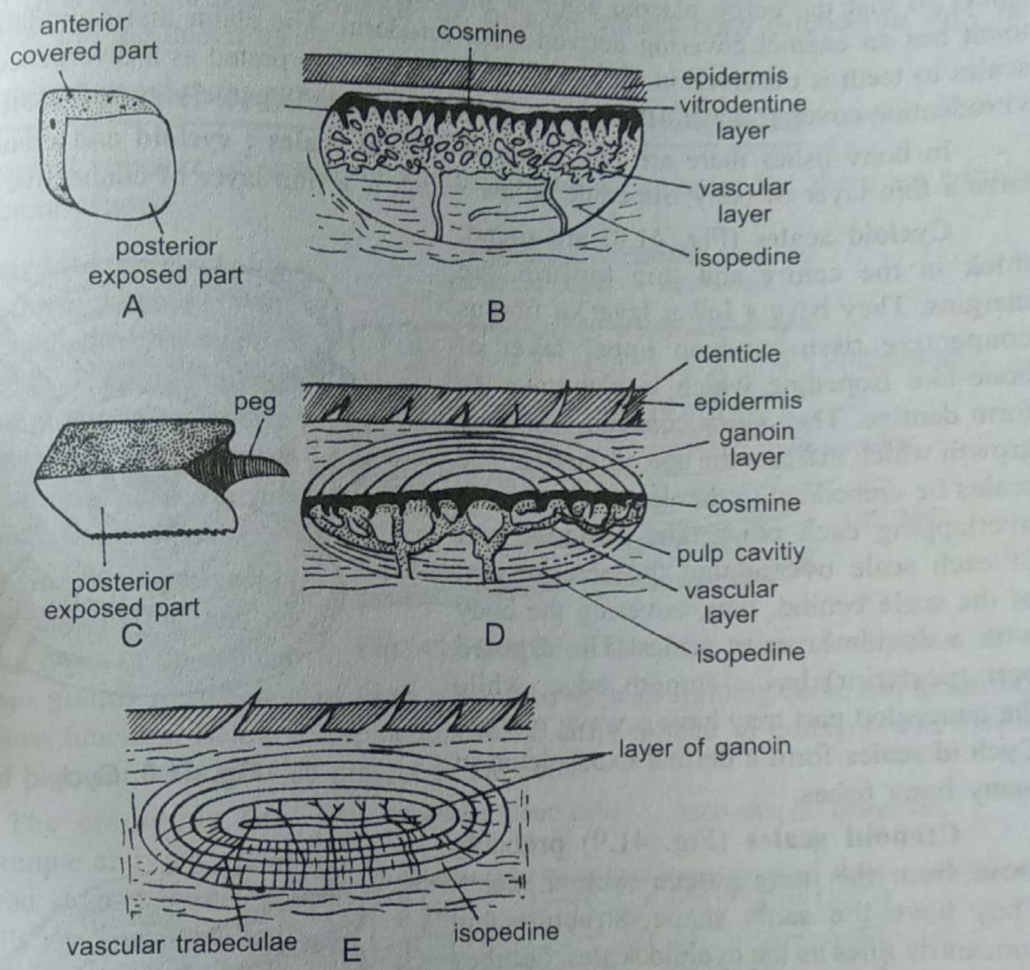


Fig. 41.7. Structure of scales of fishes. A–An isolated scale; B–T.S. of cosmoid scale; C–An isolated ganoid scale; D–T.S. of Palaeoniscoid scale; E–T.S. of lepidostoid scale.

Embedded in the dermis of elasmobranchs in oblique rows and projecting from the epidermis e dermal denticles of placoid scales forming an exoskeleton. The placoid scales were evolved loss of some layers from the cosmoid scales. Placoid scales are found only in elasmobranchs, sharks they are very small and give the skin a rough texture, but in skates they are large.

Structure. A **placoid scale** has a flat bony **basal plate** bearing a trident **spine** which ojects above the epidermis and points backwards. Inside the spine is a **pulp cavity** containing lp made of connective tissue, blood vessels, and a layer of **odontoblast** cells. The basal plate made of calcified dentine, and the spine has mostly dentine which is covered with a cap of rd modified dentine called **vitrodentine** and not enamel as often stated erroneously. The basal te and spine are both of mesodermal origin. The cured skin of sharks containing placoid scales alled **shagreen** which is used for polishing and for handle covers.

Placoid scales are the fore-runners of vertebrate teeth because the two have essentially the e form and structure and a gradation from placoid scales to teeth is seen in the mouth of rk. Shark teeth are enlarged placoid scales formed in the skin of jaws. But there are objections this supposition. A more recent view is that both placoid scales and teeth are modified nants of the bony dermal plates found in the ancestral ostracoderms and placoderms, so that th and placoid scales are lomologous strutures. Moreover, it has been shown that there is no dermal enamal layer in placoid scales, but it is a layer of **vitrodentine** formed from dermal cells. Enamel is the hardest substance in the body, whereas vitrodentine is only a hardened outer layer of dentine. The enamel organ does not secrete enamel, it only plays a role in shaping the spine, so that the entire placoid scale is mesodermal like the scales of bony fishes, whereas a tooth has an enamel covering derived from ectoderm. The claim that a gradation from placoid scales to teeth is observed in the mouth of a shark is interpreted as a divergence shown between vitrodentine-covered placoid scales, on the one hand and enamel-covered teeth on the other.

In bony fishes there are two kinds of **leptoid scales** : **cycloid** and **ctenoid scales**. They have a thin layer of bony isopedine below which is a thin layer of connective tissue.

Cycloid scales (Fig. 41.8) are round, thick in the centre and thin towards the margins. They have a lower layer of fibrous connective tissue and an upper layer of bone-like isopedine which is elaborated to form dentine. They show concentric lines of growth which indicate the age of the fish. The scales lie embedded in the dermis diagonally overlapping each other. The posterior part of each scale overlapping the anterior part of the scale behind, thus, covering the body with a double layer of scales. The exposed part (posterior) has a smooth edge, while the concealed part may have a wavy margin. Cycloid scales form a dermal exoskeleton in many bony fishes.

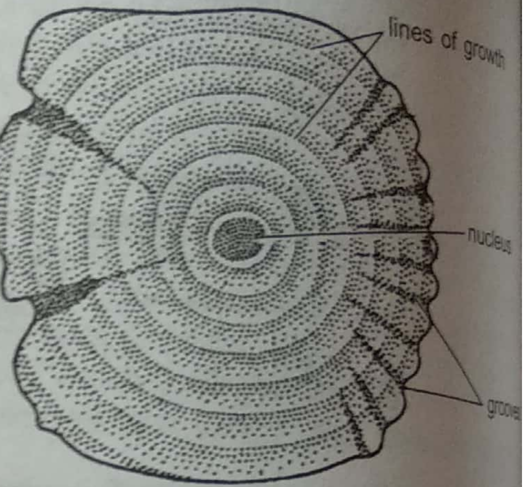


Fig. 41.8. Cycloid scale.

Ctenoid scales (Fig. 41.9) probably arose from the more simple cycloid scales. They have the same shape, structure and concentric lines as the cycloid scales, but they differ in having small teeth or **cteni** on their free posterior part. Their anterior concealed part may have notched or scalloped margin. Ctenoid scales form a dermal exoskeleton of most bony fishes. The cycloid or ctenoid scales covering the lateral line canals are perforated by a vertical tube of the lateral line opening on the surface. In some flat fishes both cycloid and ctenoid scales are present. In some catfishes there are no scales, in eels scales are very small and embedded in the dermis. In sea-horses scales form a continuous armour covering the body. Scales of bony fishes arise only from dermis, they form a protective exoskeleton but do not hamper movement.

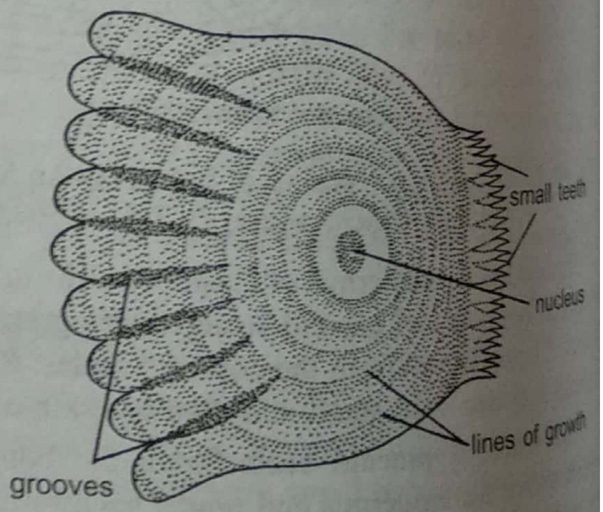


Fig. 41.9. Ctenoid scale.

In **tetrapoda** dermal scales are known as **bony plates** or **osteoderms**. In **Apoda** (Amphibia) only vestiges of osteoderms are present. They are found in pockets below the epidermis and are not visible externally. Two most ancient groups of reptiles, the turtles and crocodiles, have retained bony dermal plates. Turtles have continuous osteoderms below the epidermal plates of the carapace and plastron. These osteoderms form a rigid dermal skeleton which become connected with the endoskeleton. In crocodiles there are osteoderms below the epidermal plates only on the back and the throat.

In birds and mammals there is a tendency for elaborating epidermal structures with an companied reduction or loss of dermal derivatives. In **mammals**, osteoderms are found in madillos lying below the epidermal scales. They are bony plates of spongy texture. Extinct yptodons had a rigid bony armour of osteoderms. In some whales bony osteoderms may be esent on the back and the dorsal fin.

INTEGUMENT IN DIFFERENT CLASSES OF CHORDATES

The fundamental structure of skin in all the vertebrates is the same but there are certain riations in different classes.

1. **Protochordata.** In *Branchio-oma* the skin is simple without keratin. he **epidermis** is single layered made of ll or columnar cells. These are ciliated *Balanoglossus*. Epidermis has numer-us unicellular gland cells which secrete thin cuticle in *Branchiostoma*. **Dermis** orium) is gelatinous in *Amphioxus*.

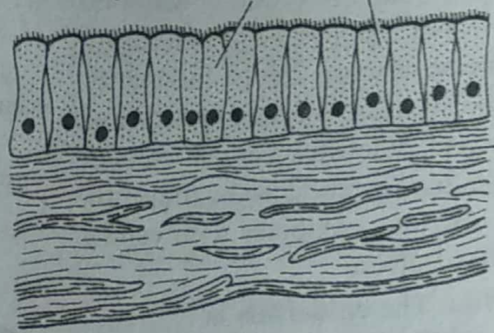


Fig. 41.10. V.S. of skin of a young *Amphioxus*.

2. **Cyclostomata. Epidermis** multilayered (stratified) but has no eratin. It has three types of unicellular land cells : **mucous glands** secrete mucous, **club cells** probably scab-forming cells, and **granular** ells are of unknown function. Below the epidermis is the **cutis** formed of collagen and elastic bres. Star-shaped pigment cells are also present in the cutis.

3. **Pisces.** The epidermis has everal layers of simple and thin cells, ut there is no dead stratum corneum. he outermost cells are nucleated and ving. The stratum Malpighii replenishes e outer layers of cells which have me keratin. Unicellular goblet or **ucous gland cells** are found in the idermis, as in all aquatic animals. The ucus makes the skin slimy reducing iction between body surface and ater, protects the skin from bacteria d fungi, and assists in the control of mosis. Multicellular epidermal glands e **poison glands** and light producing organs (photophores) may also be found. The epidermis sts on a delicate basement membrane.

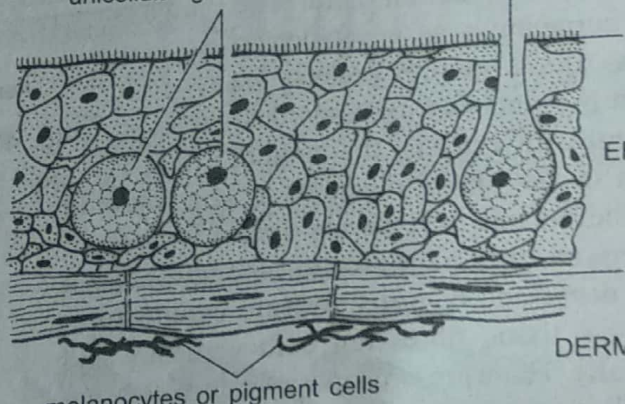


Fig. 41.11. V.S. of skin of a larval cyclostome.

The dermis contains connective tissue, smooth muscles, blood vessels, nerves, lymph vessels, d collagen fibres. The connective tissue fibres are generally not arranged at right angles, but n parallel to the surface. Scales are embedded in the dermis and projected above the epidermal rface. These are of five types. The elasmobranchs have **placoid scales**, Chondrostei and Holostei ve **ganoid scales**, while most Teleostei have **cycloid** and **ctenoid** scales lodged in pouches of e dermis. Extinct Crossopterygii had **cosmoid** scales.

Many bony fishes show more brilliant colours than any other group of animals. The colours fishes are due to **chromatophores** and **iridocytes**.

(*a*) **Chromatophores** in the dermis are derived from neural crest cells. They contain pigments which not only produce colours but also cause variations of colours. Chromatophores containing brown or black pigment are known as **melanophores** and those containing red, yellow, or orange pigment are collectively called **lipophores**.

(*b*) **Iridocytes** or **guanophores** are reflecting cells. They have no pigment but contain crystals of guanin. They lie in the dermis and cause irides-cence. Iridocytes reflect light from guanin crystals to produce white or silvery colours if the iridocytes are below the scales, if the iridocytes are above the scales they cause iridescent hues. By combinations of chromatophores and iridocytes various colours are produced, *e.g.*, blue is produced by reflection from iridocytes, the blue combines with yellow pigment to produce green.

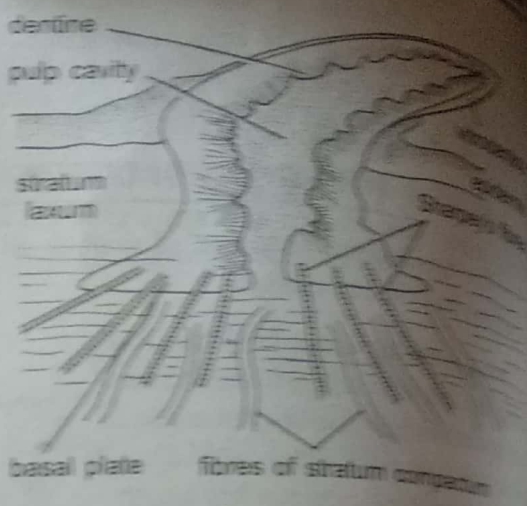


Fig. 41.12. V.S. of integument of shark.

4. Amphibia. The **epidermis** is multilayered, the outermost layer is a **stratum corneum** made of flattened, highly keratinised cells. Such a dead layer appears first in amphibians, and is best formed in those which spend a considerable time on land. The stratum corneum is an adaptation to terrestrial life, it not only protects the body but prevents any excessive loss of moisture. In ecdysis, the stratum corneum is cast off in fragments or as a whole in some. The **dermis** is relatively thin, it is made of two layers, an upper loose **stratum spongiosum** and a lower dense and compact **stratum compactum**. Connective tissue fibres run both vertically and horizontally. There are two kinds of glands, they are multicellular **mucous glands** and **poison glands** in the dermis, but they are derivatives of the epidermis. The mucous glands produce mucus which not only forms a slimy protective covering but also helps in respiration. The poison glands found in toads as parotid glands produce a mild but unpleasant poison which is protective, keep the enemies away. In the upper part of the dermis are **chromatophores** which have black melanophores and yellow lipophores, these produce the colour of the skin. The ability of the skin for changing colour to blend with the environment is well developed. Skin of labyrinthodontia, the stem Amphibia, had a covering of dermal scales. Bony dermal scales are found embedded in the skin of some Gymnophiona (Apoda) and a few tropical toads. These scales are absent in modern Amphibia.

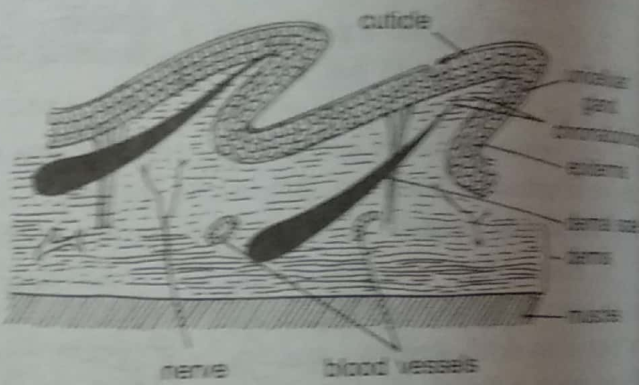


Fig. 41.13. V.S. of skin of bony fish.

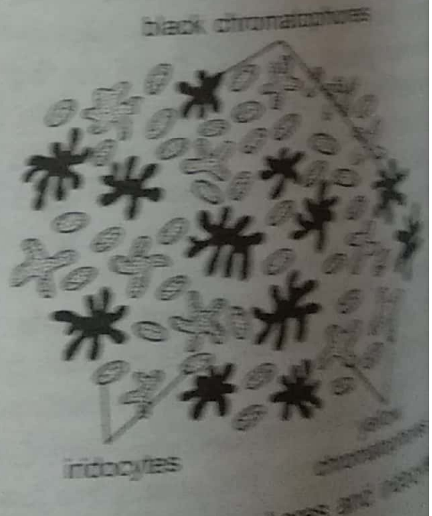


Fig. 41.14. Chromatophores and iridocytes in skin of fishes.

The skin is sensitive to light in amphibians, especially in cave-dwelling forms. It is an important organ of respiration, and also enables the frog to respire under water for long periods, during hibernation or aestivation it is the only organ of respiration.

The skin is loose being attached to muscles only at certain places by connective tissue septa which mark the boundaries of subcutaneous lymph spaces.

5. Reptilia. The integument (Fig. 41.17) is thick and dry. It prevents any loss of water. It has almost no glands, this is an adaptation to prevent evaporation of water.

The **epidermis** has a well developed **stratum corneum** which make the skin dry and prevent any loss of body moisture, thus, well adapted to a terrestrial life. The epidermis produces horny scales. Scales are shed periodically in fragments or cast in a single slough, as in snakes and some lizards. The scales often form **spines** or **crests**. Below the epidermal scales are dermal bony plates or **osteoderms** in tortoises, crocodiles, and some lizards (*Heloderma*). These are retained for life and are not shed off. These may form dermal bones in the skull lying superficially or they may be found in the dermis.

The **dermis** is thick and has an upper loose connective tissue layer and a lower layer tella subjunctiva and separating the two is a horizontal layer of fibrous connective tissue. The upper layer has an abundance of chromatophores in snakes and lizards like fishes and ampibians. Leather of high commercial value is made from the skin of lizards, snakes, and crocodiles.

Many lizards and snakes have elaborate colour patterns, for concealment or as warning colours. There is marked colour change in certain lizards, such as *Chameleon*, the colour may change with the environment for concealment, or it may change in courtship or threat. In *Calotes*, the chromatophores have no nerve fibres, they are controlled by hormones of the posterior lobe of the pituitary. In *Chameleon*, chromatophores are controlled by the autonomic nervous system.

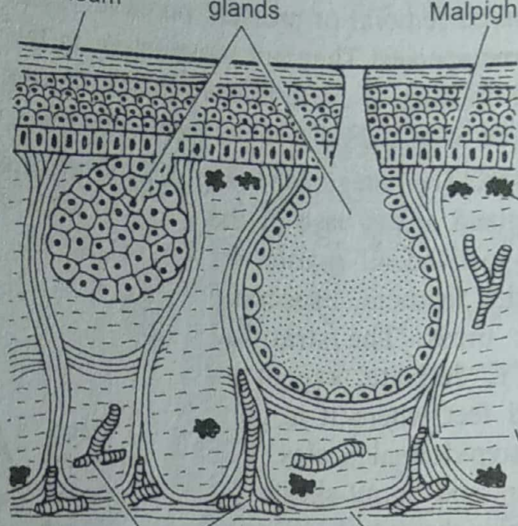


Fig. 41.15. V.S. of skin of frog.

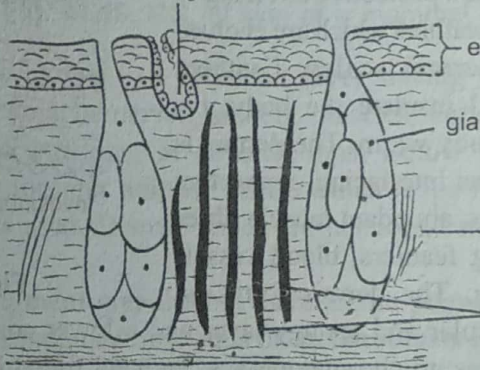


Fig. 41.16. V.S. of skin of *Ichthyophis* showing dermal scales.

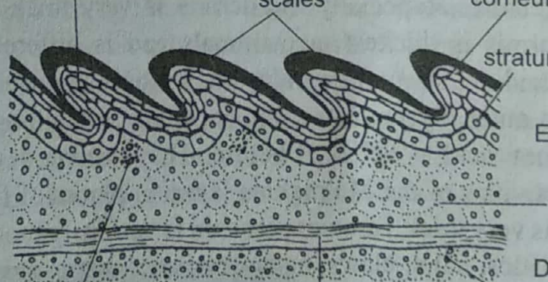


Fig. 41.17. V.S. of skin of lizard.

Reptiles essentially lack skin glands. Many lizards have glands near the cloaca. Their openings called femoral or pre-anal pores are generally smaller in female and found only in the male in some species. They are most active in the breeding season. **Musk glands** in the throat and cloacal opening of crocodilians function during courtship. Generation glands found recently are associated with periodic shedding of the skin.

6. Aves. The integument (Fig. 41.18) is thin, loose, dry and devoid of glands except a uropygial gland at the base of the tail whose secreted oil is used for preening the feathers, especially in aquatic birds. The stratified epidermis is delicate, except on shanks and feet where it is thick and forms epidermal scales. The claws, spurs and horny sheaths of beaks are also the modifications of stratum corneum of epidermis. Claws and beaks are variously modified in birds according to habitat. The rest of the body has a protective covering of epidermal feathers which are evolved from epidermal scales. Feathers protect and insulate the body, *i.e,* keep the body warm. The dermis is thin and has interlacing connective tissue fibres, abundant muscle fibres for moving feathers, blood vessels and nerves. The dermis forms an upper vascular and spongy layer and a lower compact layer. The dermis also contains fat cells. The skin has no chromatophores. Pigment found in melanocytes migrate into feathers and scales. Colour patterns of birds are vivid, they are for concealment, recognition, and sexual stimulation. The colours are mainly produced by reflection and refraction of light from surface of feathers.

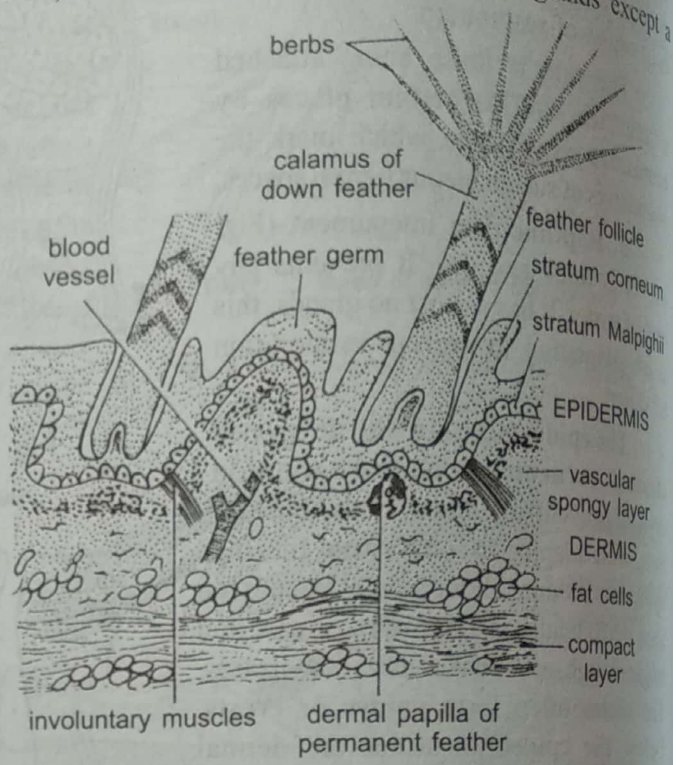


Fig. 41.18. V.S. of skin of a bird.

7. Mammalia. The skin (Fig. 41.19) is elastic and waterproof and is much thicker than in other vertebrates, especially the dermis is very thick and tough and is used for making leather. The epidermis is thickest in mammals and is differentiated into five layers : stratum corneum, stratum lucidum, stratum granulosum, stratum spinosum and stratum germinativum or Malpighian layer. The outer layer of **stratum corneum** containing keratin, its cells lose their nuclei, but the cells are not dead as believed before. They secrete several hormones, one of which represses the mitotic activities of the Malpighian layer. In places of friction, such as soles and palms, the stratum corneum is very thick. Stratum corneum is variously modified in various mammals to form epidermal scales, bristles, hairs, claws, nails, hoofs and horns etc., Below the stratum corneum is a refractive **stratum lucidum** in certain regions only. The stratum lucidum is now known as a **barrier** layer because the electron microscope has shown that its cells become compact and closely united to form a region which prevents passage of substances into or out of the body. Stratum lucidum contains a chemical known as **eleidin**. Keratohyalin and eleidin are intermediate products in the formation of **keratin**. Below this is a stratum granulosum which is having darkly-staining granules of keratohyalin. Below the stratum granulosum is a **stratum spinosum** whose cells are held together by spiny intercellular bridges, each bridge has two arms in close contact, one arm arising from each cell. Lastly there is a stratum germinativum or Malpighian layer which rests on a thin basement membrane. The Malpighian layer forms new cells continously which move towards the surface and become flat and keratinised till the stratum corneum has flat, cornified cells made only of keratin. This layer is sloughed off continuously and replaced by new cells. There are no mucous glands in the epidermis of mammals. The keratin from the epidermis at ends of digits forms claws, nails or hoofs.

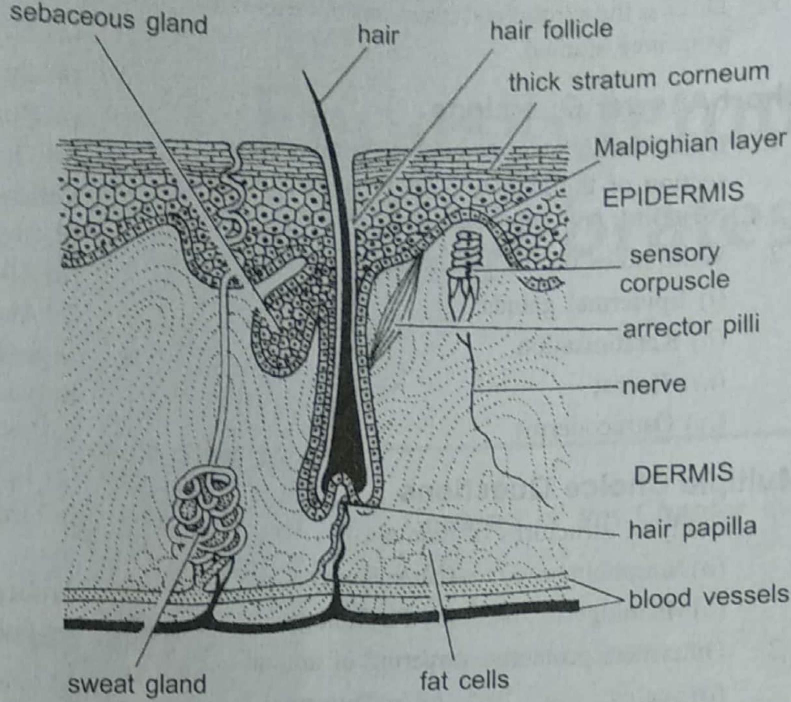


Fig. 41.19. V.S. of skin of a mammal.

The **dermis** is best developed in mammals. The upper part of the dermis in contact with the epidermis is the **papillary layer** which is made of elastic and collagen fibres with capillaries in between. It is thrown into folds to form rows of **dermal papillae**, especially in areas of friction. The greater lower part of the dermis is a **reticular layer** having elastic and collagen fibres. In both layers there are blood vessels, nerves, smooth muscles, certain glands, tactile corpuscles, and connective tissue fibres extending in all directions. Below the dermis the subcutaneous tissue has a layer of fat cells forming **adipose tissue** which helps to maintain body heat. In making leather only the dermis is used. Dermal scales are not found in mammals except armadillos.

In the lowest layer of the epidermis are **pigment** granules but there are no pigment-bearing chromatophores in mammals. In man some branching dendritic cells or **melanoblasts** lie between the epidermis and dermis, they contain pigment.

The epidermis forms hairs, sudorific glands, sebaceous glands and mammary glands. **Hairs** form an epidermal covering. Shafts of hair project above the skin and their roots are embedded in hair follicles, into each of which opens a branching sebaceous gland. Hairs form an insulating layer which prevents a loss of body heat, thus, hairs keep up the body temperature. **Sebaceous glands** are outpushings of the wall of hair follicle and produce an oily substance which keeps the hair supple and prevents its wetting in water. It also lubricates the skin. In the dermis are present coiled **sudorific** or **sweat glands**, which occur all over except lips and glans penis. **Mammary glands** are modified sebaceous glands, but in monotremes they are modified sudorific glands. They are functional only in females for producing milk for the young. **Mucous glands** are not found in mammals.

IMPORTANT QUESTIONS

Long Answer Questions

1. What is integument? Describe the integument and its derivatives in vertebrates.
2. Give an account of the integument in a vertebrate you have studied. Explain the functions of integument.
3. Discuss how the integument of reptiles and birds are adapted to their respective modes of life.
4. Give a comparative account of integument of reptiles, birds and mammals.